1783

GN

Gulf of Mexico Science, 2004(2), pp. 155–163

Standardized Visual Counts of Goliath Grouper off South Florida and Their Possible Use as Indices of Abundance

CLAY E. PORCH AND ANNE-MARIE EKLUND

Two visual surveys are examined for evidence that the number of goliath grouper has increased in the waters off South Florida since a harvest moratorium was imposed in 1990. Both surveys are standardized to account for the unbalanced design of the sampling procedure. The first survey is effectively a census of the number of goliath grouper at five artificial reef sites in the Gulf of Mexico about 90 miles north of Key West, Florida. It is standardized by use of the canonical log-linear model. The second survey includes the observations of many different SCUBA divers at 32 sites scattered along the Atlantic coast of Florida from the Dry Tortugas to Jupiter. The canonical log-linear model is not appropriate for standardizing this data set because observations of 2–10 fish are recorded only as two or more. To accommodate this feature, we developed a standardization procedure based on a censored Poisson distribution. The most important factors in standardizing the two surveys were the year and location. Seasonal effects were also statistically significant but had little effect on the results because most of the dives in any given year were conducted during the "warm" season. Both the standardized series indicate a substantial increase in abundance since the 1990 moratorium.

The goliath grouper (jewfish), *Epinephelus itajara,* is the largest grouper in the western North Atlantic and one of the largest groupers in the world (Heemstra and Randall, 1993). It is an unwary species that congregates predictably on artificial wrecks and reefs, making it especially vulnerable to fishing. Not surprisingly, it was overfished through the 1980s. All harvest of goliath grouper was prohibited in the U.S. Gulf of Mexico by emergency rule in 1990 (GMFMC, 1990). Harvest was also banned in U.S. Atlantic and Caribbean waters in 1990 and 1991, respectively (Sadovy and Eklund, 1999). The recovery of goliath grouper has been slow because of its long life span and low reproductive rate (Sadovy and Eklund, 1999). Nonetheless, anecdotal reports from fishers and divers suggest populations are increasing in U.S. waters.

The NOAA–Fisheries Southeast Fisheries Science Center is currently assessing the status of the goliath grouper stock and developing estimates of its recovery time. Traditional fishery-dependent data are of little use in this endeavor inasmuch as they extend back only a few years before the closure and are probably inaccurate (Anon, 2003). However, there are two visual surveys that may prove more helpful: the personal observations of a professional spearfisher (DeMaria[1]) and a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF) (REEF, 2000).

Sadovy and Eklund (1999) constructed an index of abundance from the DeMaria survey but did not account for the unbalanced design of the sampling procedure. An inspection of the data revealed that the counts of goliath grouper differed among locations (Fig. 1) as well as with the onset of the spawning season in late summer–early fall (Fig. 2). When coupled with uneven sampling, either situation could bias the overall trend. A similar situation occurs with the REEF data, but the matter is complicated further by the fact that the observations of 2–10 fish are recorded only as two or more. In this article, we standardize both surveys by use of generalized linear models (GLM) that compensate for the unbalanced design of each survey and, in the case of the REEF data, account for the fact that the data are censored at 2.

MATERIALS AND METHODS

Field data collection: DeMaria survey.—The protocol adopted by Captain DeMaria was to count the total number of goliath grouper he

---

[1] DeMaria, Don. P.O. Box 420975, Summerland Key, FL 33042.

[2] In the case of goliath grouper, where the categories of 11–100 fish and >100 fish were never observed, the annual mean is identical to the abundance score used by Pattengill-Semmens and Semmens (1998) and Jeffrey et al. (2001).

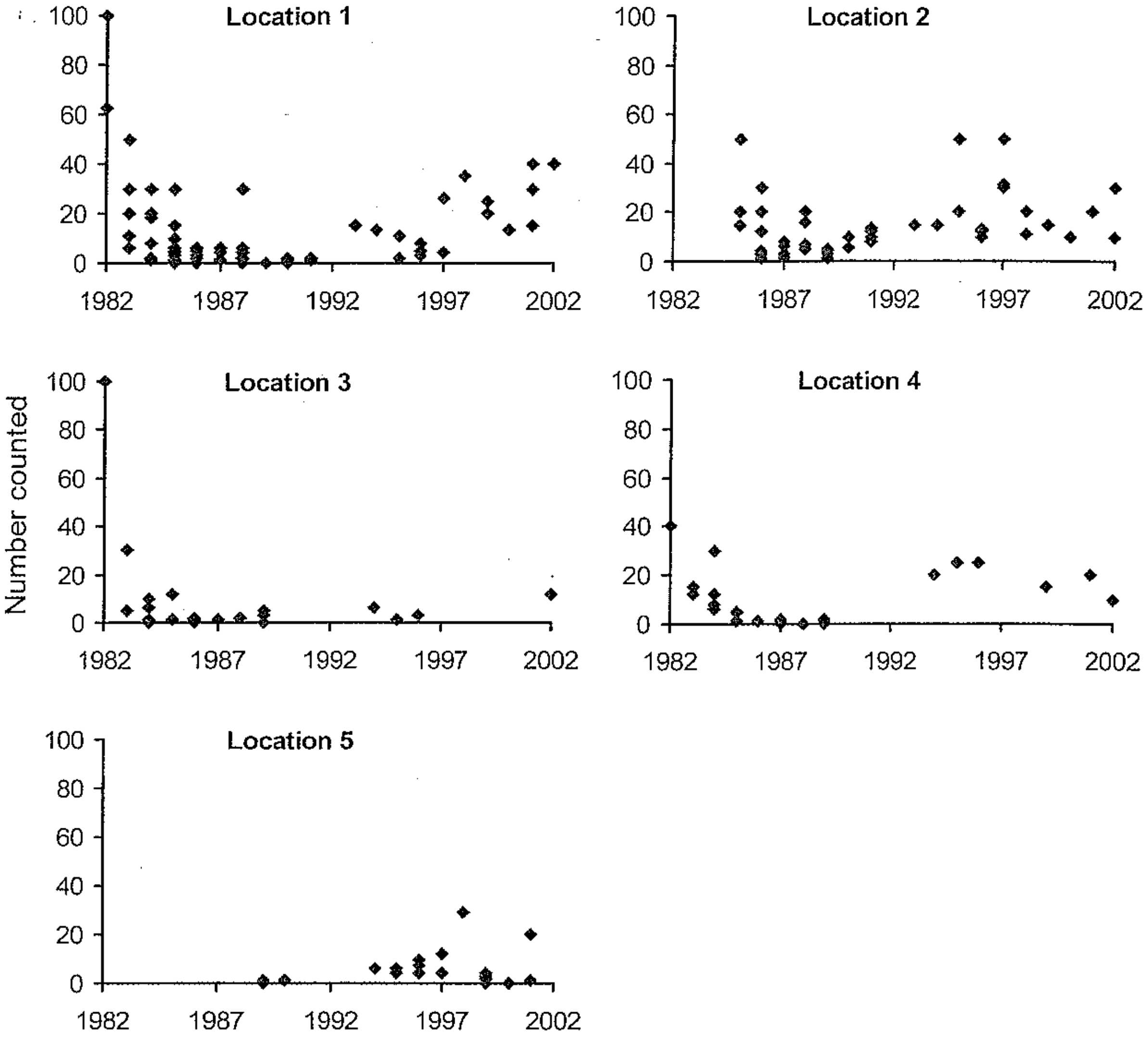

Fig. 1. Number of goliath grouper observed at each of five artificial reefs in the eastern Gulf of Mexico from 1982 to 2002.

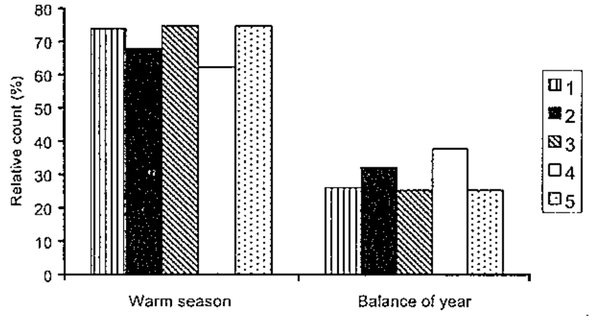

Fig. 2. Relative number of goliath grouper counted during and outside the warm season (June–Oct.) for each of five artificial reefs in the eastern Gulf of Mexico from 1982 to 2002. Only those years (N = 5) that had observations in both seasons were included.

encountered on specific sites during SCUBA dives that would typically last 25 min (because of diver-depth limitations). Before 1990, he was spearfishing and he recorded the number of fish observed as well as the number speared. After the moratorium began in 1990, he continued to visit these sites with researchers and recorded the number of fish seen on his dives. Because of the size of the fish (1–2 m in length) and the discrete area of artificial sites (all the reef fish, including the goliath grouper, typically are concentrated at the structures and not found for the most part in the adjacent sand areas), it was not difficult for him to count all fish on a particular site, particularly if there were fewer than 50 individuals. Researchers diving with Captain DeMaria found that his counts differed little from their own. However, Captain DeMaria has stated that the

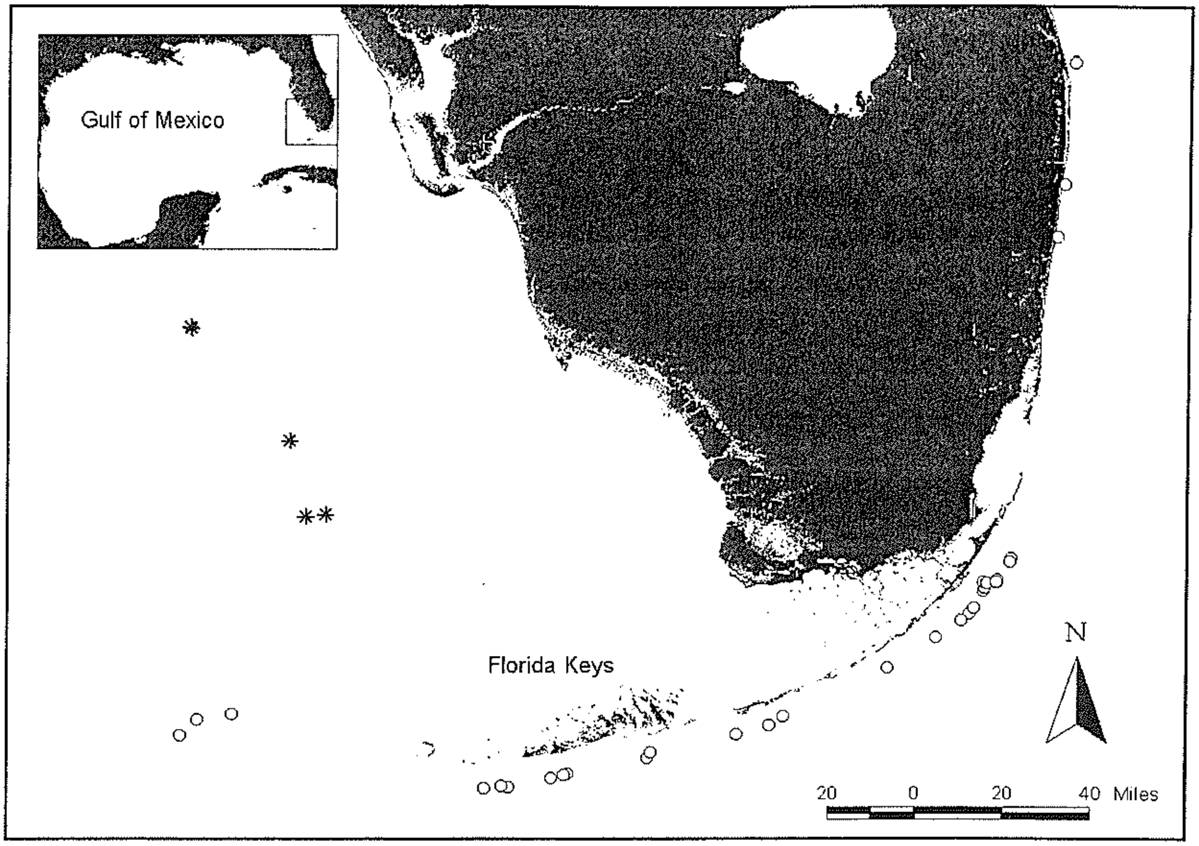

Fig. 3. Survey locations for two diver censuses: asterisks represent artificial structures in the eastern Gulf of Mexico where goliath grouper were observed from 1982 to 2002; circles represent locations where the REEF's volunteer divers observed goliath grouper from 1994 to 2002.

numbers recorded during the early years may be underestimates because there were many more fish to count at that time.

The specific locations included in Captain DeMaria's survey are indicated in Figure 3. They include (1) the wreck of the Baja California, a WWII merchant marine ship sunk 40 miles north of Key West, FL, in about 36 m of water, (2) the wreck of a small shrimp boat approximately 90 miles north of Key West, FL, at a depth of 34 m, (3–4) the stern and bow sections of a Patrol Boat about 2 miles north of site 2 in 40 m, and (5) a Navy navigation tower about 2 miles from site 1 in 30 m of water. Sites 1 and 5 are well known and frequently visited by divers and fishers. Sites 2, 3, and 4, on the other hand, were seldom visited by other fishers or divers. Several dives were made on each site during most years, particularly early in the time series.

Field data collection: REEF survey.—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 about a dive site 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 provided to us included 15,890 surveys conducted at 903 dive sites from June 1993 through 2002. Sites where goliath grouper were never observed and sites visited in fewer than six different years were culled from the analysis, leaving a total of 5,246 surveys at 32 sites (see Table 1). Most of the sites that made the cut are located in the Florida Keys, the rest being located along the Florida east coast (Fig. 3). 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 shipwrecks

TABLE 1. Sites in the REEF database used for this analysis, with the number of years between 1994 and 2002 during which at least one survey was conducted and the number of surveys where no, one, or two or more goliath grouper were observed.

Location	REEF Geozone	Number of years	Number of surveys		
			None seen	One seen	Two or more seen
Juno Ledge	33010005	7	13	2	0
Opal Tower	33010038	6	45	0	2
Delray Ledge	33010042	6	14	0	1
Anchor Chain	34030001	9	151	1	0
South Ledge	34030003	9	116	1	0
Grecian Rocks	34030004	9	293	2	0
Key Largo Dry Rocks	34030005	9	295	1	0
Carysfort Reef	34030006	8	144	1	0
South Carysfort Reef	34030007	8	74	1	0
French Reef	34030008	9	371	3	0
Molasses Reef	34030009	9	924	12	6
Benwood Wreck	34030011	9	165	7	0
City of Washington	34030014	9	131	3	0
Horseshoe Reef	34030018	9	58	9	0
NN Dry Rocks	34030023	9	174	1	0
The Elbow	34030031	9	79	2	1
Alligator Reef	34040002	6	130	1	0
Conch Reef	34040004	9	203	4	0
Tennessee Reef	34040008	7	91	2	0
Sombrero Reef	34050001	9	186	6	0
Samantha's Ledge	34050002	8	112	0	1
Looe Key Reef East	34050005	7	175	6	2
Looe Key Reef	34050006	7	70	5	0
Western Sambo	34080001	9	288	9	0
Eastern Sambo	34080002	8	102	6	0
Rock Key	34080003	9	127	1	1
Sand Key	34080004	9	193	2	0
Middle Sambo	34080005	8	98	1	0
Western Dry Rocks	34080018	7	122	1	0
Texas Rock	34100004	7	93	7	0
Pulaski	34100005	6	74	2	0
Windjammer site	34100015	6	13	7	2

and other dumped debris. On a few occasions, some of these sites were also reported as rubble, sloping drop-offs, ledges, or shear drop-offs. In such cases, rubble and sloping drop-offs were counted as mixed habitats whereas ledges and shear drop-offs were counted as high-profile reefs.

Statistical modeling: DeMaria survey.—The number of goliath grouper spotted on a given dive (N_i) at location L during year Y and season S was assumed to be lognormally distributed such that

$$\ln(N_i + c) = \alpha + \beta_Y + \beta_S + \beta_L + \beta_{YS} + \beta_{YL} + \beta_{SL} + \varepsilon_i \qquad (1)$$

where c is a small constant (1.0) added to allow for occasional zero counts, ε is a normally-distributed error term, α is the intercept parameter, and the β are categorical variables that represent the main effects and second-order interactions corresponding to each year, season, and location. There were insufficient data to estimate a third-order interaction (β_{YSL}). The categorical variable for season included two levels, one for observations made during the warm season (June–Oct.) and the other for observations made during other times (there were insufficient observations to subdivide this further and the designation June–Oct. provided the best fit to the data).

A stepwise approach was used to build a parsimonious statistical model. The procedure was initiated by constructing competing GLMs (SAS 1999), each consisting of a base model (the year main effect alone) plus one of the remaining categorical variables. The variable that most reduced the deviance per degree of freedom was then added to the original base model, provided it was statistically significant according to the sample size–corrected version of Akaike's information criteria (AIC_c, Hurvich and Tsai, 1995). This process of adding factors one at a time and updating the model with the categorical variable that most reduced the deviance per degree of freedom was repeated until no factor (main effect or interaction) met the criteria for incorporation into the final model. After the final model was identified, it was fit to the proper response variables using the SAS macro GLIMMIX (Russ Wolfinger, SAS Institute Inc., Cary, NC).

All main effects and interactions were treated as fixed effects except year interactions. There are two options for constructing annual indices of abundance when the data indicate significant year–season or year–location interactions. The first is simply to standardize the data for each season and location separately and then compute some form of weighted average, in which case the difficulty lies in determining appropriate weighting factors. The second option is to model the year interactions as random effects, i.e., assume they are effectively random over the temporal and spatial scales being examined. This allows indices of abundance to be constructed in the usual manner, but with variance estimates that appropriately reflect the added uncertainty expected when significant year interactions are present.

Standardized measures of visual counts for year Y may be computed from the log-linear predictor $\alpha + \beta_Y$ using the formula

$$N_Y = \exp\{\alpha + \beta_Y + s_R^2/2\} - c$$

where s_R^2 is the residual variance. However, this formula is biased when the GLM estimates of α and β_Y are used in place of the unknown true values. The equivalent unbiased measure is

$$N_Y = \exp\{\alpha + \beta_Y + (d + 1)(s_R^2 - s_Y^2)/2d\} - c \tag{2}$$

where d denotes the degrees of freedom for the residual variance and s_Y^2 is the estimated variance of $\alpha + \beta_Y$ (Bradu and Mundlak, 1970; Gavaris, 1980).

Statistical modeling: REEF survey.—The relative rarity of goliath grouper in the REEF samples coupled with the fact that observations of multiple animals are recorded as "2" suggests that the count data are unlikely to follow a lognormal distribution. One alternative is to treat the series as presence–absence data and model the proportion of surveys with positive counts, but this method would ignore some of the information content in the data. Instead, we model the counts using the censored Poisson distribution:

$$p(N) = \begin{cases} \dfrac{e^{-\mu}\mu^N}{N!} & N = 0, 1, \ldots, Z - 1 \\ 1 - \displaystyle\sum_{k=0}^{Z-1} \dfrac{e^{-\mu}\mu^N}{N!} & N = Z \end{cases} \tag{3}$$

where Z is the censor point and μ is the expected count of goliath grouper. In the present case, the censor point is 2, therefore maximum likelihood estimates for the parameters α and β may be obtained by minimizing the negative log-likelihood expression

$$L = \sum_{N_i=0} \mu_i + \sum_{N_i=1} (\mu_i - \ln \mu_i) - \sum_{N_i=2} \ln[1 - (1 + \mu_i)e^{-\mu_i}] \tag{4}$$

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

$$\ln \mu_i = \gamma_i + \alpha + \beta_Y + \beta_S + \beta_L + \beta_E + \beta_V + \beta_H \tag{5}$$

where the γ_i is the offset covariate (dive duration) 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–Oct., Nov.–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. Interaction effects were not estimated because of the sparseness of the observations at many of the sites.

All model fits (negative log-likelihood minimizations) were accomplished using the utilities provided in the software package AD Model Builder Version 6.0.2 (Otter Research Ltd. Sidney, Canada). Standardized measures of visual counts for each year were constructed as

$$N_Y = \exp\{\alpha + \beta_Y\} \tag{6}$$

Confidence limits for N_Y were obtained by the likelihood profile method.

RESULTS

DeMaria survey.—The main effects associated with year and location were highly significant and had the greatest impact on the model fit,

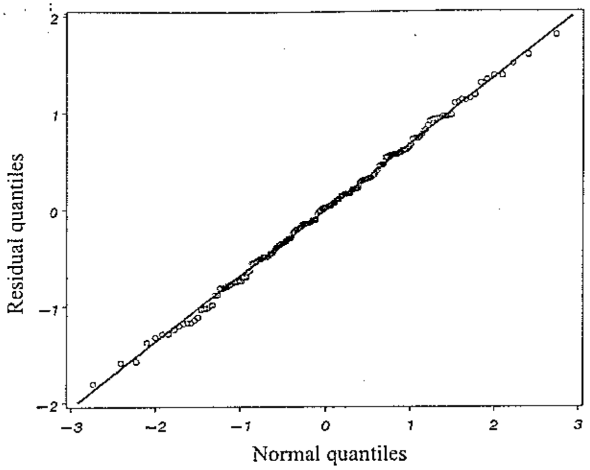

Fig. 4. Quantile–quantile plot of the residuals from the GLM fit to the DeMaria count data (circles) compared with a normal distribution with mean zero and standard error 0.685 (line).

Table 2. Relative standardized count index for goliath grouper from two diver surveys in southern Florida waters with 95% lower and upper confidence limits (LC and UC) and coefficients of variation (CV).

Year	Relative index	LC	UC	CV
DeMaria survey				
1982	6.42	3.93	10.48	0.31
1983	1.42	0.93	2.17	0.26
1984	0.88	0.62	1.25	0.22
1985	0.42	0.32	0.57	0.18
1986	0.21	0.15	0.31	0.22
1987	0.18	0.12	0.27	0.26
1988	0.33	0.22	0.49	0.25
1989	0.11	0.07	0.18	0.31
1990	0.20	0.11	0.35	0.35
1991	0.26	0.17	0.41	0.28
1992				
1993	0.76	0.33	1.72	0.53
1994	0.97	0.56	1.69	0.35
1995	0.76	0.48	1.20	0.28
1996	0.61	0.42	0.90	0.24
1997	1.42	0.86	2.34	0.31
1998	1.43	0.79	2.61	0.38
1999	0.69	0.44	1.08	0.28
2000	0.34	0.16	0.73	0.49
2001	1.42	0.89	2.27	0.29
2002	1.16	0.67	2.01	0.34
REEF survey				
1994	0.26	0.04	0.49	0.46
1995	0.002	0.00	0.01	0.46
1996	0.25	0.00	0.81	0.99
1997	0.95	0.38	1.64	0.30
1998	1.51	0.69	2.47	0.26
1999	0.93	0.32	1.57	0.32
2000	2.02	1.14	2.86	0.19
2001	1.31	0.77	1.83	0.19
2002	1.77	1.14	2.41	0.16

accounting for 27% and 22% reductions in model deviance, respectively. The season and season–location interaction effects, although significant, had much less of an impact (reducing the deviance by only about 10%). The year interactions were also statistically significant, but they did not contribute much to reducing the deviance and most of the individual terms were poorly estimated. Accordingly, they were included in the model as random effects (the point estimates for the year, location, and season effects were almost unchanged, but their confidence intervals were slightly broadened). The log-scale residuals of the final random effects model followed closely those of a normal distribution with constant variance (Fig. 4), verifying the underlying lognormal error assumption.

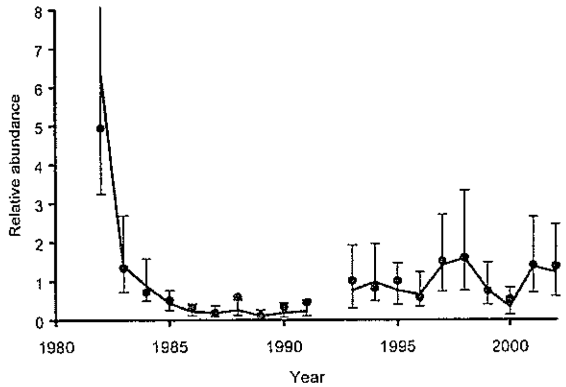

Fig. 5. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal index (circles) from Captain DeMaria's logbook of goliath grouper observations at four artificial structures in the eastern Gulf of Mexico from 1982 to 2002.

The standardized index of goliath grouper counts is similar to the time series of annual means (Fig. 5; Table 2). The wide error bars are largely a result of the high variability and low replication but also reflect the year interactions. Nevertheless, t-test comparisons of the means for different years show that the initial decline and postmoratorium increase in goliath grouper counts are statistically significant (Table 3).

REEF survey.—The main effects associated with year, location, and season all proved statistically

TABLE 3. Comparisons among selected pairs of GLM-estimated annual means for the DeMaria survey. The t-tests are two-tailed unplanned comparisons based on the Tukey–Kramer procedure (SAS 1999). The column labeled $\mu_1 - \mu_2$ contains the differences between the means corresponding to the years in the first and second columns. Generally, the means estimated for the first few years of the time series were significantly larger than those estimated for the late 1980s, and the means estimated just before and just after the moratorium was imposed were significantly less than the means estimated for the mid 1990s and later.

Year[a]	Year[a]	$\mu_1 - \mu_2$	t value	Pr > |t|
1982	1987	3.26	5.89	0.002
1982	1989	3.62	6.38	0.001
1983	1987	1.77	3.31	0.021
1983	1989	2.13	3.88	0.012
1984	1987	1.31	2.81	0.037
1984	1989	1.68	3.32	0.021
1985	1987	0.66	1.5	0.194
1985	1989	1.03	2.14	0.085
1986	1989	0.48	0.99	0.370
1987	1989	0.37	0.75	0.487
1989	1997	−2.14	−3.86	0.012
1989	2002	−2.02	−3.54	0.017
1990	1997	−1.74	−2.93	0.033
1990	2002	−1.62	−2.62	0.047
1991	1997	−1.58	−2.64	0.046
1991	2002	−1.46	−2.36	0.065
1993	1997	−0.48	−0.66	0.541
1993	2002	−0.36	−0.48	0.653

[a] The years being compared.

significant. There was no discernible relationship between the number of goliath grouper counted and dive duration; incorporating dive duration as a covariate significantly degraded the model fit according to the AIC_c. The fit of the model was poor, accounting for only about 7% of the variation in the data. Accordingly, the standardized index is very similar to the time series of annual means[2] (Fig. 6; Table 2). As was true for the DeMaria survey, the error bars are wide because of high variability and low replication, but abundance has clearly increased since the inception of the survey.

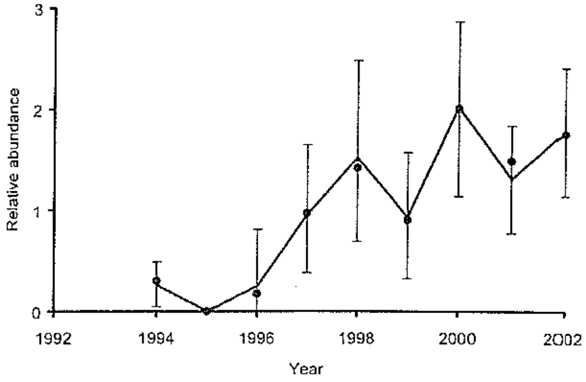

Fig. 6. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal index (circles) from the REEF database of diver observations of goliath grouper in Florida from 1994 to 2002.

DISCUSSION

The most important factors in standardizing the DeMaria and REEF data were the year and location. The seasonal effect was also statistically significant, but it had relatively little impact on the percent of the variation explained by either model because most of the dives in any given year were conducted during the "warm" season. In the case of the DeMaria survey, the estimates for the seasonal effects suggest that the abundance of goliath grouper on the five artificial reefs is about 50% higher during the warm season than during the "cold" season. Anecdotal observations (Sadovy and Eklund, 1999) as well as the recent results from an acoustic tag study appear to support this conclusion. Interestingly, exactly the opposite trend is estimated from the REEF survey data; goliath grouper appear to be about 50% less abundant during the warmer months. It is possible that the reversed trend in the REEF data is spurious because of the present scarcity of goliath grouper observations in those areas. However, it is also possible that the opposing trends reflect summer movements related to spawning or seaward migrations during the cold winter months.

The large size and generally unwary nature of goliath grouper makes them easy to spot, even under relatively poor visibility. Hence, it is not surprising that visibility and diver experience were not significant factors in the analysis of the REEF data. Furthermore, inasmuch as the range examined by each diver is limited by design to a 100-m radius, conspicuous fish-like goliath grouper are likely to be seen shortly into the dive, which explains why the number counted was independent of dive duration.

The standardized DeMaria and REEF surveys can be used as measures of the relative abundance of goliath grouper off southern Florida. In the case of the DeMaria index, such extrapolations are somewhat tenuous because of the relatively restricted geographic area surveyed and the apparently limited movements

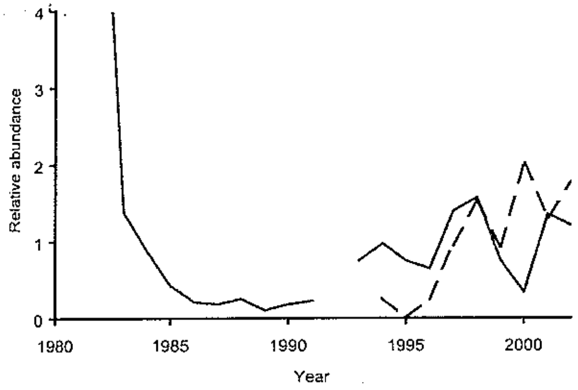

Fig. 7. Comparison of standardized counts of goliath grouper from DeMaria's logbook (solid line) and the REEF database (dashed line) normalized to the 1994–2002 means. Note that both indices are presented relative to their respective annual means. The number of goliath grouper counted on the DeMaria sites is typically an order of magnitude greater than on most of the REEF sites.

of adult goliath grouper (Smith, 1976). Captain DeMaria and others assert that these offshore sites were the last of the known goliath grouper aggregations to be exploited and had not been subjected to the decades of fishing pressure that inshore areas had experienced (Anon, 2003; D. DeMaria, pers. comm.). In other words, the high abundance of goliath grouper on these artificial sites in the early 1980s did not reflect the overall depleted state of the rest of the resource. Moreover, the rapid declines observed at sites 1, 2, and 4 in the early 1980s were largely because of heavy fishing pressure exerted at about the time the survey began (DeMaria[1]). Because these wrecks were easy to find, once they had been discovered, and harbored high concentrations of goliath grouper, they probably received proportionately more fishing pressure than the population as a whole. Hence, it is likely that the initial decline indicated by the index is more precipitous than that of the overall population.

The REEF survey includes many more sampling locations (32) and is spread over a much broader area than the DeMaria survey; therefore it is probably a reasonably good index of the relative abundance of goliath grouper along the southeast coast. Unfortunately, the center of abundance of the goliath population is along the southwest coast (as evidenced by the very low numbers seen at all REEF sites). The REEF and DeMaria surveys both indicate a substantial increase since the 1990 moratorium on harvest, but the increase in the REEF survey does not begin until several years later (Fig. 7). This delay in recovery along the east coast, relative to the increase in the west coast, may be because of a lack of nursery habitat along Atlantic shores or a concentration effect on artificial structures in the Gulf of Mexico. Anecdotal reports reveal that this species was historically observed frequently along both coasts of southern Florida (Eklund, 1994; DeMaria, 1996).

Despite the above misgivings, the surveys in question are the only such time series available for adult goliath grouper. As such, they are invaluable to any attempt at assessing the status of the resource. In this regard, the counts made after the harvest moratorium imposed in 1990 should prove especially useful as an indicator of the rebuilding potential of the stock. The most troubling aspect, the very rapid initial decline in the DeMaria index associated with local depletion, may be handled simply by ignoring the data before 1984.

ACKNOWLEDGMENTS

We thank Don DeMaria and the Reef Environmental Education Foundation for providing and explaining their data and J. Schull for preparing some of the figures. We also thank E. Brooks, W. Patterson, W. Richards, and two anonymous reviewers for their helpful comments on the manuscript.

LITERATURE CITED

ANON. 2003. Southeast Data, Assessment and Review (SEDAR) Goliath Grouper Data Workshop Report. SEFSC, Miami, FL. South Atlantic Fishery Management Council, Charleston, SC.

BRADU, D., AND Y. MUNDLAK. 1970. Estimation in lognormal linear models. J. Am. Stat. Assoc. 65:198–211.

DEMARIA, K. K. 1996. Changes in the Florida Keys marine ecosystem based upon interviews with experienced residents. The Nature Conservancy and Center for Marine Conservation Special Report. The Nature Conservancy, Key West, FL.

EKLUND, A. M. (ED.) 1994. Status of the stocks of Nassau grouper, *Epinephelus striatus*, and jewfish, *E. itajara*—Final Report. SEFSC report, Miami Lab. Contribution no. MIA-94/95-15. Southeast Fishery Science Center, Miami, FL.

GAVARIS, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37:2272–2275.

[GMFMC] GULF OF MEXICO FISHERY MANAGEMENT COUNCIL. 1990. Amendment Number 2 to the Fishery Management Plan for the Reef Fish Fishery of the Gulf of Mexico. Gulf of Mexico Fishery Management Council, Tampa, FL.

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, rockcod, hind, coral grouper and lyretail species known to date. FAO Fisheries Synopsis No. 125, Vol. 16. FAO, Rome.

Hurvich, C. M., and C. Tsai. 1995. Model selection for extended quasi-likelihood models in small samples. Biometrics 51:1077–1084.

Jeffrey, C. F. G., C. Pattengill-Semmens, S. Gittings, and M. E. Monaco. 2001. Distribution and sighting frequency of reef fishes in the Florida Keys National Marine Sanctuary. Marine sanctuaries conservation series MSD-01-1. U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD.

McCullagh, P., and J. A. Nelder. 1989. Generalized linear models. Chapman and Hall, London.

Pattengill-Semmens, C. V., and B. X. Semmens. 1998. Fish census data generated by non-experts in the Flower Garden Banks National Marine Sanctuary. J. Gulf Mexico Sci 2:196–207.

[REEF] Reef Environmental Education Foundation. 2000. Home page. www.reef.org. Accessed on 1 May 2000.

Sadovy, Y. and A.-M. Eklund. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Technical Report NMFS 146. National Marine Fisheries Service, NOAA, Seattle, WA.

SAS. 1999. SAS/STAT User's Guide, Version 8. SAS Institute Inc., Cary, NC.

Smith, G. B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Florida Marine Research Publication no. 19. Florida Department of Environmental Protection, St. Petersburg, FL.

National Marine Fisheries Service, Southeast Fisheries Science Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida 33149–1099. Send reprint requests to CEP. Date accepted: July 2, 2004.