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ARTICLE

Status and Trends of Marbled Grouper in the North-Central Gulf of Mexico

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Abstract
Marbled Grouper *Dermatolepis inermis* were categorized as "near threatened" by the International Union for Conservation of Nature in 1996, and the status of the species was set for review in 2018. Analysis used to support its global threatened status included basic parameters, such as numbers seen in a year and spatial maps of positive observations, but included no statistical approaches to interpret abundance trends. In an effort to improve the understanding of Marbled Grouper status and trends, we used the Southeast Area Monitoring and Assessment Program reef fish video survey time series in the northern Gulf of Mexico, USA, to estimate relative abundance, proportion of positive stations, and the impact of habitat variables on fish abundance. Marbled Grouper were consistently observed in low numbers on the Louisiana shelf-edge banks throughout the survey. Generalized linear mixed models using a negative binomial data distribution showed significant effects for the presence of reef and depth, while the percent coverage of rock was marginally significant. These results indicate that detection and abundance of Marbled Grouper are strongly associated with high rugosity and deep (60–100 m) reef tracts. Interpretation of annual trends was difficult due to high interannual variability, but the data appear to show no detectable trends. Given that the previous classification of near threatened was based primarily on the consistent but rare observation of the species in its preferred habitat on a global basis, and given that the annual indices produced for the northern Gulf of Mexico region were highly variable, we recommend that the current International Union for Conservation of Nature regional status be maintained. This study highlights the utility of optical surveys for collecting data on species that are rare or that are not observed using traditional fisheries sampling gears and also indicates the importance of synchronous collection of habitat information.

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The Marbled Grouper *Dermatolepis inermis* is an epinepheline grouper that inhabits shelf waters ranging from the Carolinas to southern Brazil in the Atlantic Ocean basin as well as throughout the Gulf of Mexico (GOM) and Caribbean Sea. Marbled Grouper were first categorized as "near threatened" by the International Union for Conservation of Nature (IUCN) in 1996 (Rocha et al. 2008) and were classified as "vulnerable" by the American Fisheries Society (Musick et al. 2000). In 2015, a regional IUCN assessment for Marbled Grouper in the GOM listed it as a species of "least concern" (Claro et al. 2015), which was a down-listing from its global IUCN assessment in 2008 as a species of near-threatened status (Rocha et al. 2008). The global and GOM regional IUCN assessments for Marbled Grouper are nearly identical except for more extensive spatial maps in the global assessment. Claro et al. (2015) stated that the Marbled Grouper was listed as a species of least concern in the GOM because there do not appear to be any major threats to the species in that region. However, despite the species' assumed wide-ranging spatial distribution, there is actually very little information available in the literature or from unpublished or anecdotal sources. Increased and detailed knowledge of the Marbled Grouper's spatial distribution and abundance trends would be useful for an upcoming IUCN status review of the species, to supply information on spatial management zones and conservation efforts, and to serve as a benchmark for the species' continued evaluation.

Marbled Grouper are broadly described as reef-associated and are often observed in close proximity to deep ledges and at sand–reef interfaces at depths between 30 and 210 m (Heemstra et al. 2002). Several surveys conducted in the GOM report that observations are rare and suggest that Marbled Grouper tend to be solitary and shy. Diver- and remotely operated vehicle (ROV)-based surveys conducted at the Flower Garden Banks National Marine Sanctuary (FGBNMS; Figure 1) have observed the species in the upper reaches of mesophotic portions of the banks and have reported densities between 0.11 and 0.16 fish/100 m^2 (Rocha et al. 2008; Caldow et al. 2009; Clark et al. 2014). The Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video (RFV) survey, which targets snappers and groupers associated with mesophotic reefs in the region (Rademacher et al. 2016), shows a spatial distribution that extends from the Flower Garden Banks to Midnight Lumps (aka Sackett Bank) just south of the Mississippi River Delta (Figure 1). The SEAMAP-RFV survey produces Max*N*-type data (Ellis and DeMartini 1995; Cappo et al. 2006; Campbell et al. 2015), which reports the maximum number of individuals observed at any one specific time over the course of a camera deployment and thus does not typically report comparable fish density information. Marbled Grouper are infrequently reported in commercial and recreational catch records; however, in April 2006, a headboat (Captain Elliot's, Freeport, Texas) confirmed landing 67 Marbled Grouper over several days. Information concerning the location was not specific but did indicate that fishing took place on the shelf-edge banks off the Louisiana coast, which corresponds to the spatial trends observed in the fisheries-independent data collections. Beyond general observations, little is known about Marbled Grouper life history characteristics, but it is assumed that they likely form spawning aggregations similar to their congeners. In addition, it seems likely that the concentrated catch reported from the headboat was the result of having targeted an aggregation, as the species is otherwise observed in low numbers or densities. Due to the paucity of even basic information, it is apparent that improved data collection and analysis are needed to properly assess the status of Marbled Grouper.

Given the rarity of Marbled Grouper observations and the relatively narrow spatial and depth zones occupied by this species, it has proven difficult to determine the Marbled Grouper's status. In the past, Marbled Grouper have been described as consistently observed in low numbers at select north-central GOM banks (Rocha et al. 2008), but no abundance trends have been estimated (e.g., relative abundance). Species status and listings have therefore relied upon the low observation rate reported from fisheries-independent and fisheries-dependent surveys, coupled with the likelihood that the formation of spawning aggregations makes them vulnerable to fishing. The SEAMAP-RFV survey of the GOM was reaching maturation as a time series in 2004 and was first used as an abundance index in the Southeast Data, Assessment, and Review (SEDAR) of GOM Red Snapper *Lutjanus campechanus* (Gledhill and Ingram 2004). When data were submitted to the IUCN for a review of Marbled Grouper in 2008, abundance indices were not estimated and instead focused simply on sightings, perhaps because of the novel nature of using video data to evaluate abundance trends. However, as the time series has matured, the SEAMAP-RFV survey has been included in SEDAR data workshops and assessments for 17 GOM reef fish species. Recently, the SEAMAP-RFV survey provided one of the more important data sets used to evaluate data-poor stocks during SEDAR 49, which evaluated the Almaco Jack *Seriola rivoliana*, Lesser Amberjack *S. fasciata*, Snowy Grouper *Hyporthodus niveatus*, Speckled Hind *Epinephelus drummondhayi*, Lane Snapper *L. synagris*, Wenchman *Pristipomoides aquilonaris*, and Yellowmouth Grouper *Mycteroperca interstitialis* (SEDAR 2016) and for which indices were generated. In some cases, the SEAMAP-RFV survey was the only survey providing abundance data for a species (e.g., Yellowmouth Grouper). Given that the next IUCN Red List status for Marbled Grouper in the GOM was scheduled to be reviewed in 2018, and given the recent use of the SEAMAP-RFV data to evaluate data-poor stocks, we

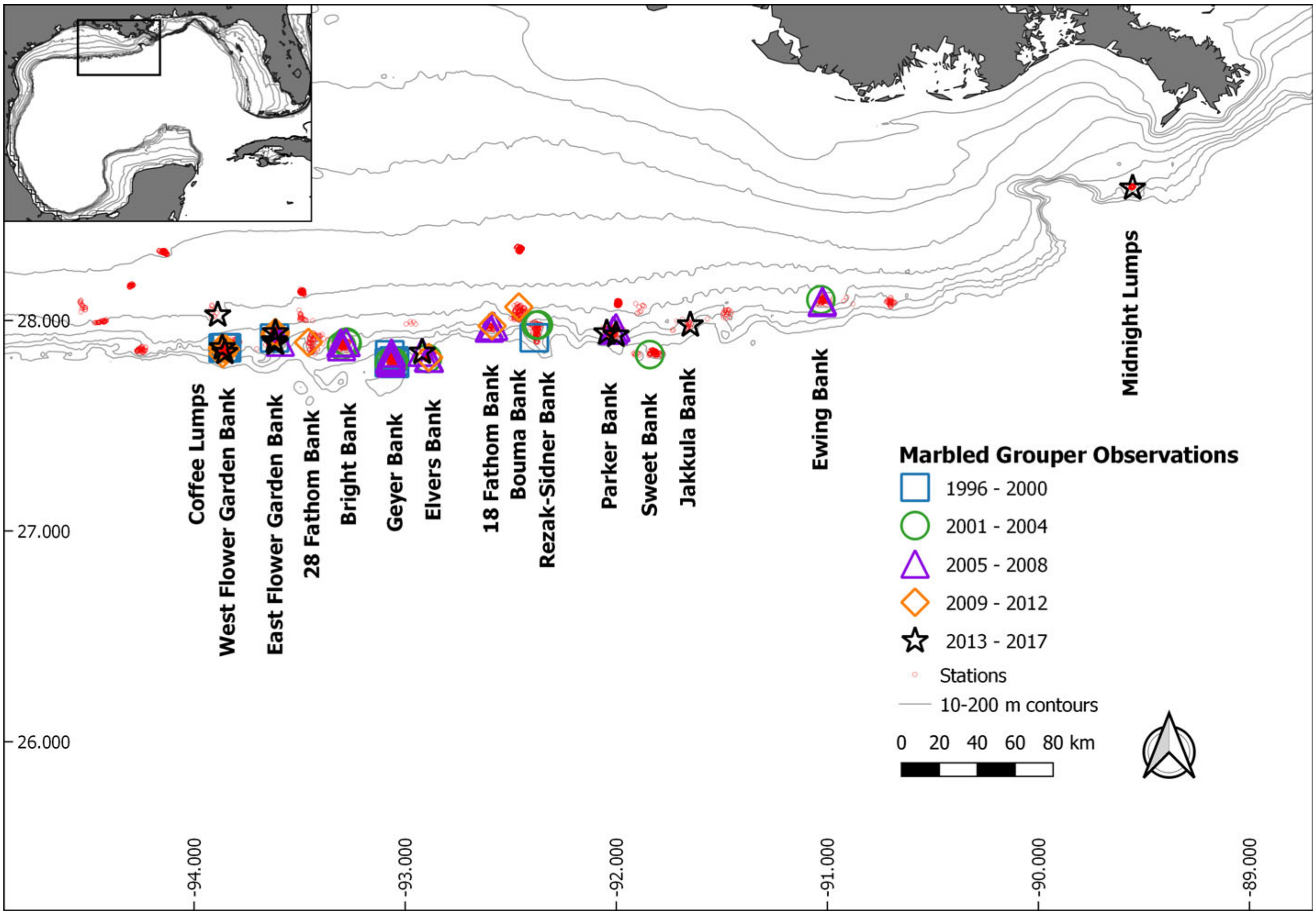

FIGURE 1. Northwest Gulf of Mexico sampling locations used during the Southeast Area Monitoring and Assessment Program reef fish video survey from 1996 to 2017. Positive sightings of Marbled Grouper are depicted by large color symbols, while negative stations are depicted by small red circles. Reef names are included only for banks with positive identifications of Marbled Grouper. Coffee Lumps is approximately 20 km north of West Flower Garden Bank. Midnight Lumps is often referred to as Sackett Bank; 18-Fathom Bank is often referred to as McGrail Bank.

present an analysis of the status and trends of Marbled Grouper observed in the SEAMAP-RFV survey.

METHODS

The National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center has conducted the SEAMAP-RFV survey of hard-bottom habitats of the GOM, which includes the north-central banks, since 1992 (Figure 1). The annual survey is conducted between April and May and has sampled approximately 300 sites per year, targeting high-relief reef habitat throughout the GOM (east GOM: 1,244 km^2; west GOM: 527 km^2). Roughly half of the sites in any given year are located in the northwest GOM in a region that extends west from the Mississippi River delta and south to the United States–Mexico international border. There are no records of Marbled Grouper in the SEAMAP-RFV survey in the east GOM (i.e., east of the Mississippi River delta) or south of the Flower Garden Banks; therefore, this analysis focuses on the high-relief banks along the Louisiana shelf stretching from the Flower Garden Banks to Midnight Lumps (Figure 1).

Survey design and information on cameras and deployment methods follow standard protocols described in detail by Campbell et al. (2015). In brief, at each sampling site, the orthogonal stereo-camera array (OSCAR) system was baited and deployed remotely for 40 min. Video data were analyzed from one randomly selected OSCAR camera out of four possible cameras mounted on the array. Videos were viewed and annotated for 20 min starting from the time when suspended sediment, resulting from the impact of the camera on the bottom, no longer obscured the view. During the 20-min annotation time, video readers identified all Marbled Grouper and enumerated them using the Max*N* method (Ellis and DeMartini 1995). The Max*N* (also termed "mincount") represents the maximum number of individuals observed in any single video frame during the official video annotation time and thereby avoids the problem of a single individual being counted or measured multiple times. In addition, video readers also notated when species were observed outside of the official read time but only recorded presence–absence data in those cases (i.e., add-species list). All identifications were reviewed by a second video reader to confirm positive Marbled Grouper identifications and counts. Fish lengths and the ranges to the fish were measured at the same video segment as the Max$N$ value, thereby preventing measurement bias (i.e., no single fish was measured more than once). Fish were measured from the tip of the snout to the centerline between the tips of the upper and lower caudal lobes. Parallel lasers were first mounted on the camera array in 1995 and were in use until 2008 to measure fish lengths. From 2008 to present, lengths were measured using stereo-camera imagery in an effort to increase the number of measurements, as fish were rarely hit by lasers. Stereo-camera calibrations were conducted and fish measurements were calculated using Vision Measurement System (VMS) software (Geometric Software P/L, Coburg, Australia; www.geomsoft.com) through 2016; since 2016, calibrations and measurements have been performed using SeaGIS (SeaGIS Pty. Ltd., Bacchus Marsh, Australia).

Fish count, range to fish, and camera field-of-view (FOV) data were used to calculate Marbled Grouper densities (fish density = count/100 m^2). The sampled area was assumed to be a triangle with a 70° FOV, which, when halved, created two right triangles, with one side of the triangle equal to the maximum effective distance at which positive Marbled Grouper identifications were possible. Evaluation of the range data showed this to be about 7 m for Marbled Grouper; therefore, this range was used to set the base of the triangle. Simple Euclidean geometry and algebra were then used to calculate one-half of the area sampled, which was then doubled to represent the total area sampled in a single camera drop (i.e., two right triangles summed). Site-specific and bank-specific average Marbled Grouper densities were then calculated as follows:

$$\text{Site-specific fish density} = \left(\frac{\sum \text{fish counts}}{\text{camera sampling area in m}^2}\right) \times 100,$$

$$\text{Average fish density by bank} = \frac{\sum \text{site-specific fish densities on a bank}}{\sum \text{sites sampled on a bank}}.$$

All index development and analysis were conducted using SAS version 9.4 (SAS Institute, Inc., Cary, North Carolina), during which we explored and evaluated three different error distributions, including delta-lognormal, Poisson, and negative binomial, following established methods (Hall 2000; Guenther et al. 2014; SEDAR 2015). Final error distribution selection was determined by evaluation of model fit criteria, such as q–q plots (i.e., conformity to linearity) and extra-dispersion scaling (e.g., Pearson chi-square/df). Once the proper error distribution was determined, backwards selection using the GENMOD procedure in SAS was performed to evaluate the effects of year, depth (m), reef (a Boolean variable indicating whether reef was directly observed), and rock (percent cover). Final model selection was determined by evaluation of model fit criteria, including q–q plots, extra-dispersion scaling, and information criterion methods (e.g., Akaike's information criterion). In 2002, we encountered an aggregation of 13 Marbled Grouper at a single location, but in general, the counts were 1–3 fish. To test the effect of this single encounter with a fish aggregation on the index results, we conducted an additional model run that excluded this data point (i.e., the aggregation was treated as an outlier).

RESULTS

During the SEAMAP-RFV survey conducted from 1996 to 2017, the OSCAR system was deployed 1,796 times on mesophotic banks of the Louisiana shelf-edge region of the northwest GOM (Figure 1). During that time, 111 Marbled Grouper were observed at 62 stations (3.45% positive stations) during the 20-min read time and at an additional 13 stations outside of the read time (i.e., add species). The add-species observations were conducted over varying times and only provide presence–absence information; thus, those observations could not be used in estimating the relative index, but they were used to evaluate spatial distributions. Marbled Grouper were spatially distributed across the majority of the high-relief banks of the region, including Coffee Lumps, East and West Flower Garden banks, 28-Fathom Bank, Bright Bank, Geyer Bank, Elvers Bank, McGrail Bank, Bouma Bank, Rezak-Sidner Bank, Parker Bank, Sweet Bank, Jakkula Bank, Ewing Bank, and Midnight Lumps (Figure 1). McGrail Bank has historically also been referred to as 18-Fathom Bank, and Midnight Lumps is also known as Sackett Bank. The most consistent observations were associated with banks located on the western edge of this region, including Geyer Bank (13 stations in 8 years), East Flower Garden Bank (8 stations in 7 years), West Flower Garden Bank (8 stations in 5 years), Elvers Bank (6 stations in 5 years), Bright Bank (6 stations in 4 years), and McGrail Bank (5 stations in 4 years). Observations of Marbled Grouper appeared to expand spatially to the east after 2000 (Figure 1). Sample sizes were fairly consistent over this time frame, and all of these banks were available to the survey over the time frame analyzed. Therefore, the slight eastward expansion does not seem to be related to improved detection due to the discovery of new reefs or increased sampling. When observed, Marbled Grouper counts were approximately 1–3 fish; however, in 2002, an aggregation of 13 fish was recorded at Rezak-Sidner Bank. Marbled Grouper were observed at depths ranging from 40 to 160 m, but most of the observations were concentrated between 60 and 100 m (Figure 2). Marbled Grouper were frequently observed at high-relief, high-rugosity reefs that contained many cracks and crevices, but the specific habitat composition varied by bank (e.g., rock, hard corals, and soft corals).

In most years, fewer than five Marbled Grouper were measured (the exception was in 2002, when $n = 34$); therefore, length-frequency histograms and central tendencies reflect data that were pooled over years (Figure 3). No Marbled Grouper were measured prior to 2001, likely due to the low observation rates and the use of parallel lasers to obtain lengths. Fork lengths ranged from 342 to 847 mm, with a mean ± SD of 577.8 ± 146.4 mm. Mean FL varied through the years but showed an increasing trend through time; however, this is based on, at most, five fish in any given year (Table 1).

Evaluation of model fit diagnostics (*q–q* plots and overdispersion parameters) resulting from base model runs (i.e., year only) showed that the negative binomial error distribution produced the best fits to the data. This result was likely associated with the low percentage of positive stations coupled with count data that, on average, observed few individuals (95% of positive stations' counts were between 1 and 3 fish). Therefore, the delta-lognormal and Poisson models were not evaluated further. Model fits that included all variables improved substantially over year-only runs (Table 2) as well as in comparison to any of the various submodels using combinations of the four variables. Thus, we retained all habitat variables in the model (depth, reef, and rock), and year was retained because we were evaluating annual changes. Exclusion of the 13-fish aggregation from the model runs in all cases improved model fits but did not substantially alter the resultant trends through time for proportion positive or relative indices except for the year 2002 (Figures 4, 5). Additionally, exclusion of the aggregation did not result in changes to significant variables. Thus, the model that excluded this 13-fish aggregation was preferred for evaluating trends through time and was considered the final model.

Final model output indicated that the presence of reef ($P < 0.002$), the depth ($P < 0.02$), and the percent coverage of rocky substrate ($P < 0.08$) were all either significant or marginally significant in the model. Year was nonsignificant ($P = 0.74$) but was retained to evaluate relative

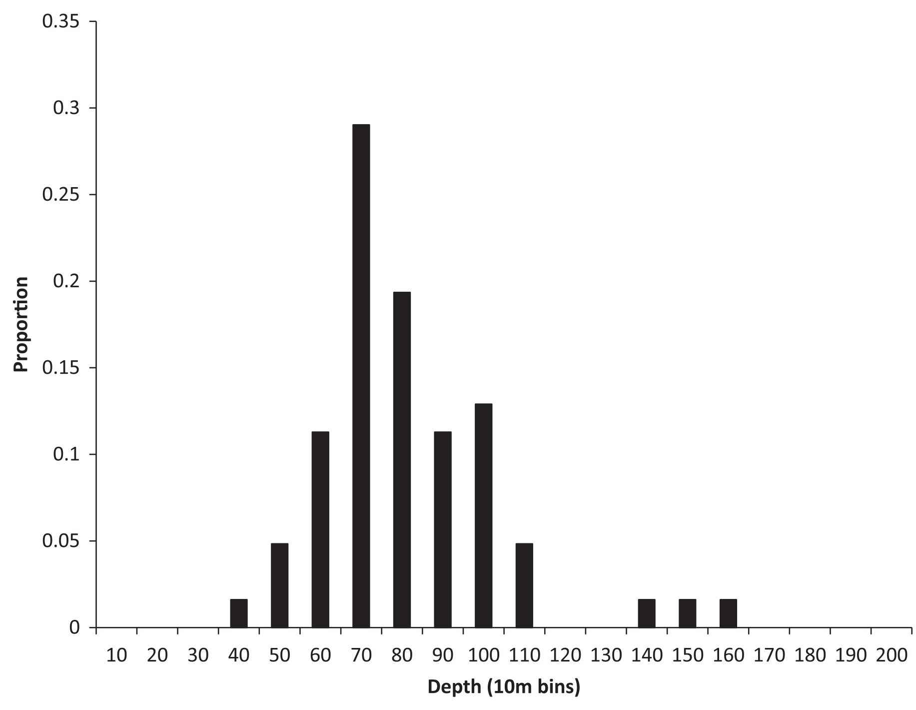

FIGURE 2. Depth frequency histogram of Gulf of Mexico reef fish video survey stations (Southeast Area Monitoring and Assessment Program) with positive identifications of Marbled Grouper.

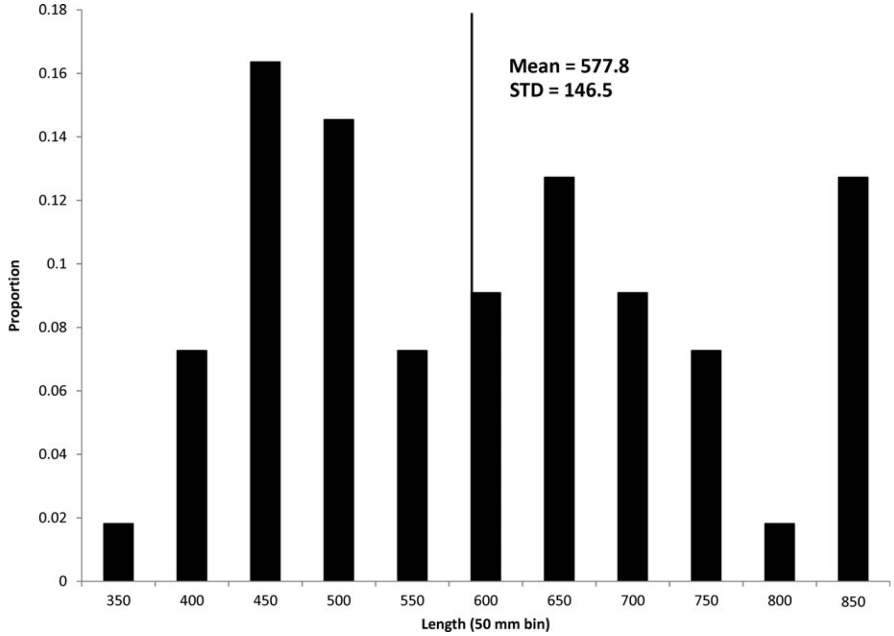

FIGURE 3. Length frequency histogram and mean FL (single vertical line, with SD) of Marbled Grouper measured in the Gulf of Mexico reef fish video survey (Southeast Area Monitoring and Assessment Program; data pooled across study years, 1996–2017).

TABLE 1. Annual mean, SD, and sample size of Marbled Grouper FLs measured from the Southeast Area Monitoring and Assessment Program reef fish video survey in the northern Gulf of Mexico, 2001–2017.

Year	Mean FL (mm)	SD	*N*
2001	556.60	72.74	5
2002	554.32	157.63	34
2005	612.00	na	1
2008	765.72	64.05	2
2009	542.91	13.30	2
2010	679.56	na	1
2011	657.84	97.28	2
2013	516.67	99.55	5
2016	748.34	na	1
2017	795.37	53.65	2
Pooled	577.76	146.45	55

annual change. Annual variability in both the proportion positive and the relative indices was large, as evidenced by the reported confidence intervals (Figures 4, 5) and coefficients of variation (CVs). Annual estimates of CV ranged from 73% (1997) to 138% (2017). Proportion of sites with positive Marbled Grouper identifications ranged from 0.6% (2012) to 7% (2004). The effect of inclusion or exclusion of the 13-fish aggregation did not impact the proportion positive trends; however, the inclusion of that single data point would suggest a higher relative abundance estimate for the year 2002. Thus, this lone observation had a disproportionate effect on the index and was treated as an outlier in the data. Regardless of the inclusion or exclusion of the aggregation, the underlying annual trends were noisy (i.e., high CV), and exclusion improved model fit and reduced the CV, all of which led to preference for the relative index that excluded the aggregation.

The range at which 90% of the positively identified and measured fish were observed was 7 m, and the camera FOV was 70°; thus, the effective sampling area of the camera system during a single camera drop was estimated to be 34.31 m^2. Average Marbled Grouper densities (mean ± SE) ranged from 0.07 ± 0.05 fish/100 m^2 (Ewing Bank) to 0.6 ± 0.5 fish/100 m^2 (Rezak-Sidner Bank; Table 3).

DISCUSSION

Marbled Grouper were rarely but consistently observed on the Louisiana shelf-edge banks throughout the course of time in the SEAMAP-RFV survey. Despite their low frequency of observation and their generally low counts when observed, we were able to estimate a relative abundance index for the species. The presence of reef and the depth at a station were significant variables in the model, while the percentage of rock coverage was marginally significant and year was not significant. Thus, the effects of our habitat variables were strongly associated with the detection and abundance of Marbled Grouper. The interpretation of annual trends indicates that there has been

TABLE 2. Model fit diagnostics for year-only model (count ~ year) and full-model (count ~ year + reef + depth + rock) runs that included (#) or excluded (*) the observation of 13 Marbled Grouper in 2002. The final (best) model selection is shown in bold italics.

	Model			
Diagnostic	Count ~ year#	Count ~ year*	Count ~ year + reef + depth + rock#	Count ~ year + reef + depth + rock*
Log-likelihood	610.96	591.58	580.9	***561.14***
Akaike's information criterion	646.96	627.58	622.9	***603.14***
Bayesian information criterion	610.96	591.58	580.9	***561.14***
Overdispersion	0.88	0.89	0.78	***0.88***
Sample size	1,796	1,795	1,796	***1,795***

little change in abundance over time—or, more likely, that annual trends are too noisy to interpret easily. In spite of the high variability in annual estimates, the analysis presents a more robust approach to analyzing annual trends, spatial distributions, and habitat associations than previously available data that were used to place Marbled Grouper on the IUCN's near-threatened list.

The various models analyzed all indicated that the ability of the survey to target reef habitat was significantly associated with the detection and abundance of Marbled Grouper. This matches other survey reports on the species (Rocha et al. 2008; Caldow et al. 2009; Clark et al. 2014) and fits with anecdotal information provided by our team of videotape readers that the species is generally observed in close proximity to craggy/rough reef tracts. Year was a nonsignificant variable in the model, which in most cases indicates that annual variability is steady and population trends are stable. This might be the case for Marbled Grouper; however, the high annual variability in the annual relative index and proportion positive values (i.e., SEs) precludes interpretation of the annual trends. Despite the high variability, the model does provide some insight relative to the stability of the proportion positive data, suggesting that we consistently observe the species (3% of sites in the region) at low abundance and always in association with high-rugosity habitats on the banks.

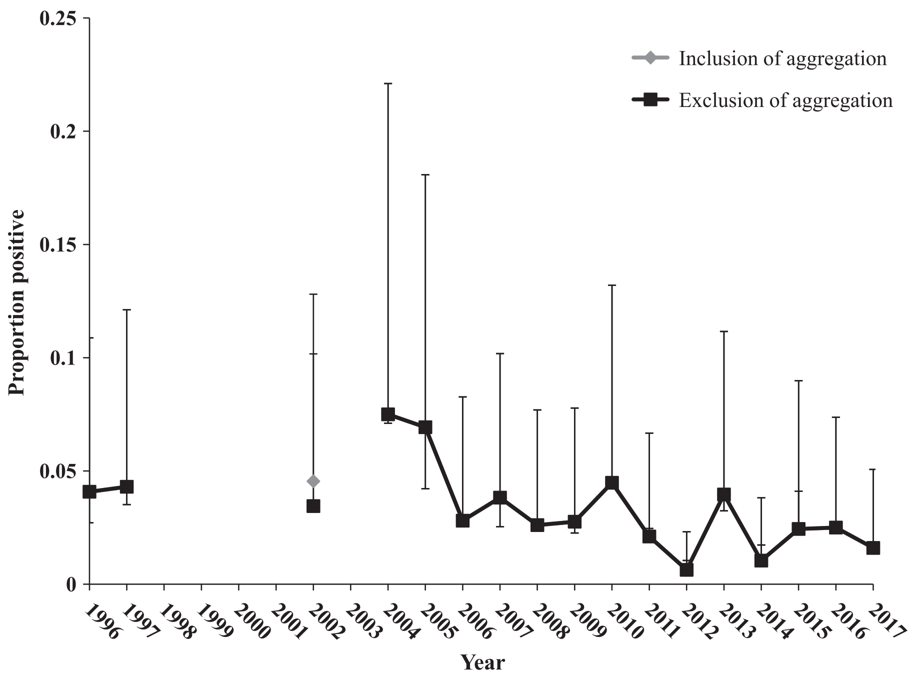

FIGURE 4. Proportion (±95% confidence interval) of sites with positive identifications of Marbled Grouper on the Louisiana shelf-edge break, as observed during the Southeast Area Monitoring and Assessment Program reef fish video survey of the northern Gulf of Mexico, 1996–2017. Data points including or excluding the aggregation of 13 Marbled Grouper (observed in 2002) are shown.

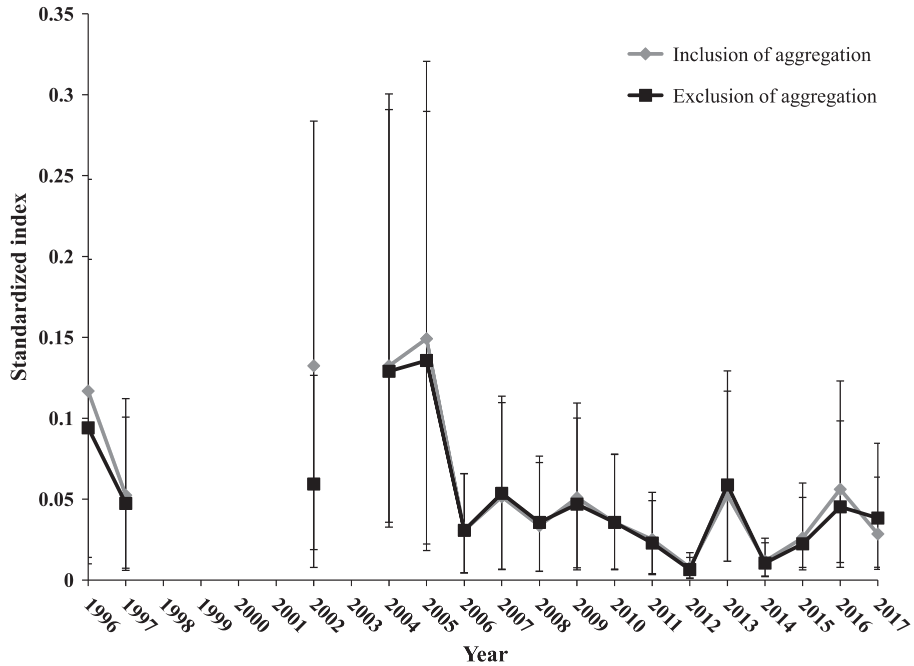

FIGURE 5. Index of relative abundance (±95% confidence interval) of Marbled Grouper on the Louisiana shelf-edge break, as observed during the Southeast Area Monitoring and Assessment Program reef fish video survey of the northern Gulf of Mexico, 1996–2017. Data points including or excluding the aggregation of 13 Marbled Grouper (observed in 2002) are shown.

The species was observed more frequently on the east and west FGBNMS but at an increased depth range relative to the ROV- and diver-based surveys (Rocha et al. 2008; Caldow et al. 2009; Clark et al. 2014). We estimated average Marbled Grouper densities at east FGBNMS to be 0.2 ± 0.08 fish/100 m^2, while Clark et al. (2014) reported 0.14 ± 0.03 fish/100 m^2 and Caldow et al. (2009) reported 0.16 fish/100 m^2. We estimated Marbled Grouper density at west FGBNMS to be 0.12 ± 0.04 fish/100 m^2, whereas Clark et al. (2014) reported 0.009 ± 0.009 fish/100 m^2, and Caldow et al. (2009) reported a density of 0.16 fish/100 m^2. Clark et al. (2014) also reported significant increases in density with increasing depth at both banks, which could explain why our estimates are slightly higher than those from the other two surveys, as the SEAMAP-RFV survey samples deeper portions of the banks. Density estimates were higher at many of the other banks sampled in the SEAMAP-RFV survey; however, it should be noted that total area sampled was also lower at all other banks in comparison to the FGBNMS. In most years, the FGBNMS is selected for sampling, whereas the other banks have some gaps in selection through time, which is a function of the reef/area sample weighting scheme incorporated into the sampling design. It could be that with increasing effort at other banks, the density estimates would be lower. Despite the potential sampling frequency effect, Rezak-Sidner, Parker, Geyer, Elvers, Bright, and Bouma banks all represent at least 50% of the area relative to FGBNMS and are therefore significant features on the shelf and in the survey. Furthermore, all of those banks had estimated densities equivalent to or higher than those reported for FGBNMS. Marbled Grouper were not observed at any of the other sampled banks throughout the northern GOM (Rocha et al. 2008; Claro et al. 2015); thus, maps depicting spatial distributions throughout the continental shelf and in the eastern GOM need to be updated accordingly. Consideration of the status of Marbled Grouper should incorporate data from these Louisiana banks that appear to hold higher densities of the species. Furthermore, surveys targeting Marbled Grouper should consider a research design that encompasses the spatial domain described here as well as the depth and habitat considerations that were significant in the models.

Although we do not think that baited stationary camera systems should generally be used to produce density estimates, it is interesting that the estimates presented here are very close to those produced by the ROV and diver surveys. This could be indicative of the rarity, strong habitat affinity, and generally slow-moving habits of Marbled Grouper, which would create a situation wherein effective and calculated sampling areas are equivalent. Ergo, the bait on the array does not appear to concentrate fish or to increase the effective sampling area relative to the calculated sampling area. Marbled Grouper might prefer live prey to dead baits and thus do not scavenge and perhaps

TABLE 3. Estimated mean Marbled Grouper densities (with SEs) at various banks sampled during the Southeast Area Monitoring and Assessment Program reef fish video survey in the northern Gulf of Mexico.

Bank	Camera stations	Area (m^2)	Average density (fish/m^2)	SE
McGrail	52	1,784.12	0.28	0.14
28-Fathom	29	994.99	0.10	0.10
Bouma	78	2,676.18	0.11	0.11
Bright	113	3,877.03	0.28	0.13
Coffee Lumps	10	343.1	0.58	0.58
East Flower Garden	185	6,347.35	0.20	0.08
Elvers	113	3,877.03	0.13	0.06
Ewing	76	2,607.56	0.08	0.05
Geyer	172	5,901.32	0.36	0.11
Jakkula	9	308.79	0.32	0.32
Parker	103	3,533.93	0.17	0.09
Rezak-Sidner	78	2,676.18	0.60	0.50
Midnight Lumps	29	994.99	0.10	0.10
Sweet	11	377.41	0.27	0.26
West Flower Garden	240	8,234.4	0.12	0.04

were not interested in investigating the bait. Observations on camera indicate that, in fact, the species does investigate the array, but the motivation cannot be resolved (e.g., curiosity or foraging). An alternative explanation is that at low densities, the bait plume is simply not reaching other Marbled Grouper in the area and thus is not increasing local density—therefore, the estimates presented here are similar to the two transect-based ROV/diver surveys. Interestingly, SEs estimated using baited stationary cameras are in line with the ROV- and diver-based estimates, which are typically thought to be more precise due to the increased area surveyed with those methods. When estimating Marbled Grouper densities, we ignored the potential effects of the array and bait; hence, these density estimates should be thought of as a simple method to compare stationary camera data with those generated from transect-based surveys. However, interpretation of the stationary camera densities should be used with careful consideration of the inherent bias underlying the data collection (i.e., the concentrating effect of bait plumes).

As with the abundance and density data, the length composition information was also affected by the frequency of observation. Length data were further impacted by the fact that not all fish could be measured, as they were not hit by the scaling lasers or were in a poor orientation for stereo-camera measurement. Low sample sizes associated with the length composition data prevented further evaluation of annual trends and use in size- or age-based assessment models. Average FLs reported by Clark et al. (2014) and Caldow et al. (2009) ranged from 450 to 570 mm, and those in this study ranged from 516 to 795 mm. This result suggests that the SEAMAP-RFV survey is observing larger Marbled Grouper on average. Because of the limited amount of data, it cannot be determined whether this is an effect of depth or of increased survey area covered by the SEAMAP-RFV survey. More intensive and focused sampling would be needed to determine whether there is a spatial or depth-related effect on Marbled Grouper length, weight, and age.

This study highlights the strengths and utility of optical surveys for collecting data on species that are either rare or not vulnerable to traditional fisheries sampling gears and the directed reef-fish fishery. For instance, analysis from this study versus the available fishery-dependent data would lead to extremely different conclusions on the status of this stock. Querying the NMFS Marine Recreational Information Program database between the years 1981 and 2017 showed catch records in only 5 years and always in low numbers and weight (NMFS, Fisheries Statistics Division, personal communication). In contrast, our study showed consistent annual trends in positive observations, albeit at low counts. Recent investigations comparing synchronously collected optical data and either hook or trap data routinely showed that the optical surveys collected higher diversity, had improved detection (i.e., decreased false negatives), and tracked population abundance more precisely (Harvey et al. 2012; Parker et al. 2016a, 2016b; Streich et al. 2018). Additionally, using habitat-based designs (Smith et al. 2011; Ault et al. 2018) or habitat data as covariates in models improves precision in abundance trends, particularly for species that are habitat specialists (Bacheler et al. 2013, 2016), such as Marbled Grouper. Thus, we recommend expansion of optical-based surveys, whether those are conducted by stationary- or vehicle-based systems.

The analysis presented here is a more robust evaluation of Marbled Grouper abundance trends than those presented in the two IUCN documents (Rocha et al. 2008; Claro et al. 2015) and relative to the general descriptions provided from various surveys conducted at the FGBNMS. Furthermore, this study provides model-based analysis of the Marbled Grouper's habitat preferences and spatial distributions for which there is nothing available in the literature but which does corroborate anecdotal observations cited in the IUCN reviews and other documents. The habitat preference information could be used to create a habitat-based survey design that would increase precision about the annual trend data and provide clarity on species status, but if this is desired, it would require a dedicated survey effort. Given that the previous regional IUCN classification of least concern status was based primarily on the consistent but rare observation of the Marbled Grouper in its preferred habitat, and given that the annual indices produced here are highly variable, we recommend that the current regional status (i.e., least concern) be maintained. However, because Marbled Grouper appear to aggregate similar to other groupers, they are potentially vulnerable to targeted fishing; hence, close attention should be paid to the harvest of the species, particularly around spawning times. Spatial management through national marine sanctuaries, such as the FGBNMS, does not prohibit hook-and-line fishing and thus would not be effective at protecting the spawning aggregations of Marbled Grouper. Furthermore, the remoteness of these banks (>185.2 km [>100 nautical miles] offshore) would make it difficult, if not impossible, to enforce some kind of spatial regulation. A better choice in this regard for Marbled Grouper would be a temporal closure that is focused on the timing of their spawning and that could be monitored by concurrent dockside interventions. Therefore, at this time, no further regional protection of Marbled Grouper is warranted given that (1) the banks in question are extremely remote from all major fishing ports, (2) Marbled Grouper are rarely captured with the commercial bandit reels used on fishing vessels that represent the primary effort on the remote banks, and (3) temporal trends remain consistent despite the low observation rates associated with the species.

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