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# SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Gulf of Mexico Gray Triggerfish 

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## Introduction

The primary objective of the annual Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video survey is to provide an index of the relative abundances of fish species associated with topographic features (e.g reefs, banks, and ledges) located on the continental shelf of the Gulf of Mexico (GOM) from Brownsville, TX to the Dry Tortugas, FL (Figures 1, and 14-33). Secondary objectives include quantification of habitat types sampled (video, multi-beam and side-scan), and collection of environmental data throughout the survey. Because the survey is conducted on topographic features the species assemblages targeted are typically classified as reef fish (e.g. red snapper, Lutjanus campechanus), but occasionally fish more commonly associated with pelagic environments are observed (e.g. Amberjack, Seriola dumerili). The survey has been executed from 1992-1997, 2001-2002, and 2004-present and historically takes place from April - May, however in limited years the survey was conducted through the end of August. The 2001 survey was abbreviated due to ship scheduling, during which, the only sites that were completed were located in the western Gulf of Mexico. Types of data collected on the survey include diversity, abundance (min-count), fish length, habitat type, habitat coverage, bottom topography and water quality. The size of fish sampled with the video gear is species specific however gray triggerfish (Balistes capriscus) sampled over the history of the survey had fork lengths ranging from $178-697 \mathrm{~mm}$, and mean annual fork lengths ranging from 313-421 mm (Table 7 and Figure 35). Age and reproductive data cannot be collected with the camera gear but beginning with the 2012 survey, a vertical line component was coupled with the video drops to collect hard parts, fin clips, and gonads and was included in the life history information provided by the NMFS Panama City Laboratory.

## Methods

Sampling design
Total reef area available to select survey sites from is approximately $1771 \mathrm{~km}^{2}$, of which $1244 \mathrm{~km}^{2}$ is located in the eastern GOM and $527 \mathrm{~km}^{2}$ in the western GOM. The large size of the survey area necessitates a two-stage sampling design to minimize travel times between stations. The first-stage uses stratified random sampling to select blocks that are 10 minutes of latitude by 10 minutes of longitude in dimension (Figure 1). The block strata were defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas), and by total reef habitat area contained in the block (blocks $\leq 20 \mathrm{~km}^{2}$ reef, block $>20 \mathrm{~km}^{2}$ reef). There are a total of 7 strata. A 0.1 by 0.1 mile grid is then overlaid onto the reef area contained
within a given block and the ultimate sampling sites (second stage units) are randomly selected from that grid.

## Gear and deployment

The SEAMAP reef fish survey has employed several camcorders in underwater housings since 1992. Sony VX2000 DCR digital camcorders mounted in Gates PD150M underwater housings were used from 2002 to 2005 and Sony PD170 camcorders during the years 2006 and 2007. In 2008 a stereo video camera system was developed and assembled at the NMFS Mississippi Laboratories - Stennis Space Center Facility and has been used in all subsequent surveys. The stereo video unit consists of a digital stereo still camera head, digital video camera, CPU , and hard drive mounted housed in an aluminum casing. All of the camcorder housings are rated to a maximum depth of 150 meters while the stereo camera housings are rated to 600 meters. Stereo cameras are mounted orthogonally at a height of 50 cm above the bottom of the pod and the array is baited with squid during deployment.

At each sampling site the stereo video unit is deployed for 40 minutes total, however the cameras and CPU delay filming for 5 minutes to allow for descent to the bottom, and settling of suspended sediment following impact. Once turned on, the cameras film for approximately 30 minutes before shutting off and retrieval of the array. During camera deployment the vessel drifts away from the site and a CTD cast is executed, collecting water depth, temperature, conductivity, and transmissivity from the surface to the maximum depth. Seabird units are the standard onboard NOAA vessels however the model employed was vessel/cruise dependent.

## Video tape viewing

One video tape from each station is randomly selected for viewing out of all viewable videos. Videos that have issues with visibility, obstructions or camera malfunction cannot be randomly selected and are not viewed. Selected videos are viewed for twenty minutes starting from the time when the view clears from suspended sediment. Viewers identify, and enumerate all species to the lowest taxonomic level during the 20 minute viewable segment. From 19932007 the time when each fish entered and left the field of view was recorded a procedure referred to as time in - time out (TITO) and from these data a minimum count was calculated. The minimum count is the maximum number of individuals of a selected taxon in the field of view at one instance. Each 20 minute video is evaluated to determine the highest minimum count observed during a 20 minute recording. From 2008-present the digital video allows the viewer to record a frame number or time stamp of the image when the maximum number of individuals of a species occurred, along with the number of taxon identified in the image, but does not use the TITO method. Both the TITO and current viewing procedure result in the minimum count estimation of abundance (i.e. - mincount). Minimum count methodology is preferred because it prevents counting the same fish multiple times (e.g. if a fish were swimming in circles around the camera). Annotated data from the video include: year (Y), region (R), block (B), strata (ST), depth (D), water temperature (T), dissolved oxygen (DO), salinity (S), silt sand clay (SSC), shell gravel (SG), rock (RK), attached epifauna (AE), grass (G), sponge (SP), unknown sessiles (US), algae (AL), hardcoral (HC), softcoral (SC), seawhips (SW), relief maximum (RM), relief average (RA), reef (RF), habitat diversity (Hperc), habitat diversity (Hbin), habitat evenness (Jperc). Data definitions are listed in appendix 1.

## Fish length measurement

Beginning in 1995 fish lengths were measured from video using lasers attached on the camera system with known geometry. However, the frequency of hitting targets with the laser is low and to increase sample size any measureable fish during the video read was measured (i.e. not just at the mincount), and fish could have potentially been measured twice. The stereo cameras used in 2008-present allow size estimation from fish images. From 2008-2013 Vision Measurement System (VMS, Geometrics Inc.) was used to estimate size of fish and in 2014 we began use of SeaGIS software (SeaGIS Pty. Ltd.). Fish measurement is only performed at the point in the video corresponding to the mincount therefore there is no potential to measure any fish twice.

## Data reduction

Various limitations either in design, implementation, or performance of gear causes limitations in calculating mincount and are therefore dropped from the design-based indices development and analysis as follows. In 1992, each fish was counted every time it came into view over the entire record time and the total of all these counts was the maximum count. Maximum count methodologies are not preferred and the 1992 video tapes were destroyed during Hurricane Katrina and cannot be re-viewed, so 1992 data is excluded from analyses (unknown number of stations). From 1998 - 2000 and in 2003 the survey was not conducted. In 2001 the survey was spatially restricted to the west and was an abbreviated survey and therefore we removed that year as well. Occasionally tapes are unable to be read (i.e. organisms cannot be identified to species) for the following reasons including: 1) camera views are more than $50 \%$ obstructed, 2) sub-optimal lighting conditions, 3 ) increased backlighting, 4) increased turbidity, 5) cameras out of focus, 6) cameras failed to film.

## Index Construction

Video surveys produce count data that often do not conform to assumptions of normality and are frequently modeled using Poisson or negative-binomial error distributions (Guenther et al. 2014). Video data frequently has high numbers of 'zero-counts' commonly referred to as 'zero-inflated' data distributions, they are common in ecological count data and are a special case of over dispersion that cannot be easily addressed using traditional transformation procedures (Hall 2000). Delta lognormal models have been frequently used to model video count data (Campbell et al. 2012) but recent exploration of models using negative-binomial, poisson (SEDAR 2015), zero-inflated negative-binomial, and zero-inflated poisson models(Guenther et al. 2014) have been accepted for use in assessments in the southeast U.S. Additionally for certain species like Gulf of Mexico red grouper (SEDAR 2015) it has been determined that a combined video index was useful and included data from NMFS-Mississippi Labs, NMFSPanama City, and FWRI index. We explored model fit using three different error distribution models to construct relative abundance indices including delta-lognormal, poisson and negative binomial.

Gulf wide, east gulf, and west gulf models were run and independent variables tested in the model included year and reef as class variables. In addition we tested several habitat complexity variables (Hperc, Hbin and Jperc) calculated using Shannon-Wiener and Pielou's J calculations and which were included as continuous variables. Model formulation was as
follows:mincount = year + reef + habitat complexity. We used the composite variable 'reef' and the habitat complexity variables rather than the percent coverage of individual habitat variables because of the strong relationship demonstrated between gray triggerfish and habitat use. Additionally, in data webinars leading up to the workshop it was decided that a combination of video indices submitted by NMFS-Mississippi Labs, NMFS-Panama City and FWRI was desired. These individual indices are submitted for review but an additional index was submitted for the combined index in a separate document. The GLIMMIX and MIXED procedure in SAS (v. 9.4) were used to develop the binomial and lognormal sub-models in the delta lognormal model (Lo et al. 1992), and GLIMMIX used to develop the poisson and negative binomial models. Best fitting models were determined by evaluating the conditional likelihood, overdispersion parameter (Pearson chi-square/DF), and visual interpretation of the $\mathrm{Q} / \mathrm{Q}$ plots.

## Results

Initial runs of the delta lognormal model produced poor fits to the data that were nonlinear (e.g. 'S shaped' QQ plots), therefore no subsequent runs were made using that error distribution, and only poisson and negative binomial error distributions were used thereafter. Evaluation of model iterations (by region and parameters) showed improved fit statistics for the negative binomial runs regardless of model run (e.g. region or variable inclusion). Negative binomial models consistently showed lower conditional likelihoods and Pearson chi-square /DF that were consistently closer to 1 . Both the poisson and negative binomial models showed nearly linear QQ plots (Figures 5, 9, and 13). Therefore the negative binomial model was selected as the best fitting model and we chose to only present model output and graphs from those runs for the Gulf wide, east Gulf, and west Gulf indices.

Gray triggerfish were observed throughout the eastern and western Gulf of Mexico in most years (Figures 14-34). The species is not commonly observed on reefs of the central and southern portions of the west Florida shelf and the Dry Tortugas. Spatial distributions of gray triggerfish we observed are highly reflective of the reef sampling universe used to select sampling sites (Figures 1 and 14-34). Gaps in habitat level information exist on the central portion of the west Florida shelf, Mississippi river delta region, and portions of the Texas coast. Gaps in the reef universe have slowly decreased since 2012 as habitat mapping efforts slowly discovered reef in previously unknown regions and since the survey began to be conducted on NOAA ship Pisces. Decreases in sampling gaps are particularly evident beginning in 2014. In most years the survey shows good coverage in the defined sampling universe, and coverage improved through time as the sampling universe expanded and more sites were added to the survey.

In all three spatial runs (east, west, and Gulf wide) year and reef were significant variables. Additionally, and depending on model run, each of the habitat complexity (Hperc and Jperc) were significant. Because the variable reef measures whether or not we believe the camera landed on the reef and the habitat complexity variable scales the complexity of the habitat we believed these variables were correlated and thus models were reduced to use one of them. Further because model fits was improved and resulted in decreased coefficient of variation's (CVs) we selected the Pielou's J evenness habitat complexity variable to use in all model runs (Jperc).

Through time it appears that the Gulf wide index shows a lot of variability and a slightly declining trend through time. Proportion positives are highest but steadily decline in the early years of the survey (1993-2005) but stabilized in recent years (2005 to present). Proportion
positives generally reflect the abundance trends in which there is a general decline through the time series (Table 5, Figure 2). Highest mincounts were observed in 1993, 1994, and 1997 whereas low index values were observed in 2007 and 2014 (Table 4, Figures 2-4). Since 2004 mincount observations of gray triggerfish appear to be fairly stable in the Gulf wide model with the exception of two high years in 2007, 2009 and 2011 (Figures 3 and 4).

The east gulf showed steeper declines than did the Gulf wide model for proportion positives, observed mincounts, and predicted mincounts (Table 5, Figures 6-8). Highest mincounts were observed in 1993-2002 as was the case in the Gulf wide model. Similar to the Gulf wide model the population appears to stabilize around 2004, however the mincount is generally on a negative trend but with intermittent up/down years. After 2004 peak abundance was observed in 2009 with a smaller peak observe din 2011 similar to the Gulf wide model.

Unlike in the east and the Gulf wide model, the west Gulf model shows a general slighting increasing to a static trend over the course of the time series for the proportion positives, observed mincounts, and predicted mincounts (Table 7, Figures 10-12). Highest mincounts were observed in 1997, 2004, and 2011-2013. Since 2004 the population appears to be stable, but unlike the east and Gulf wide models shows a general increasing trend in abundance.

The size of fish sampled with the video gear is species specific however gray triggerfish (Balistes capriscus) sampled over the history of the survey had fork lengths ranging from 178 697 mm , and mean annual fork lengths ranging from 313-421 mm (Table 7 and Figure 35). There does not appear to be any trend through time. Largest fish were measured in the west Gulf in 1995. Peaks in length were observed in 1995, 2003, 2009, 2010, and 2012. There appears to be no difference between length composition by region (Table 7, Figure 35).

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Figure 1. Spatial distribution of known reef from which stations are randomly selected for sampling for the reef fish video survey. Over the history of the survey (1992-2013) new reef tract has been discovered and mapped and therefore this map represents what was available in 2013, and not necessarily what has been available over the entire time series.


Table 1. Gulf wide negative binomial (Neg-Bin) model run test of type III fixed effects.

| Type III Tests of Fixed Effects |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | :---: |
| Effect | Num DF | Den DF | F Value | Pr > F |  |
| year | 19 | 6126 | 4.08 | $<.0001$ |  |
| Jperc | 1 | 6126 | 33.45 | $<.0001$ |  |

Table 2. East Gulf negative binomial (Neg-Bin) model run test of type III fixed effects.

| Type III Tests of Fixed Effects |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Effect | Num DF | Den DF | F Value | Pr>F |
| year | 19 | 3879 | 6.34 | $<.0001$ |
| Jperc | 1 | 3879 | 90.48 | $<.0001$ |

Table 3. West Gulf negative binomial (Neg-Bin) model run test of type III fixed effects.

| Type III Tests of Fixed Effects |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: |
| Effect | Num DF | Den DF | F Value | Pr>F |
| year | 19 | 2226 | 3.30 | $<.0001$ |
| Jperc | 1 | 2226 | 0.5 | 0.4779 |

Table 4. Output for the negative binomial index of relative abundance of gray triggerfish by year, Gulf wide model run.

| Year | N | Proportion <br> positive | Mincount | Standardized <br> index | CV |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{1 9 9 3}$ | 159 | 0.245 | 0.440 | 0.429 | 17.870 |
| $\mathbf{1 9 9 4}$ | 127 | 0.299 | 0.433 | 0.418 | 22.794 |
| $\mathbf{1 9 9 5}$ | 99 | 0.182 | 0.303 | 0.308 | 23.936 |
| $\mathbf{1 9 9 6}$ | 298 | 0.178 | 0.262 | 0.266 | 18.992 |
| $\mathbf{1 9 9 7}$ | 289 | 0.277 | 0.626 | 0.604 | 18.371 |
| $\mathbf{2 0 0 2}$ | 243 | 0.165 | 0.325 | 0.319 | 17.551 |
| $\mathbf{2 0 0 4}$ | 200 | 0.180 | 0.320 | 0.312 | 19.558 |
| $\mathbf{2 0 0 5}$ | 410 | 0.139 | 0.244 | 0.243 | 21.724 |
| $\mathbf{2 0 0 6}$ | 415 | 0.118 | 0.217 | 0.213 | 23.901 |
| $\mathbf{2 0 0 7}$ | 490 | 0.098 | 0.147 | 0.142 | 23.491 |
| $\mathbf{2 0 0 8}$ | 337 | 0.128 | 0.217 | 0.225 | 20.304 |
| $\mathbf{2 0 0 9}$ | 429 | 0.156 | 0.217 | 0.219 | 24.161 |
| $\mathbf{2 0 1 0}$ | 327 | 0.098 | 0.229 | 0.263 | 24.699 |
| $\mathbf{2 0 1 1}$ | 440 | 0.173 | 0.314 | 0.336 | 20.736 |
| $\mathbf{2 0 1 2}$ | 481 | 0.127 | 0.252 | 0.267 | 24.033 |
| $\mathbf{2 0 1 3}$ | 300 | 0.123 | 0.247 | 0.251 | 24.505 |
| $\mathbf{2 0 1 4}$ | 343 | 0.079 | 0.114 | 0.121 | 27.401 |
| $\mathbf{2 0 1 5}$ | 192 | 0.109 | 0.156 | 0.151 | 25.086 |
| $\mathbf{2 0 1 6}$ | 373 | 0.121 | 0.193 | 0.197 | 24.515 |
| $\mathbf{2 0 1 7}$ | 410 | 0.117 | 0.185 | 0.185 | 25.605 |

Figure 2. Plot of the proportion positives for gray triggerfish, Gulf wide model run.


Figure 3. Plot of the least squares means of inverse linked mincount with $95 \%$ CI's for gray triggerfish, Gulf wide negative-binomial model run.

## LS-M eans for year

With 95\% Confidence Limits


Figure 4. Mean gray triggerfish counts for the observed (mincount) and predicted ( Mu ) mincounts from the Gulf wide negative binomial model run.


Figure 5. QQ plot of conditional residuals for the Gulf wide negative binomial model run.

## Q-Q Plot of Conditional Residuals Grey Triggerfish M incounts~ Neg Bin



Table 5. Output for the negative binomial index of relative abundance of gray triggerfish by year, east Gulf model run.

| Year | N | Proportion <br> positive | Mincount | Standardized <br> index | CV |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{1 9 9 3}$ | 114 | 0.32 | 0.59 | 0.58 | 35.07 |
| $\mathbf{1 9 9 4}$ | 82 | 0.37 | 0.54 | 0.53 | 41.91 |
| $\mathbf{1 9 9 5}$ | 55 | 0.29 | 0.49 | 0.53 | 49.68 |
| $\mathbf{1 9 9 6}$ | 133 | 0.29 | 0.41 | 0.43 | 34.70 |
| $\mathbf{1 9 9 7}$ | 162 | 0.31 | 0.49 | 0.53 | 30.48 |
| $\mathbf{2 0 0 2}$ | 151 | 0.21 | 0.40 | 0.40 | 31.27 |
| $\mathbf{2 0 0 4}$ | 149 | 0.19 | 0.27 | 0.27 | 32.14 |
| $\mathbf{2 0 0 5}$ | 274 | 0.16 | 0.23 | 0.22 | 43.01 |
| $\mathbf{2 0 0 6}$ | 276 | 0.16 | 0.27 | 0.27 | 44.56 |
| $\mathbf{2 0 0 7}$ | 319 | 0.11 | 0.15 | 0.15 | 45.98 |
| $\mathbf{2 0 0 8}$ | 206 | 0.10 | 0.15 | 0.15 | 37.61 |
| $\mathbf{2 0 0 9}$ | 262 | 0.19 | 0.28 | 0.29 | 47.40 |
| $\mathbf{2 0 1 0}$ | 221 | 0.09 | 0.18 | 0.19 | 48.27 |
| $\mathbf{2 0 1 1}$ | 337 | 0.17 | 0.23 | 0.24 | 39.33 |
| $\mathbf{2 0 1 2}$ | 281 | 0.09 | 0.12 | 0.12 | 48.13 |
| $\mathbf{2 0 1 3}$ | 164 | 0.10 | 0.13 | 0.14 | 42.80 |
| $\mathbf{2 0 1 4}$ | 230 | 0.05 | 0.05 | 0.06 | 52.57 |
| $\mathbf{2 0 1 5}$ | 144 | 0.13 | 0.18 | 0.19 | 44.96 |
| $\mathbf{2 0 1 6}$ | 205 | 0.13 | 0.19 | 0.20 | 45.79 |
| $\mathbf{2 0 1 7}$ | 221 | 0.10 | 0.13 | 0.14 | 49.70 |

Figure 6. Plot of the proportion positives for gray triggerfish, east Gulf model run.


Figure 7. Plot of the least squares means of inverse linked mincount with $95 \%$ CI's for gray triggerfish for the east Gulf negative binomial model run.

LS-M eans for year
With 95\% Confidence Limits


Figure 8. Mean gray snapper counts for the observed (mincount) and predicted (Mu) mincounts from the east Gulf negative binomial model run.


Figure 9. QQ plot of conditional residuals for the east Gulf negative binomial model run.


Table 6. Output for the negative binomial index of relative abundance of gray triggerfish by year, west Gulf model run.

| Year | N | Proportion <br> positive | Mincount | Standardized <br> index | CV |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{1 9 9 3}$ | 45 | 0.07 | 0.07 | 0.07 | 4.35 |
| $\mathbf{1 9 9 4}$ | 45 | 0.18 | 0.24 | 0.23 | 5.97 |
| $\mathbf{1 9 9 5}$ | 44 | 0.05 | 0.07 | 0.07 | 5.07 |
| $\mathbf{1 9 9 6}$ | 165 | 0.08 | 0.15 | 0.15 | 4.50 |
| $\mathbf{1 9 9 7}$ | 127 | 0.23 | 0.80 | 0.73 | 5.03 |
| $\mathbf{2 0 0 2}$ | 92 | 0.10 | 0.21 | 0.21 | 4.84 |
| $\mathbf{2 0 0 4}$ | 51 | 0.16 | 0.47 | 0.48 | 6.54 |
| $\mathbf{2 0 0 5}$ | 136 | 0.10 | 0.28 | 0.29 | 5.25 |
| $\mathbf{2 0 0 6}$ | 139 | 0.04 | 0.12 | 0.11 | 5.82 |
| $\mathbf{2 0 0 7}$ | 171 | 0.08 | 0.14 | 0.13 | 5.72 |
| $\mathbf{2 0 0 8}$ | 131 | 0.17 | 0.32 | 0.33 | 5.43 |
| $\mathbf{2 0 0 9}$ | 167 | 0.10 | 0.12 | 0.12 | 5.90 |
| $\mathbf{2 0 1 0}$ | 106 | 0.11 | 0.34 | 0.38 | 6.17 |
| $\mathbf{2 0 1 1}$ | 103 | 0.17 | 0.57 | 0.62 | 5.63 |
| $\mathbf{2 0 1 2}$ | 200 | 0.18 | 0.44 | 0.47 | 5.76 |
| $\mathbf{2 0 1 3}$ | 136 | 0.15 | 0.39 | 0.39 | 6.46 |
| $\mathbf{2 0 1 4}$ | 113 | 0.13 | 0.24 | 0.27 | 6.73 |
| $\mathbf{2 0 1 5}$ | 48 | 0.06 | 0.08 | 0.05 | 7.04 |
| $\mathbf{2 0 1 6}$ | 168 | 0.11 | 0.20 | 0.21 | 6.06 |
| $\mathbf{2 0 1 7}$ | 189 | 0.14 | 0.25 | 0.24 | 6.12 |

Figure 10. Plot of the proportion positives for gray triggerfish, west Gulf model run.


Figure 11. Plot of the least squares means of inverse linked mincount with $95 \%$ CI's for gray triggerfish, west Gulf negative binomial model run.


Figure 12. Mean generic species counts for the observed (mincount) and predicted (Mu no blups \& Mu blups) mincounts from the west Gulf negative binomial model run.


Figure 13. QQ plot of conditional residuals for the west Gulf negative binomial model run.

## Q-Q Plot of Conditional Residuals Grey Triggerfish M incounts~Neg Bin



Figure 14. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 1993.


Figure 15. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 1994.


Figure 16. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 1995.


Figure 17. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 1996.


Figure 18. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 1997.


Figure 19. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2001.


Figure 20. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2002.


Figure 21. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2004.


Figure 22. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2005.


Figure 23. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2006.


Figure 24. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2007.


Figure 25. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2008.


Figure 26. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2009.


Figure 27. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2010.


Figure 28. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2011.


Figure 29. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2012.


Figure 30. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2013.


Figure 31. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2014.


Figure 32. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2015.


Figure 33. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2016.


Figure 34. Map of gray triggerfish mincounts during the SEAMAP reef fish video cruise in 2017.


Table 7. Gray triggerfish fork lengths (FL) from the SEAMAP reef fish video cruise from 1993 - 2017. Includes estimates for the mean and standard deviation by region and Gulf wide.

|  |  | Mean |  |  | SD |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Year | EGOM | WGOM | GOM | EGOM | WGOM | GOM |  |
| $\mathbf{1 9 9 5}$ | 300.00 | 500.00 | 350.00 | 43.30 | na | 106.07 |  |
| $\mathbf{1 9 9 6}$ | 374.34 | 369.44 | 373.40 | 80.01 | 64.68 | 76.68 |  |
| $\mathbf{1 9 9 7}$ | 311.11 | 316.67 | 313.33 | 35.60 | 54.01 | 42.12 |  |
| $\mathbf{2 0 0 2}$ | 367.37 | 410.71 | 375.68 | 66.35 | 60.22 | 67.05 |  |
| $\mathbf{2 0 0 3}$ | 421.43 | na | 421.43 | 39.34 | na | 39.34 |  |
| $\mathbf{2 0 0 4}$ | 400.00 | 313.89 | 364.77 | 45.28 | 53.01 | 64.32 |  |
| $\mathbf{2 0 0 5}$ | 377.82 | 362.35 | 368.97 | 64.67 | 78.12 | 72.84 |  |
| $\mathbf{2 0 0 6}$ | 350.00 | 313.60 | 334.13 | 50.00 | 40.85 | 49.52 |  |
| $\mathbf{2 0 0 7}$ | 375.00 | 365.83 | 371.01 | 73.22 | 92.26 | 81.53 |  |
| $\mathbf{2 0 0 8}$ | 366.67 | 394.12 | 378.05 | 59.28 | 88.62 | 73.14 |  |
| $\mathbf{2 0 0 9}$ | 360.61 | 420.83 | 369.87 | 55.91 | 87.20 | 64.17 |  |
| $\mathbf{2 0 1 0}$ | 425.00 | 354.55 | 360.42 | na | 64.05 | 64.37 |  |
| $\mathbf{2 0 1 1}$ | 379.55 | 364.29 | 374.62 | 73.98 | 58.93 | 69.39 |  |
| $\mathbf{2 0 1 2}$ | 365.00 | 416.67 | 387.14 | 74.96 | 93.86 | 86.26 |  |
| $\mathbf{2 0 1 3}$ | 375.00 | 364.13 | 366.94 | 64.09 | 47.57 | 51.39 |  |
| $\mathbf{2 0 1 4}$ | 458.33 | 401.56 | 417.05 | 91.74 | 66.75 | 76.53 |  |
| $\mathbf{2 0 1 5}$ | 381.25 | 375.00 | 380.56 | 76.10 | 70.71 | 73.54 |  |
| $\mathbf{2 0 1 6}$ | 400.00 | 380.00 | 392.86 | 66.87 | 60.65 | 64.70 |  |
| $\mathbf{2 0 1 7}$ | 425.00 | 400.00 | 410.94 | 121.69 | 72.76 | 96.29 |  |
| Overall | 373.14 | 361.86 | 368.45 | 68.90 | 74.58 | 71.49 |  |

Figure 35. Gray triggerfish length-frequency plots (fork length) observed during the SEAMAP reef fish video cruise from 1993 - 2017 for the east and west Gulf of Mexico.


## Appendix 1. Explanatory variables and definitions

Year $(\mathrm{Y})=$ The survey is conducted on an annual basis during the spring and the objective is to calculate standardized observation rates by year. Years included 1993-1997, 2001-2002, and 2004-2014.

Region $(R)=$ The survey is conducted throughout the northern Gulf of Mexico, however historically the SEDAR data workshop has requested separate indices for the western and eastern Gulf which is divided at $89^{\circ}$ west longitude. This variable is not included in the model itself.

Block $(B)=$ The first stage of the random site selection process is selected from 10 ' latitude x 10' longitude blocks. Only blocks containing known reef are eligible for selection. Ten sites are randomly selected from within the blocks. Initial models always include a random block factor to test for autocorrelation among sites within a block.

Strata $(S T)=$ Strata are defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas), and by total reef habitat area contained in the block (blocks $\leq 20 \mathrm{~km}^{2}$ reef, block $>20 \mathrm{~km}^{2}$ reef). There are a total of 7 strata.

Depth $(D)=$ Water depth at the lat-lon where the camera was deployed via TDR placed on the array.

Temperature $(\mathrm{T})=$ Water temperature on the bottom $\left(\mathrm{C}^{\circ}\right)$ taken during camera deployment via TDR placed on the camera array.

Dissolved oxygen (DO) = Dissolved oxygen (mg/l) taken via CTD cast slightly away from where the camera is deployed.

Salinity $(\mathrm{S})=$ Salinity $(\mathrm{ppt})$ taken via CTD cast slightly away from where the camera is deployed.

Silt sand clay $(S S C)=$ Percent bottom cover of silt, sand, or clay substrates.
Shell gravel $(\mathrm{SG})=$ Percent bottom cover of shell or gravel substrates .
Rock $($ RK $)=$ Percent bottom cover of rock substrates .
Attached epifauna $(\mathrm{AE})=$ Percent bottom cover of attached epifauna on top of substrate.
Grass $(\mathrm{G})=$ Percent bottom covered by grass.
Sponge $(\mathrm{SP})=$ Percent bottom covered by sponge .
Unknown sessiles $(\mathrm{US})=$ Percent bottom covered by unknown sessile organisms.

Algae $(A L)=$ Percent bottom covered by algae .
Hardcoral $(\mathrm{HC})=$ Percent bottom covered by hard coral.

Softcoral $(\mathrm{SC})=$ Percent bottom covered by soft coral.
Seawhips $(\mathrm{SW})=$ Percent bottom covered by seawhips .
Relief Maximum $(\mathrm{RM})=$ Maximum relief measured from substrate to highest point.
Relief Average $(R A)=$ Average relief measured from substrate to all measurable points.
Reef $(\mathrm{RF})=$ Boolean variable indicating whether or not a station landed on reef or missed reef. It is a composite variable where positive reef stations area identified as having one of the following: $>5 \%$ hard coral or $>5 \%$ rock or $>5 \%$ soft coral

Diversity $($ Hperc $)=$ Shannon weiner diversity index. We calculated Hperc using the percent coverage data associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).

Diversity (Hbin) = Shannon weiner diversity index. We calculated Hbin using the percent coverage data transformed to binary (presence/absence) values and which are associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).

Evenness (Jperc) = Pielou's evenness. J' = H'/H'max. Evenness is calculation of how equal a community is across species/groups. We calculated Jperc using the percent coverage data associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).

