Fisheries-independent data for Hogfish (*Lachnolaimus maximus*) from reef-fish video surveys on the West Florida Shelf, 2005-2012.

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Introduction:

Reef fishes, including Hogfish, are targeted commercially and recreationally along the West Florida Shelf (WFS). Historically, the assessment and management of reef fishes in the Gulf of Mexico has relied heavily on data from fisheries-dependent sources, although limitations and biases inherent to these data are admittedly a major source of uncertainty in current stock assessments. The accuracy of harvest estimates, particularly on the recreational side, has been challenged in recent years. Additionally, commercial, headboat, and recreational landings data are restricted to harvestable-sized fish, and thus are highly influenced by regulatory changes (i.e., size limits, recreational bag limits, and seasonal closures). These limitations render it difficult to forecast potential stock recovery associated with strong year classes entering the fishery. There has been a renewed emphasis in recent years to increase the availability of fisheries-independent data on reef fish populations in the Gulf of Mexico because these data reflect the status of fish populations as a whole, rather than just the portion of the population taken in the fishery. To meet this need for fisheries-independent data for reef fishes, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) has been working collaboratively with scientists from the National Marine Fisheries Service (NMFS) to expand regional monitoring capabilities and provide timely fisheries-independent data for a variety of state- and federally-managed reef fishes. Results for Hogfish are summarized from fisheries-independent reef fish surveys conducted by NMFS – Panama City in the northeastern Gulf of Mexico and FWRI along the West Florida Shelf. Although both surveys employ a combination of stationary underwater video arrays and chevron traps, results are only presented for the video survey because Hogfish are only rarely collected with chevron traps.

Survey Design and Sampling Methods – PC:

The NMFS – Panama City video survey, which includes natural reef habitat on the inner shelf of the northeastern Gulf of Mexico (Figure 1), was initiated in 2005. Video sampling was only conducted in Apalachee Bay in 2005 but was subsequently expanded to the entire survey area in 2006. Sampling was conducted during daytime hours (1 hr after sunrise until 1 hr before sunset) between May and early October, with most sampling during June through September. At each site, a CTD cast was made to collect water-column temperature, salinity, oxygen, and turbidity data.

The survey sampling design was systematic through 2009 because of a very limited universe of possible sample sites. Beginning in 2010, a two-stage random survey design was employed because side-scan sonar surveys conducted in that year yielded an order of magnitude increase in sites within the sampling universe. Five by five minute blocks known to contain reef sites, and proportionally allocated by region, sub-region, and depth (10-20, 20-30, 30+ m) to ensure uniform geographic and bathymetric coverage, were randomly chosen. Then two known reef sites a minimum of 300 m apart within each selected block were randomly selected. Alternates were also selected and were sampled if another boat was fishing the site or if no hard bottom was detected by sonar.

Visual data were collected using a stationary camera array composed of 4 High 8 video cameras (2005 only) or 4 high definition (HDEF), digital video cameras (2006-08) mounted orthogonally

30 cm above the bottom of an aluminum frame. From 2007 to 2009, parallel lasers (100 mm spacing) mounted above and below each camera were used to estimate the sizes of fish which crossed the field of view perpendicular to the camera. In 2009 and 2010, one of the HDEF cameras was replaced with a stereo imaging system (SIS) consisting of two high resolution black and white still cameras mounted 8 cm apart, one digital video (mpeg) color camera, and a computer to automatically control these cameras as well as store the data. The SIS provides images from which fish measurements can be obtained with the Vision Measurement System (VMS) software. Beginning in 2011, a second SIS facing 180º from the other SIS was added, reducing the number of HDEFs to two; and both SISs were also upgraded with HDEF, color mpeg cameras. The camera array was unbaited from 2005-2008. Since 2009, the array has been freshly baited prior to each drop with one previously frozen Atlantic Mackerel placed in a mesh bag near the center.

Before stereo camera systems were used (prior to 2009), soak time for the array was 30 min to allow sediment stirred up during camera deployment to dissipate and ensure tapes with an unoccluded view duration of at least 20 min. With the addition of stereo cameras in 2009, soak time was increased to 45 min to allow sufficient time for the SIS to be settled on the bottom before starting its hard drive and to insure that the hard drive had time to shut down before retrieval. Prior to 2009, tapes of the 4 HDEF cameras were scanned, with the one with the best view of the habitat analyzed in detail. If no view was obviously better, one was randomly chosen. In 2009 only the 3 HDEF video cameras were scanned, and the one with the best view of the reef was analyzed. Starting in 2010, all 4 cameras – the HDEFs and the SIS MPEGs, which have virtually the same fields of view (64 vs. 65º) – were scanned, and again, the one with the best view of the habitat was analyzed. Twenty minutes of the tape were viewed, beginning when the cloud of sediment disturbed by the landing of the array had dissipated. All fish captured on videotape were identified to the lowest discernible taxon. Data on habitat type and reef morphometrics were also recorded. If the quality of the mpeg video derived from the SIS was less than desirable (a common problem), fish identifications were confirmed on the much higher quality and concurrent stereo still frames. The estimator of abundance was the maximum number of a given species in the field of view at any time during the 20 min analyzed (MaxN), and VMS measurements were only taken from a still frame showing the minimum count of a given species to eliminate the possibility of measuring the same fish more than once. Even for deployments where the SIS did not provide a good view of the reef habitat, the files were examined to obtain fish measurements using VMS, and again, those measurements were only taken from a still frame showing the minimum count of a given species. In contrast, when using the scaling lasers on the array to obtain length data, there was no way to eliminate the possibility of double measuring a given fish, although this was probably not a serious problem because usable laser hits were typically rare for any one sample.

Survey Design and Sampling Methods – FWRI:

The FWRI reef fish survey includes a portion of the WFS bounded by 26^{o} and 28^{o} N latitude and depths from 10 – 110 m (Figure 1). The boundaries of the WFS sampling universe were chosen to compliment ongoing NMFS reef-fish surveys. To assure adequate spatial coverage of sampling, the WFS survey area was subdivided into four sampling zones comprised of two NMFS statistical zones (Tampa Bay: NMFS statistical zone 5; Charlotte Harbor: NMFS statistical zone 4) and two depth zones (Nearshore: 10 – 37 m; Offshore: 37 – 110 m). Prior to conducting exploratory sampling in 2008, the WFS survey area was subdivided into 1 km x 1 km sampling units. Results from 2008 indicated that the 1 km x 1 km spatial scale was too large in relation to the small-scale habitat features characteristic of the WFS; accordingly, from 2009 onward the WFS survey area was subdivided into 0.1 nm x 0.3 nm sampling units (E/W by N/S). Overall sampling effort (annual goal of 200 sampling units) was proportionally allocated among the four sampling zones (TBN: Tampa Bay Nearshore; TBO: Tampa Bay Offshore; CHN: Charlotte Harbor Nearshore; CHO: Charlotte Harbor Offshore) based on habitat availability, and specific sampling units were selected randomly within each sampling zone.

Very little is known regarding the fine-scale distribution of reef habitat throughout much of the WFS, and due to anticipated cost and time requirements, mapping the entire WFS survey area was not feasible prior to initiating the WFS reef fish survey. For the 2008 reef fish survey, the identification of sampling units with an increased probability of containing reef habitat (and inclusion in the sampling frame for the reef-fish survey) was based on bottom rugosity calculated from 100-m-resolution interpolated bathymetry data. An examination of results from the 2008 survey indicated that a high proportion of sampling effort occurred at sites with no reef habitat (i.e., unconsolidated sediment). Accordingly, the sampling universe was updated in 2009 to include habitat information provided by commercial fishermen as well as published literature. Further, we implemented an adaptive strategy where a three-pass acoustic survey was conducted covering an area of 1 nm to the east and west of the pre-selected sampling unit prior to sampling. In 2009 and part of 2010, the acoustic survey was conducted using the research vessel echosounder, whereas for part of 2010 and 2011 onward the acoustic survey was conducted using an L3- Klein 3900 side scan sonar. If these acoustic surveys produced evidence of reef habitat in a nearby sampling unit, but not in the pre-selected sampling unit, sampling effort was randomly relocated the nearby sampling unit.

At each sampling station, stationary underwater camera arrays (SUCA) were deployed, and gear deployments and collection and processing of field data followed established NMFS protocols. At each station, 1-2 SUCAs were deployed that consisted of a pair of stereo imaging system (SIS) units positioned at an angle of 180º from one another to maximize the total field of view. Each SIS unit consisted of an underwater housing containing a digital camcorder to record video and a pair of stereo cameras to capture still images at a rate of one per second. Each SUCA was baited (generally Atlantic Mackerel) and deployed for thirty minutes to assure that twenty minutes of continuous video and stereo images were recorded. Video data from one SIS per SUCA deployment were processed to quantify the relative abundance of Hogfish (MaxN, or the maximum number of Hogfish observed on a single video frame). All individual gear deployments were spaced a minimum of 100 m apart; nevertheless, since these deployments were generally closer than those conducted by PC, data from replicate SUCA deployments at a station were combined (maximum of the two MaxN values) for subsequent analyses. In addition to data on Hogfish, geographic coordinates, depth, physiochemical conditions (e.g., temperature, salinity, dissolved oxygen, pH), and time of day were recorded at each sampling site.

Analytical Methods:

Hogfish were rarely observed to the west of Cape San Blas, and very few Hogfish were observed in waters deeper than 40 m (Figure 1). Accordingly, data from these areas were excluded prior to conducting statistical analyses. Data were also excluded from video deployments in which water was too turbid to conduct meaningful video reads and from unsuccessful video deployments (i.e., array landed on the side, array moved during the video). Data from the PC and FWRI surveys were combined for statistical analyses. Nominal statistics were calculated for each year and sampling zone, including frequency of occurrence and mean (± SE) relative abundance (average MaxN) of Hogfish.

For assessment purposes, indices of abundance have traditionally been calculated using delta-lognormal modeling methods. However, during the data workshop for SEDAR 33, the indices working group discussed the fact that this approach is likely inappropriate for many analyses because the distribution of positive catches often does not follow a lognormal distribution, as is the case with Hogfish (Figure 2). Accordingly, model-based estimates of annual abundance for Hogfish were calculated using generalized linear modeling methods. The downside to this approach is that traditional model diagnostic criteria, including residual diagnostics, are currently unavailable, and so it is difficult to select the most appropriate base model (e.g., negative binomial vs. Poisson). Nevertheless, exploratory analyses conducted during the SEDAR 33 data workshop indicated that model choice had little influence on annual relative abundance patterns among the various indices constructed.

Generalized linear modeling analyses were used to construct annual indices of relative abundance of Hogfish using SAS software and the GLIMMIX procedure. The relative abundance of Hogfish (MaxN) represents count data, the distribution of which is bound by zero and highly nonnormal; accordingly, data were fit using the negative binomial distribution. Year and survey (PC and FWRI) were included as categorical explanatory variables in the model, while depth was included as a covariate. Additionally, the presence or absence of hard bottom habitat observed on video was included as a categorical explanatory variable because this is the only consistent measure of the presence of reef habitat that could be constructed for video data from both surveys throughout the entire survey time period. Variables identified as nonsignificant ($\alpha = 0.10$) were excluded, and the analysis was repeated in a stepwise fashion until only significant variables remained in the model. Results are reported only for final variables included in the models. For each model, annual least-square-mean estimates (± SE) of relative abundance of Hogfish were exported in the scale of the original data to assess temporal variability in Hogfish relative abundance. Based on final model results, annual coefficients of variation (mean / standard deviation) were calculated to assess the ability of the model to assess interannual recruitment variability. Because standard deviation values associated with annual least square means from generalized linear analyses are not available, we created a sampling distribution by repeatedly (n = 10,000 times) calculating a random deviate from the standard normal distribution ($\mu = 0$, $\sigma^2 = 1$). These deviates were then multiplied by the standard error, and products were added to the least square mean to generate the sampling distribution from which standard deviation values were calculated.

Results / Discussion:

In shallow waters (< 40 m) east of Cape San Blas, a total of 556 camera deployments have been made by NMFS – Panama City from 2005 – 2012 (Figure 1; Table 1). Concurrently, a total of 312 camera deployments have been made by FWRI in shallow waters (< 40 m) off Tampa Bay and Charlotte Harbor from 2008 – 2012. Overall, frequency of occurrence and the mean nominal number of Hogfish observed per station has generally been higher in the NMFS – Panama City survey, although both frequency of occurrence and mean number of Hogfish observed per station have increased in the FWRI survey through time. Hogfish lengths ranged from 162 – 552 mm FL (Figure 3). Although individuals were slightly larger in the Panama City survey, size-frequency distributions were generally similar, with most individuals between 200 and 400 mm FL (likely representing individuals between 1 and 10 years of age; Collins and McBride 2011).

All categorical explanatory variables (year, survey, and presence/absence of hard bottom habitat) and the depth covariate were retained for the generalized linear model (Table 2). For the final model, the ratio of Pearson Chi-Square to degrees of freedom was approximately 1 (1.11). Combined abundance indices were constructed for 2005 – 2012 (Figure 4; Table 3); excluding an extremely low index for 2007, these indices appear to indicate that the relative abundance of Hogfish is increasing slightly thorough time. Aside from 2007, coefficients of variation are satisfactorily low.

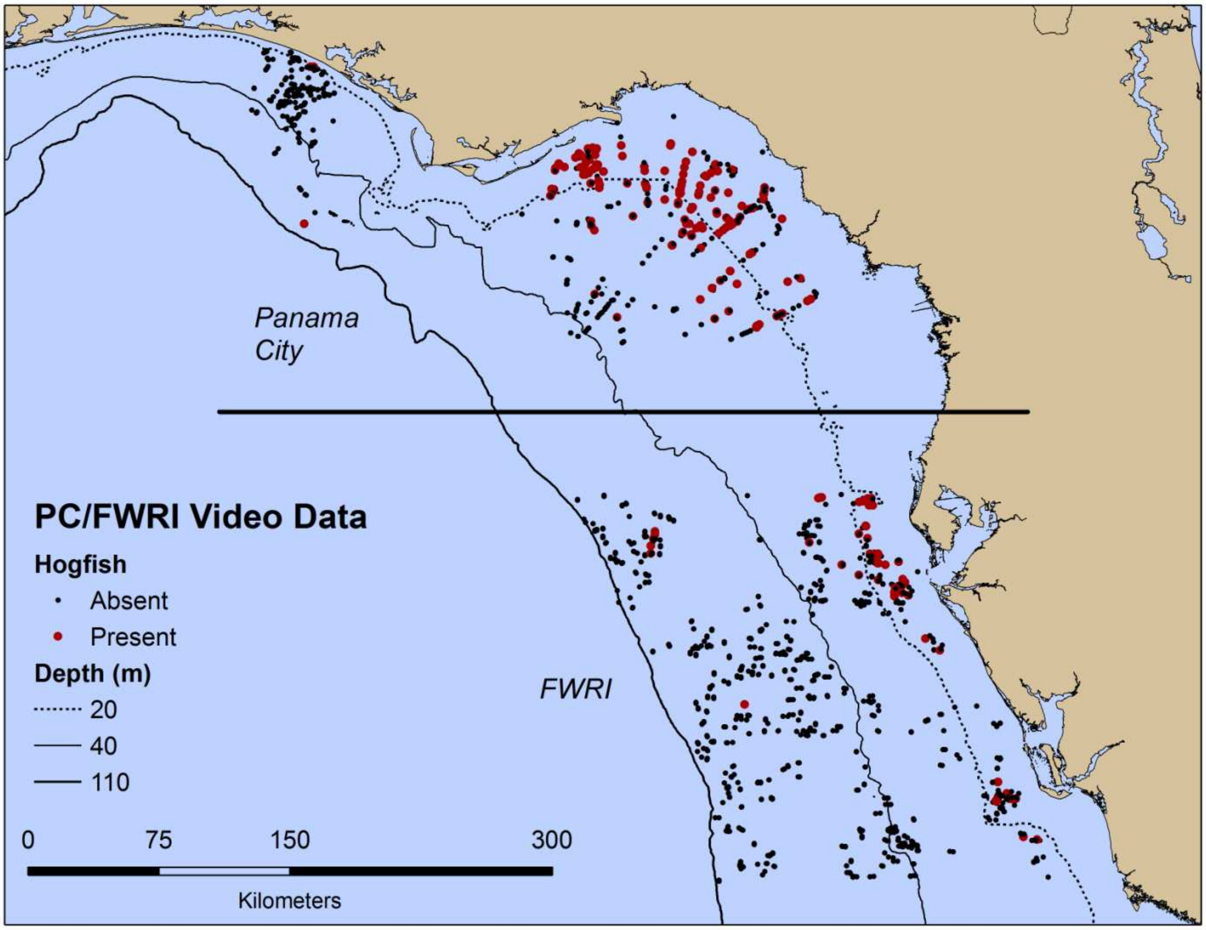

Figure 1. Locations of all stations sampled during annual reef fish video surveys conducted by NMFS – Panama City (2005 – 2012) and FWRI (2008 – 2012). Black dots represent stations where Hogfish were not observed, whereas red dots represent stations where Hogfish were observed on video.

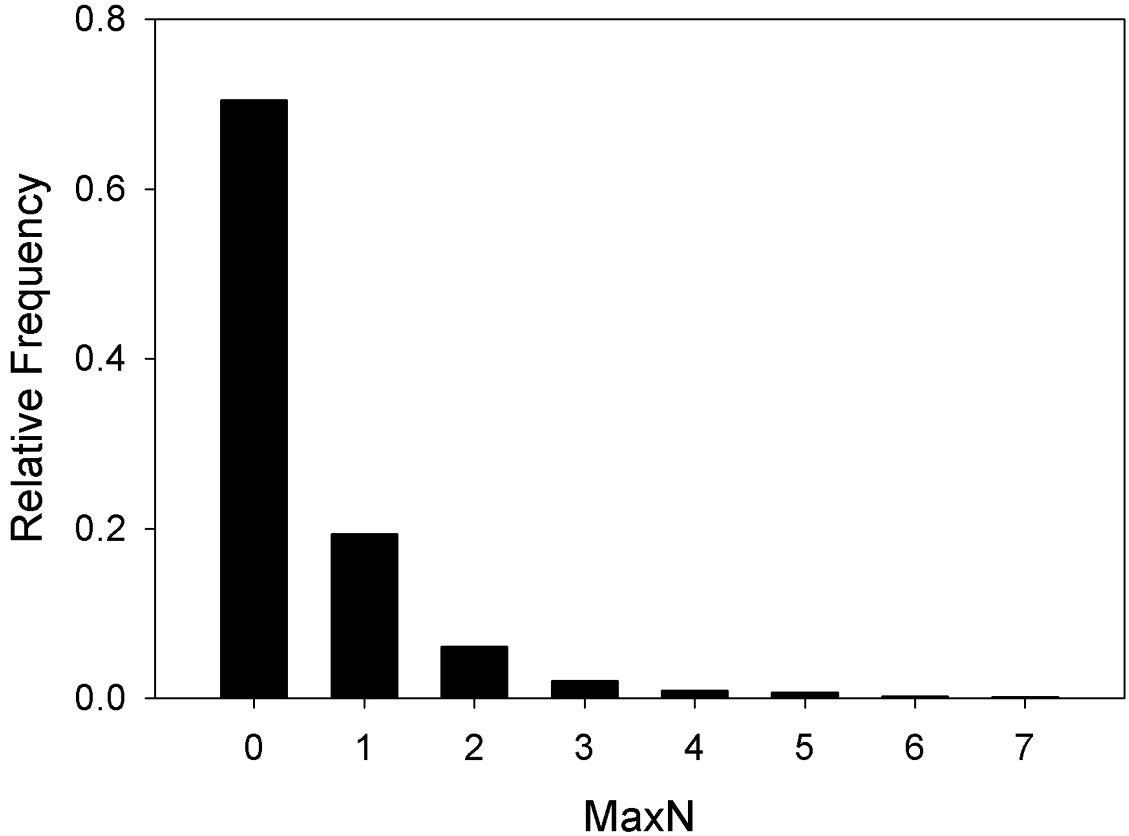

Figure 2. Frequency distribution of relative abundance (MaxN) values of Hogfish observed in the NMFS – Panama City and FWRI video surveys, combined. Values were calculated using censored data sets (see Analytical Methods section).

Table 1. Annual video survey sample sizes, frequency of occurrence, and mean nominal video MaxN counts (± SE) of Hogfish observed in the NMFS – PC and FWRI video surveys. Estimates calculated using censored data sets (see Analytical Methods section).

	Total sites sampled		% Frequency of occurrence		Mean (± SE) nominal MaxN	
Year	NMFS – PC	FWRI	NMFS – PC	FWRI	NMFS – PC	FWRI
2005	34		41.2		0.76 ± 0.203	
2006	57		35.1		0.54 ± 0.123	
2007	29		3.4		0.03 ± 0.034	
2008	58	24	58.6	0.0	0.97 ± 0.161	0.00 ± 0.000
2009	80	43	68.8	7.0	0.94 ± 0.098	0.09 ± 0.056
2010	95	32	28.4	9.4	0.38 ± 0.069	0.19 ± 0.114
2011	100	110	24.0	15.5	0.31 ± 0.061	0.31 ± 0.086
2012	103	103	33.0	23.3	0.45 ± 0.070	0.61 ± 0.140

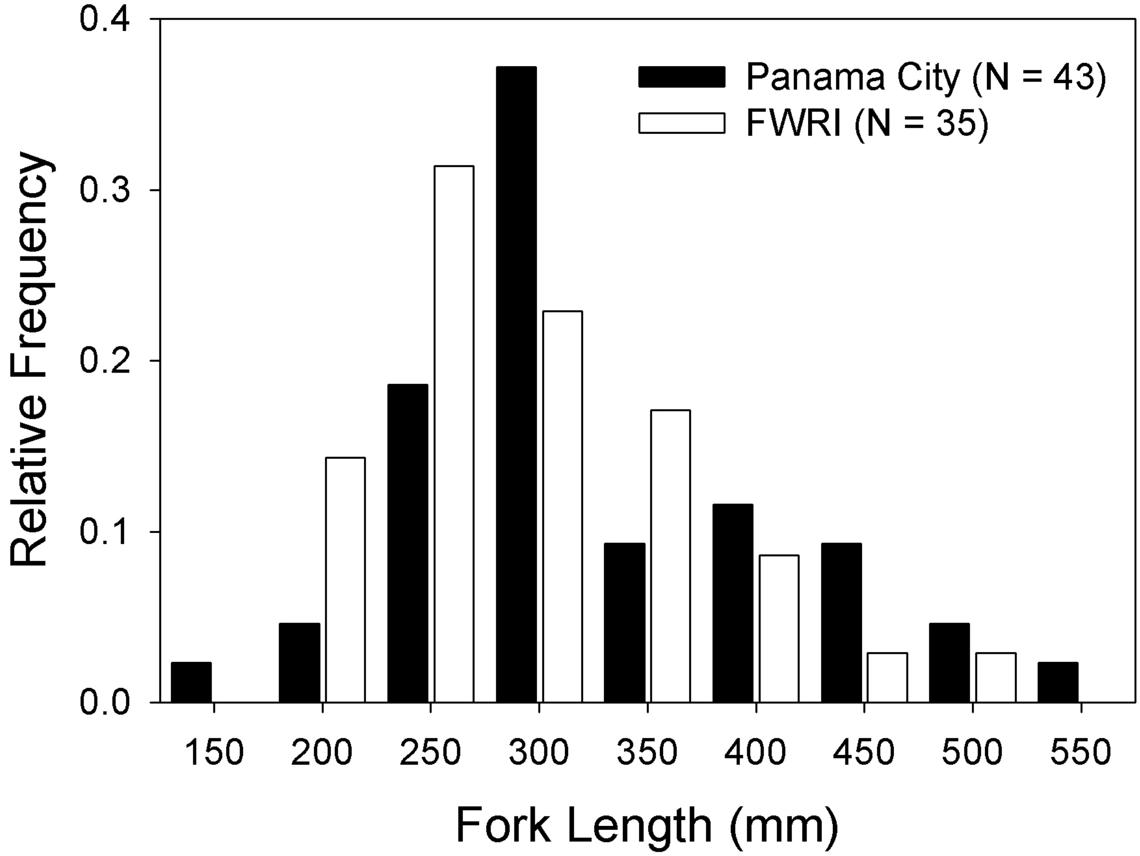

Figure 3. Length frequency distribution of Hogfish observed in the NMFS – PC and FWRI video surveys. This summary only includes individuals from the censored data sets (see Analytical Methods section).

Table 2. Type III tests of fixed effects from the final generalized linear model of the relative abundance (MaxN) of Hogfish observed in the NMFS – PC and FWRI video surveys. Analyses were calculated using censored data sets (see Analytical Methods section).

Effect	Numerator DF	Denominator DF	F Value	Pr > F
Year	7	852	5.26	< 0.0001
Survey	1	852	3.53	0.0607
Rock presence/absence	1	852	28.21	< 0.0001
Depth	1	852	87.09	< 0.0001

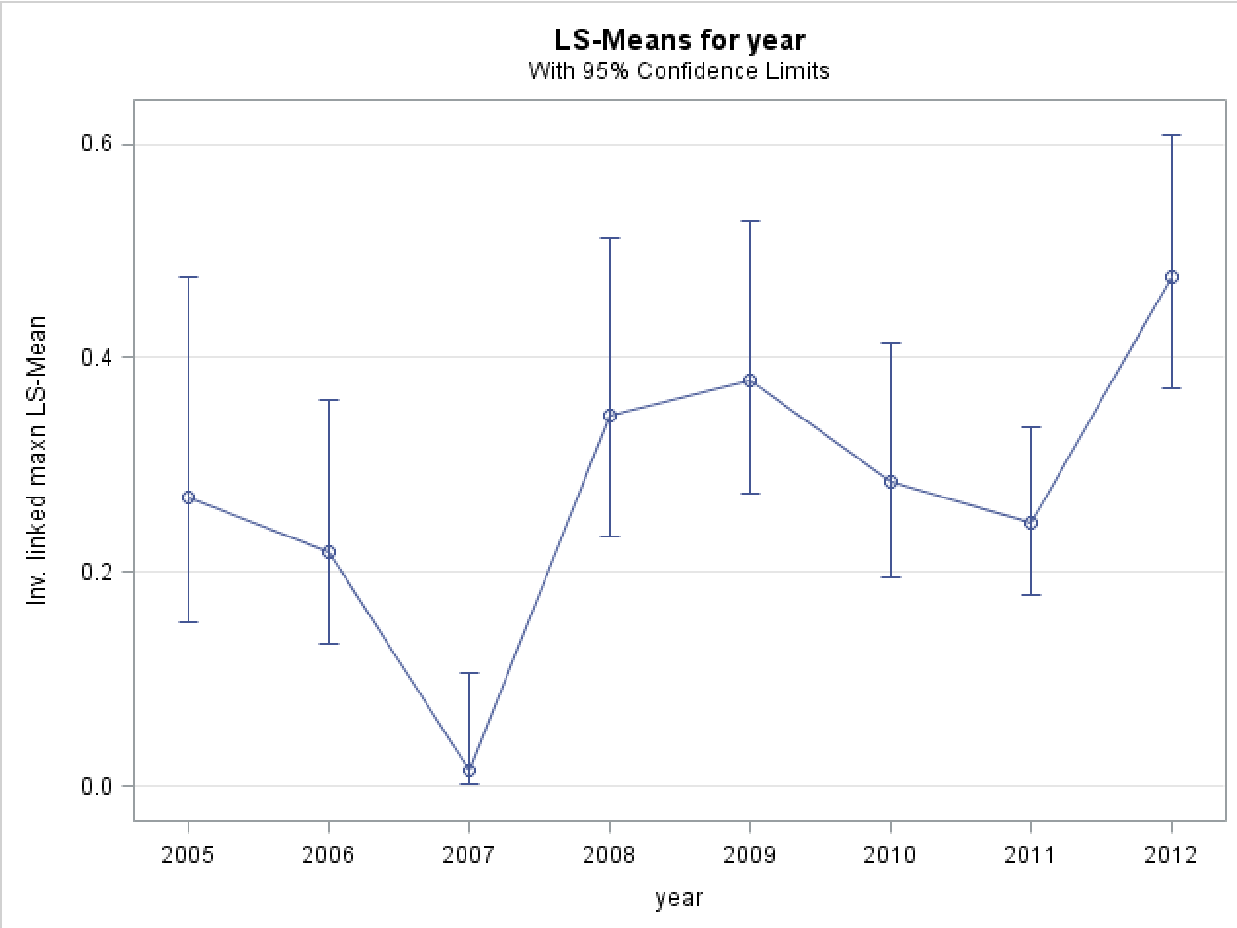

Figure 4. Annual estimates of relative abundance (MaxN) of Hogfish as determined via a generalized linear modeling analysis of data from the NMFS – PC and FWRI video surveys. Analyses were calculated using censored data sets (see Analytical Methods section).

Table 5. Annual indices of relative abundance (MaxN) as well as coefficient of variation (CV) and lower (LCL) and upper (UCL) 95% confidence limits for Hogfish as determined via a generalized linear modeling analysis of data from the NMFS – PC and FWRI video surveys. Analyses were calculated using censored data sets (see Analytical Methods section).

Year	Standardized Index	CV	LCL	UCL
2005	0.2702	0.3023	0.1534	0.4760
2006	0.2187	0.2616	0.1325	0.3610
2007	0.0142	1.4799	0.0019	0.1060
2008	0.3453	0.2062	0.2328	0.5122
2009	0.3791	0.1707	0.2724	0.5275
2010	0.2838	0.1958	0.1948	0.4134
2011	0.2452	0.1610	0.1793	0.3353
2012	0.4761	0.1254	0.3724	0.6085