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Gray Triggerfish (*Balistes capriscus*) indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2016

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Abstract: *The occurrence and abundance of gray triggerfish captured during Southeast Area Monitoring and Assessment Program (SEAMAP) ichthyoplankton resource surveys in the Gulf of Mexico (GOM) have been used to reflect trends in the relative spawning stock size of gray triggerfish since 2005. Estimates of annual relative abundance are based on larval and juvenile catch from SEAMAP Fall Plankton neuston net samples. Indices presented in this document are an update to the SEDAR9 Update Assessment and SEDAR38 Assessment indices, and incorporate the most recent data available from the 1986 to 2016 SEAMAP Fall Plankton Surveys.*

Introduction

The Southeast Area Monitoring and Assessment Program (SEAMAP) has supported the collection and analysis of ichthyoplankton samples from resource surveys in the Gulf of Mexico (GOM) since 1982 with the goal of producing a long-term database on the early life stages of fishes. Occurrence and abundance of larval and juvenile gray triggerfish captured during these surveys were initially reviewed as a potential source of fishery-independent data to reflect trends in the relative spawning stock size of gray triggerfish during the Southeast Data Assessment and Review (SEDAR9) process in 2005 (Lyczkowski-Shultz et al., 2005 and SEDAR9, 2006). Examinations of nominal proportion of positive occurrence and mean abundance of gray triggerfish larvae and juveniles indicated that they consistently occurred most frequently and in highest abundance in neuston net samples collected during the annual SEAMAP Fall Plankton survey. Therefore, the recommendation was made to develop an index of the adult spawning stock based on larval and juvenile catches of gray triggerfish from neuston samples collected during this time series.

The initial index developed for SEDAR9 was based on the 1986 to 2002 Fall Plankton time series and methods utilized are documented in SEDAR9 Assessment Report 1 (SEDAR, 2006). In 2011, the index was updated for the SEDAR9 Update Assessment utilizing the same methods to extend the time series through 2007 (SEDAR9, 2011). The larval/juvenile index was not updated for SEDAR43 in 2014/2015 due to a backlog of unidentified balistid and monacanthid larvae and juveniles from SEAMAP plankton samples. However, the SEDAR9 Update index (1986 to 2007) was incorporated into the SEDAR43 assessment model (SEDAR43, 2015). Currently, the time series of data from the Fall Plankton survey available for analysis extends from 1986 to 2016. This document outlines the development of gray triggerfish larval/juvenile indices for the U.S Gulf of Mexico continental shelf based on the same sample selection methodology (continuity) used for previous SEDAR assessments and updated (current) methodology that addresses inconsistent spatial coverage from several years of the Fall Plankton Survey in the eastern Gulf of Mexico.

Methodology

SEAMAP Plankton Sample Methodologies

The standard sampling gear and methods used to collect plankton samples during SEAMAP surveys is similar to those recommended by Kramer et al. (1972), Smith and Richardson (1977) and Posgay and Marak (1980). A single or double 2x1 m pipe frame neuston net fitted with 0.947 (0.950) mm mesh netting is towed at the surface with the frame half submerged for a targeted tow time of 10 minutes. Nets are then retrieved and the sample rinsed into the net's cod end. The samples are condensed and preserved initially in 10% formalin or 95% ethanol. Samples are then transferred to fresh 95% ethanol within 24 to 48 hours. Small adult fish and invertebrates that can easily fit in the sample jar are preserved in the sample. Larger fish are allowed to be discarded if identifications and sizes are noted on data sheets or in digital comments (Rester, 2016). Catches of larvae and juveniles from neuston nets are standardized to account for sampling effort and expressed as number of fish per 10 min tow.

Sample Processing and Identification of Gray Triggerfish

Initial processing of most SEAMAP plankton samples has been carried out at the Sea Fisheries Institute, Plankton Sorting and Identification Center (ZSIOP), in Szczecin, Poland, under a Joint Studies Agreement with NMFS. Larvae and juveniles were removed from neuston net samples and identified to the lowest possible taxon which in most cases was the family level. Body length (BL) in mm was measured and recorded.

Triggerfish larvae are distinctive and can be identified at the smallest sizes found in plankton collections, i.e. ~2 mm. Larval development of gray triggerfish was first described by Matsuura and Katsuragawa (1981). Lyczkowski-Shultz and Ingram (2003) described distinguishing characteristics that allow the larvae of five of the six species of triggerfishes found in the Gulf of Mexico to be identified. Only the larvae of *Balistes vetula* remain undescribed. All specimens of gray triggerfish used in these analyses were re-examined by ichthyoplankton specialists at the Southeast Fisheries Science Center, Mississippi Laboratories. Identification to species level was accomplished using descriptions in Lyczkowski-Shultz and Ingram (2003). Length at transformation[1] from larval to juvenile occurs at 10mm.

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[1] Length at transformation in gray triggerfish is defined as the smallest size at which fin ray complements are complete, snout length is greater than eye diameter and the mottled pigment pattern of the juvenile states is present (Watson, 1996)

Standardized of the SEAMAP Data Set

The SEAMAP Fall Plankton survey area covers the northern GOM from the 10 m isobath out to the continental shelf edge within the U.S. EEZ, and originally comprised approximately 132 designated sampling sites i.e. 'SEAMAP' stations. Beginning in 1999 and continuing to the present, samples have been taken at 11 additional SEAMAP stations located off the continental shelf in the western GOM during the survey. Most stations are located at 30-nautical mile or 0.5° (~56 km) intervals in a fixed, systematic, 2-dimensional (latitude-longitude) grid of transects across the GOM. Some SEAMAP stations are located at < 56 km intervals especially along the continental shelf edge, while others have been moved to avoid obstructions, navigational hazards or shallow water.

The intended sample design for SEAMAP surveys calls for a single neuston sample to be taken at each site (SEAMAP station) in the systematic grid. However, over the years additional samples have been taken using SEAMAP gear and collection methods at locations other than designated SEAMAP stations. Some locations were also sampled more than once during a survey year. In instances where more than one sample was taken at a SEAMAP station, the sample closest to the central position of the systematic grid location was selected for inclusion in the data set. When SEAMAP stations were sampled by more than one vessel during the survey, priority was given to samples taken by the NMFS (and not the state) vessel.

Spatial coverage of the Fall Plankton Survey from 1986 to 2016 has at times been impacted due to severe weather, vessel breakdowns and/or time constraints (Appendix Figure 1). Sampling for both the western (> 89.25° West Longitude) and eastern (< 89.25° West Longitude) GOM was severely curtailed or cancelled due to tropical storms in 1998, 2005 and 2008 and by mechanical issues in 2015. Spatial coverage in the western GOM has been consistent over the time series with the exception of the four years impacted by tropical storms and mechanical issues. In the eastern GOM, spatial coverage has been considerably more variable. Curtailed neuston sampling during the 1992, 2000, 2002 and 2004 surveys resulted in large portions of the eastern GOM remaining un-sampled. Much of the spatial variability in the eastern GOM stems from the typical west to east progression of the survey. Due to this progression, any reduction in survey time often limits sampling effort in the southern (Tampa, FL to Key West, FL) portion of the survey area.

Year to year variability in spatial coverage during the Fall Plankton Survey is addressed by limiting observations to samples taken at SEAMAP stations that were sampled during at least 66% (current methods) or 75% (continuity methods) of all years for which there was consistent spatial coverage (Figure 1). Samples from 1992, 2000, 2002 and 2004 were included in previous indices, but have since been determined to lack consistent spatial coverage in the eastern GOM. Therefore, samples taken during the 1992, 2000, 2002 and 2004 years are included in the continuity index but excluded from the calculations of gray triggerfish larval/juvenile indices based on current methods.

Adjustments to Catch to Account for Discarded Fish

Counts and measurements of fishes discarded from SEAMAP neuston net samples are not recorded in identifications and length measurements of processed samples. A review of digital comments archived with the dataset found only a small subset of records (~25) from all SEAMAP plankton surveys regarding the presence of gray triggerfish juveniles and small adults in samples. Most noted the presence of gray triggerfish in samples, with at least 10 records indicating removal of fish with recorded lengths. These counts and measurements of removed gray triggerfish identified in comments were added to the analytical dataset. In nearly all cases, gray triggerfish removed from samples were greater than 50 mm. There is concern that the recording of removed fish in digital records was not consistent over the time series, especially prior to 1995. However, the concern is mitigated by the rarity of the events and that over 95% of larvae and juveniles captured in neuston nets are less than 45 mm. Examinations of nominal annual proportion positive and CPUE based only on specimens of gray triggerfish less than 45 mm indicated similar trends to those utilizing all lengths. Therefore, even in the event that the removed gray triggerfish were not recorded in the comments there should minimal impact on the relative indices of abundance.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for gray triggerfish based on current and continuity methods for sample selection (Pennington, 1983; Bradu and Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2006). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (*cf.* Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) was estimated as:

(1) $$I_y = c_y p_y,$$

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $$\ln(c) = X\beta + \varepsilon$$

and

(3) $$p = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE (c_y) and SE (p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated using the delta method approximation

(4) $$V(I_y) \approx V(c_y) p_y^2 + c_y^2 V(p_y).$$

A covariance term is not included in the variance estimator since there is no correlation between the estimator of the proportion positive and the mean CPUE given presence. The two estimators are derived independently and have been shown to not covary for a given year (Mary Christman, MCC Statistical Consulting LLC, unpublished).

In addition to the delta-lognormal methods, gray triggerfish indices of relative abundance based on current sample selection methods were also estimated using Poisson and negative binomial models. CPUE for the Poisson and negative binomial models was model as count data with effort as an offset.

The factors Year, Time of Day (TOD), Region and Depth were examined as possible influences on the proportion of positive occurrence, abundance of nonzero catch and counts of gray triggerfish for all models based on current methods for sample selection; and only the factors Year and TOD to be consistent with the original methodology were examined for the delta-lognormal continuity model (Table 1). All models were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. The year effect is integral to the calculation of annual estimates and is forced into the standardization procedure regardless of significance when at least one other factor is significant. The binomial submodel performance of the delta-lognormal was evaluated using AIC, while the performance of the lognormal submodel of the delta-lognormal, Poisson and negative binomial models were evaluated based on analyses of residual scatter and QQ plots in addition to AIC. QQ and residual scatterplots for the Poisson and negative binomial models were assessed using randomized quantile residuals (Dunn and Smyth, 1996).

Results and Discussion

Distribution, Abundance and Size at Capture

A total of 709 gray triggerfish larvae and juveniles were captured in the 2,634 neuston net samples (current index samples only) during 23 Fall Plankton surveys from 1986-2016. Gray triggerfish were taken in 11.4 % of samples with a mean CPUA of 0.27 fish per 10 minute tow (Table 2). They were captured throughout the survey area but occurred 2.0 times more often and at 1.8 times greater CPUE in the western than in the eastern GOM (Table 2 and Figure 2). Catches of gray triggerfish varied by time of day (Table 3). CPUE of gray triggerfish larvae and juveniles was 2.0 times higher during the morning and evening crepuscular periods than during the day with larvae taken 1.6 times more often. However, the mean CPUE of gray triggerfish was only 1.1 times higher during the crepuscular period than at night with larvae taken 1.2 times as often. Larvae were captured over station depths ranging from 5 to 534 m with a mean station depth of 66 m and a median station depth of 41 m.

Length data was available for 682 gray triggerfish larvae and juveniles taken in index samples. Captured fish ranged from 1.9 to 79.5 mm in body length (BL) with a mean BL of 17.7 mm and a median BL of 14.6 mm (Figure 3). Ninety-five percent of larvae in bongo net samples were less than 45 mm BL. Based on a size at transformation of 10 mm BL, juvenile stages accounted for 76% of gray triggerfish taken in neuston net samples.

Standardized Indices of Abundance

The continuity delta-lognormal index of gray triggerfish CPUE is based on the same sample selection methods and factors utilized for the SEDAR9 Update assessments. Annual estimates of relative abundance for the continuity model are shown in Table 4 and Figure 4. The backward selection procedure retained the factors year and TOD in both the binomial and lognormal submodels (Table 5). The diagnostic plots for the lognormal submodel are show in Figure 5 and indicate that the distribution of the residuals are positively skewed.

The current delta-lognormal, Poisson and negative binomial indices of gray triggerfish CPUE are based on updated sample selection methods utilized for the development of indices from SEAMAP ichthyoplankton data. The models also examine the effect of region and depth in addition to year and TOD on gray triggerfish proportion positive and CPUE. Factor selection was identical for the delta-lognormal binomial submodel and the Poisson and negative binomial models with the factors year, TOD, region and depth retained in the models. Factor selection for the delta-lognormal positive CPUE submodel retained year, TOD and region (Table 6). Diagnostic plots for the delta-lognormal positive CPUE submodel and the Poisson and negative binomial models are shown in Figure 6. Residuals from the delta-lognormal positive CPUE submodel model are positively skewed. The Poisson model residuals indicate a high degree of right skew and a lack of fit to high CPUE observations. The negative binomial model also indicates some degree of right skew and a lack of fit to higher CPUE observations but in general provides a good overall fit. Direct comparison of the delta-lognormal positive CPUE model residuals to only the positive CPUE residuals of the negative binomial model indicate a better fit by the negative binomial model (Figure 7). Therefore, the negative binomial model was selected as the best fitting CPUE model. Annual indices of gray triggerfish larval and juvenile CPUE from the negative binomial are show in Table 7 and Figure 8. The delta-lognormal indices of relative gray triggerfish larval and juvenile abundance are included to allow for a more direct comparison to the continuity model and are shown in Table 8 and Figure 9.

The lack of fit to high CPUE values was examined for samples (n=300) with positive catch. The number of gray triggerfish in individual samples ranged from 1 to 43 individuals with 285 (95%) of samples catching 6 or fewer fish. The remaining samples were those poorly fit by the negative binomial model. These high count samples occurred only in 11 out of the 23 years included in the time series. When occurring they accounted for less than 5% to 15% of positive samples in a given year, but accounted for 17% to 57% of total fish. In most cases, this translates into 1 or 2 samples accounting for over 30% of total fish caught in a given year. In order to examine effects of these high CPUE samples on the negative binomial CPUE model, it was compared to a standardize index of relative abundance based on the proportion positive delta-lognormal binomial submodel (Tables 6 and 9 and Figure 10). The negative binomial and proportion positive models were highly correlated (r = 0.7832) with divergences at annual point estimates aligned with years in which extreme CPUE values from one or two samples accounted for the majority of annual abundance in the negative binomial model (Figure 11).

The current negative binomial CPUE and the binomial proportion positive indices of relative abundance show a cyclic pattern of high and low abundance periods of varying length and magnitude over the time series. Intermittent sampling coverage from 1997 to 2007 does not allow for a clear assessment of trend during that time frame.

The indices of abundance developed from SEAMAP Fall Plankton Surveys have historically been used reflect trends in the relative abundance of the adult spawning stock of a target species. The majority of SEAMAP plankton indices are based on larvae taken in 61 cm bongo net samples which typically catch fishes ranging in age from 3 to 35 days. Indices of gray triggerfish from the Fall Plankton Surveys are based on neuston net collections which often catch older larvae and young juvenile fishes. There are no studies that correlated age at length for larval and juvenile gray triggerfish, but based on a 10 mm size at transformation 76% of gray triggerfish in neuston nets are classified as juveniles.

Estimating abundance of gray triggerfish in neuston net collections is further complicated by the unique early life history of gray triggerfish. Once larvae hatch from demersal nests, they become pelagic and remain in the plankton for an indeterminate period. This pelagic period can last a few weeks to several months to as much as a year (Dooley 1972; Richards & Lindeman 1987). Young gray triggerfish are also consistently associated with *Sargassum* suggesting that circulation patterns may determine dispersal and distribution patterns (Ingram 2001). In this way, young gray triggerfish may rely on *Sargassum* as, not only a method to deliver them to suitable adult habitat, but provide a refuge until that habitat is encountered.

Sargassum mats/patches are encountered in the northern Gulf of Mexico throughout the sampling year and are readily collected in SEAMAP neuston samples. These Sargassum aggregations can form habitat in the open GOM, providing refuge for young fish species (Kingsford 1995, Casazza & Ross 2008, Ballard & Rakocinski 2012). Although present during most of the year in the GOM, currents constantly move these mats limiting their time over one area. In the GOM, one of the most abundant species present in *Sargassum* is the gray triggerfish, *Balistes capriscus*, (Bortone et al. 1977, Wells & Rooker 2004).

SEAMAP ichthyoplankton surveys began to quantify the amount of *Sargassum* collected in neuston samples in 2006. These samples (n = 1,347) from 2006 to 2017 Fall Plankton Surveys we used to examine the lengths of gray triggerfish larvae and juveniles from primary samples in relation to increasing catches of *Sargassum* (Figure 12). Mean, median and the range of body length measurements of gray triggerfish all tended to increase coinciding with higher levels of *Sargassum* abundance. Juvenile stages (>10 mm) were taken consistently across all levels of *Sargassum* abundance, but nearly all larval stages were taken only when no *Sargassum* or trace amounts were reported in the sample. The analysis while providing insight into the differential use of varying degrees of complexity in *Sargassum* habitat by larvae and juveniles is not without its caveats. SEAMAP protocols only records *Sargassum* taken in the neuston net, but does not record information on relative density of *Sargassum* at the surface, at depth nor patchiness along a neuston tow.

The indices of relative abundance of gray triggerfish collected in neuston nets are dominated by juvenile stages which exhibit a complex relationship with *Sargassum* habitat. These juvenile stages are much further removed from the larval stages that are typically used to reflect trends in adult spawning stock. This raises the question as to whether the current gray triggerfish indices reflect trends in the adult spawning stock or more likely represent a recruitment index of larvae and early stage juvenile fish to *Sargassum* nursery habitat.

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Table 1. Factors considered for inclusion into the binomial and lognormal sub-models of the Delta-lognormal and the Poisson and negative binomial models for the current and continuity indices. Asterisk (*) indicates factors included only in current models.

Factors	Levels	Description
Year (current)	23	1986 - 1991, 1993 - 1997, 1999, 2001, 2003, 2006-2007, 2009 - 2014 and 2016
Year (continuity)	27	1986 - 1997, 1999 - 2004, 2006 - 2007, 2009 - 2014 and 2016
Region*	2	West = Western Gulf of Mexico (>89.25 Degrees W Longitude) East = Eastern Gulf of Mexico (< 89.25 Degrees W Longitude)
Time of Day (TOD)	2	D = Day (45 minutes after sunrise to 45 minutes prior to sunset) N = Night (45 minutes after sunset to 45 minutes prior to sunrise) C = Crepuscular(±45 minutes of sunrise and ±45 minutes of sunset)
Depth*		Water Depth

Table 2. Nominal catch per unit effort (CPUE) and proportion positive of larval and juvenile gray triggerfish in neuston net samples Gulfwide (GOM) and from the western GOM and the eastern GOM.

Region	N	CPUA	SE CPUA	Proportion Positive	SE Proportion Positive
West	1218	0.3600	0.0366	0.1560	0.0104
East	1416	0.1988	0.0410	0.0777	0.0071
GOM	2634	0.2733	0.0278	0.1140	0.0062

Table 3. Nominal catch per unit effort (CPUE) and proportion positive of larval and juvenile gray triggerfish in neuston net samples by time of day.

Time of Day	N	CPUA	SE CPUA	Proportion Positive	SE Proportion Positive
Day	1249	0.1912	0.0306	0.0935	0.0083
Night	1137	0.3374	0.0512	0.1275	0.0099
Crepuscular	257	0.3859	0.0892	0.1518	0.0224

Table 4. SEAMAP Fall Plankton Survey continuity indices of Gulf of Mexico larval and juvenile gray triggerfish relative abundance developed using the delta-lognormal (DL) model. The nominal frequency of occurrence (NominalFrequency), number of samples (N), the DL CPUE (LoIndex) expresses as number per 10 minute tow, the DL index scaled to a mean of one (ScaledLoIndex) for the time series, the coefficient of variation on the mean (CV), and lower (LCL) and upper (UCL) confidence of the scaled index are listed.

SurveyYear	*NominalFrequency*	*N*	*LoIndex*	*ScaledLoIndex*	*CV*	*LCL*	*UCL*
1986	0.13725	102	0.29245	0.92237	0.32023	0.49377	1.72302
1987	0.05505	109	0.20044	0.63217	0.50021	0.24569	1.62665
1988	0.08333	96	0.17078	0.53863	0.42939	0.23659	1.22627
1989	0.06250	96	0.09948	0.31376	0.49964	0.12206	0.80655
1990	0.09009	111	0.16027	0.50550	0.38478	0.24042	1.06284
1991	0.17857	112	0.32080	1.01180	0.26436	0.60164	1.70156
1992	0.19792	96	0.92838	2.92806	0.26999	1.72258	4.97714
1993	0.18447	103	0.36985	1.16650	0.27067	0.68538	1.98537
1994	0.15789	114	0.39710	1.25245	0.28090	0.72176	2.17333
1995	0.16216	111	0.41698	1.31515	0.28037	0.75865	2.27986
1996	0.17544	114	0.44014	1.38818	0.26475	0.82485	2.33625
1997	0.10714	112	0.27793	0.87658	0.34958	0.44449	1.72873
1998							
1999	0.06195	113	0.09509	0.29991	0.46257	0.12431	0.72353
2000	0.25000	104	0.77660	2.44936	0.22680	1.56502	3.83341
2001	0.08257	109	0.15749	0.49670	0.40572	0.22753	1.08433
2002	0.14286	91	0.35090	1.10672	0.33039	0.58139	2.10673
2003	0.12727	110	0.28399	0.89568	0.32191	0.47798	1.67841
2004	0.10227	88	0.18419	0.58091	0.40297	0.26741	1.26195
2005							
2006	0.22222	108	0.62589	1.97403	0.23843	1.23343	3.15931
2007	0.14912	114	0.46766	1.47497	0.28956	0.83621	2.60166
2008							
2009	0.10000	110	0.19655	0.61991	0.36554	0.30530	1.25873
2010	0.08182	110	0.23181	0.73111	0.40557	0.33499	1.59563
2011	0.08571	105	0.13260	0.41821	0.40468	0.19193	0.91129
2012	0.05357	112	0.11693	0.36879	0.50039	0.14328	0.94923
2013	0.16216	111	0.44126	1.39171	0.27990	0.80353	2.41044
2014	0.11429	105	0.23831	0.75162	0.34716	0.38282	1.47572
2015							
2016	0.07143	112	0.18682	0.58921	0.43100	0.25807	1.34525

Table 5. Summary of factor selection for the delta-lognormal modeled continuity index of Gulf of Mexico gray triggerfish relative abundance.

	Binomial Submodel Type 3 Tests(AIC=2149.82)						Lognormal Submodel Type 3 Tests (AIC=890.82)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	26	2849	65.92	2.54	<.0001	<.0001	26	333	1.61	0.0318
TOD	2	2849	13.55	6.77	0.0011	0.0012	2	333	4.92	0.0078

Table 6. Summary of factor selection for the delta-lognormal, Poisson and negative binomial modeled indices of Gulf of Mexico gray triggerfish relative abundance based on current sample selection methods.

	Binomial Submodel Type 3 Tests(AIC=1768.33)						Lognormal Submodel Type 3 Tests (AIC=707.81)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	22	2607	58.75	2.67	<.0001	<.0001	22	274	1.18	0.2692
TOD	2	2607	14.99	7.49	0.0006	0.0006	2	274	3.64	0.0275
REGION	1	2607	51.89	51.89	<.0001	<.0001	1	274	6.95	0.0089
DEPTH	1	2607	46.45	46.45	<.0001	<.0001			Dropped	

Poisson Type 3 Tests (AIC=4033.51)				
Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	22	2607	12.22	<.0001
TOD	2	2607	35.92	<.0001
REGION	1	2607	87.02	<.0001
DEPTH	1	2607	211.44	<.0001

Negative Binomial Type 3 Tests (AIC=2652.29)				
Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	22	2607	3.11	<.0001
TOD	2	2607	9.82	<.0001
REGION	1	2607	51.08	<.0001
DEPTH	1	2607	53.03	<.0001

Table 7. SEAMAP Fall Plankton Survey index of Gulf of Mexico larval and juvenile gray triggerfish relative abundance developed using the negative binomial (NB) model. The nominal frequency of occurrence (NominalFrequency), number of samples (N), the CPUE (Index) expresses as number per 10 minute tow, the NB index scaled to a mean of one (ScaledIndex) for the time series, the coefficient of variation on the mean (CV), and lower (LCL) and upper (UCL) confidence of the scaled index are listed.

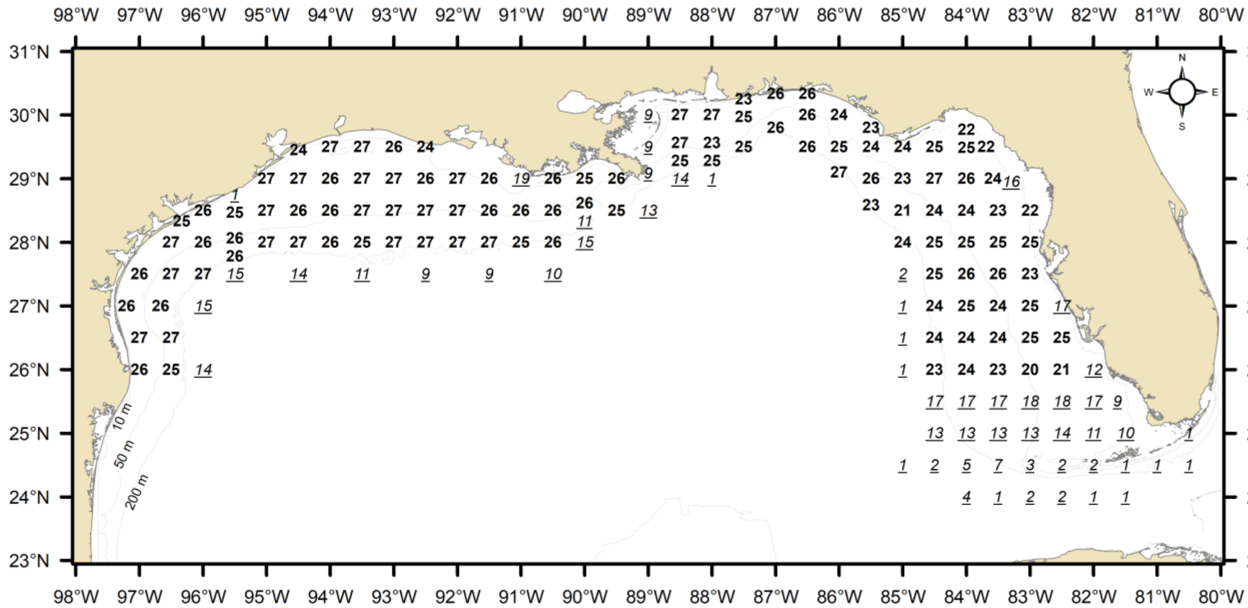
SurveyYear	*NominalFrequency*	*N*	*Index*	*ScaledIndex*	*CV*	*LCL*	*UCL*
1986	0.12844	109	0.24440	1.01181	0.33711	0.52241	1.95967
1987	0.05172	116	0.26284	1.08812	0.36979	0.52694	2.24693
1988	0.07767	103	0.10688	0.44247	0.41311	0.19682	0.99468
1989	0.05825	103	0.05776	0.23914	0.49191	0.09115	0.62742
1990	0.08850	113	0.11936	0.49415	0.39462	0.22793	1.07132
1991	0.17699	113	0.24282	1.00524	0.34215	0.51392	1.96626
1992							
1993	0.18095	105	0.25646	1.06172	0.34766	0.53697	2.09930
1994	0.14876	121	0.28278	1.17069	0.32075	0.62416	2.19578
1995	0.16949	118	0.35525	1.47070	0.31117	0.79898	2.70717
1996	0.17241	116	0.61043	2.52711	0.30665	1.38510	4.61070
1997	0.10169	118	0.20590	0.85240	0.34612	0.43241	1.68034
1998							
1999	0.05983	117	0.07657	0.31699	0.46679	0.12692	0.79170
2000							
2001	0.07759	116	0.16149	0.66855	0.38979	0.31131	1.43576
2002							
2003	0.12821	117	0.20753	0.85916	0.34103	0.44020	1.67684
2004							
2005							
2006	0.22018	109	0.56697	2.34721	0.31458	1.26664	4.34961
2007	0.14754	122	0.59166	2.44943	0.30193	1.35501	4.42778
2008							
2009	0.09402	117	0.17853	0.73911	0.37541	0.35401	1.54316
2010	0.07627	118	0.17324	0.71718	0.38439	0.33751	1.52398
2011	0.08036	112	0.09188	0.38038	0.43568	0.16188	0.89380
2012	0.05000	120	0.07798	0.32282	0.43770	0.13684	0.76156
2013	0.15126	119	0.37403	1.54846	0.32639	0.81648	2.93667
2014	0.10714	112	0.16193	0.67039	0.37697	0.32011	1.40396
2015							
2016	0.07500	120	0.14898	0.61677	0.35317	0.30858	1.23276

Table 8. SEAMAP Fall Plankton Survey index of Gulf of Mexico larval and juvenile gray triggerfish relative abundance developed using the delta-lognormal (DL) model. The nominal frequency of occurrence (NominalFrequency), number of samples (N), the DL CPUE (LoIndex) expresses as number per 10 minute tow, the DL index scaled to a mean of one (ScaledLoIndex) for the time series, the coefficient of variation on the mean (CV), and lower (LCL) and upper (UCL) confidence of the scaled index are listed.

SurveyYear	*NominalFrequency*	*N*	*LoIndex*	*ScaledLoIndex*	*CV*	*LCL*	*UCL*
1986	0.12844	109	0.25828	1.03362	0.31871	0.55488	1.92539
1987	0.05172	116	0.20646	0.82623	0.49325	0.32491	2.10105
1988	0.07767	103	0.14140	0.56588	0.42327	0.25125	1.27448
1989	0.05825	103	0.07865	0.31475	0.49280	0.12387	0.79976
1990	0.08850	113	0.14065	0.56286	0.37884	0.27059	1.17081
1991	0.17699	113	0.30757	1.23088	0.25949	0.73874	2.05088
1992							
1993	0.18095	105	0.33397	1.33652	0.26853	0.78847	2.26552
1994	0.14876	121	0.34028	1.36175	0.27758	0.78968	2.34823
1995	0.16949	118	0.42766	1.71144	0.26130	1.02360	2.86148
1996	0.17241	116	0.43615	1.74542	0.26048	1.04558	2.91369
1997	0.10169	118	0.23239	0.93002	0.34470	0.47583	1.81773
1998							
1999	0.05983	117	0.08300	0.33214	0.45827	0.13870	0.79534
2000							
2001	0.07759	116	0.15452	0.61836	0.40239	0.28494	1.34193
2002							
2003	0.12821	117	0.27734	1.10989	0.30955	0.60609	2.03247
2004							
2005							
2006	0.22018	109	0.58568	2.34385	0.23470	1.47503	3.72442
2007	0.14754	122	0.44368	1.77554	0.28140	1.02223	3.08398
2008							
2009	0.09402	117	0.16217	0.64899	0.36448	0.32024	1.31523
2010	0.07627	118	0.18845	0.75417	0.40199	0.34778	1.63546
2011	0.08036	112	0.10336	0.41362	0.40430	0.18995	0.90067
2012	0.05000	120	0.09547	0.38206	0.49398	0.15006	0.97275
2013	0.15126	119	0.37730	1.50992	0.28052	0.87076	2.61827
2014	0.10714	112	0.19878	0.79549	0.34774	0.40473	1.56351
2015							
2016	0.07500	120	0.17407	0.69660	0.40241	0.32098	1.51177

Table 9. SEAMAP Fall Plankton Survey index of Gulf of Mexico larval and juvenile gray triggerfish relative abundance based on the proportion of positive occurrence delta-lognormal binomial submodel. The nominal frequency of occurrence (NominalFrequency), number of samples (N), the proportion positive (Index), the index scaled to a mean of one (ScaledIndex) for the time series, the coefficient of variation on the mean (CV), and lower (LCL) and upper (UCL) confidence of the scaled index are listed.

SurveyYear	*NominalFrequency*	*N*	*Index*	*ScaledIndex*	*CV*	*LCL*	*UCL*
1986	0.12844	109	0.13195	1.12487	0.25703	0.66826	1.82117
1987	0.05172	116	0.05229	0.44579	0.40001	0.20075	0.95559
1988	0.07767	103	0.07442	0.63442	0.34488	0.31780	1.21961
1989	0.05825	103	0.05707	0.48653	0.40184	0.21800	1.04423
1990	0.08850	113	0.08953	0.76324	0.30764	0.41132	1.36560
1991	0.17699	113	0.18768	1.60000	0.20624	1.04981	2.34797
1992							
1993	0.18095	105	0.18205	1.55200	0.21291	1.00470	2.30601
1994	0.14876	121	0.15770	1.34440	0.22147	0.85727	2.03486
1995	0.16949	118	0.18317	1.56151	0.20848	1.02025	2.30186
1996	0.17241	116	0.18390	1.56777	0.20703	1.02738	2.30501
1997	0.10169	118	0.10891	0.92848	0.27798	0.53004	1.56769
1998							
1999	0.05983	117	0.06130	0.52258	0.37613	0.24641	1.06832
2000							
2001	0.07759	116	0.08292	0.70687	0.32657	0.36692	1.31117
2002							
2003	0.12821	117	0.12906	1.10023	0.24983	0.66375	1.75948
2004							
2005							
2006	0.22018	109	0.23444	1.99858	0.18454	1.36645	2.80841
2007	0.14754	122	0.15209	1.29655	0.22556	0.82029	1.97834
2008							
2009	0.09402	117	0.09171	0.78181	0.29656	0.43083	1.37032
2010	0.07627	118	0.07759	0.66145	0.32782	0.34285	1.23158
2011	0.08036	112	0.07822	0.66679	0.33041	0.34374	1.24715
2012	0.05000	120	0.04953	0.42224	0.40537	0.18824	0.91519
2013	0.15126	119	0.15279	1.30252	0.22592	0.82336	1.98853
2014	0.10714	112	0.10480	0.89340	0.28318	0.50492	1.52396
2015	.	.	.	.	.	.	
2016	0.07500	120	0.07484	0.63797	0.32834	0.33050	1.18994



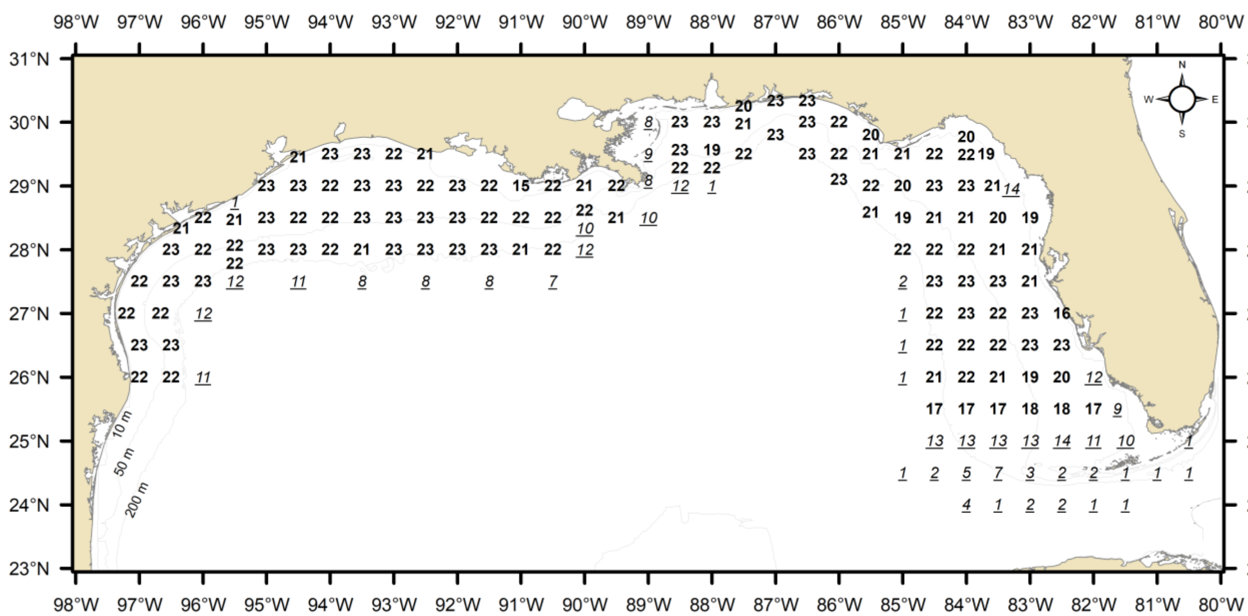


Figure 1. Number of primary neuston net samples taken at each SEAMAP B-number location from the annual SEAMAP Fall Plankton Surveys included in the continuity index (top) and current indices (bottom). Only locations with primary samples equal to or exceeding 20 were included in the continuity index and samples equal to or exceeding 15 were included in indices based on current methods. Bold numbers represent locations of primary samples included in the index and those underlined and in italics represent locations of primary samples excluded from the index.

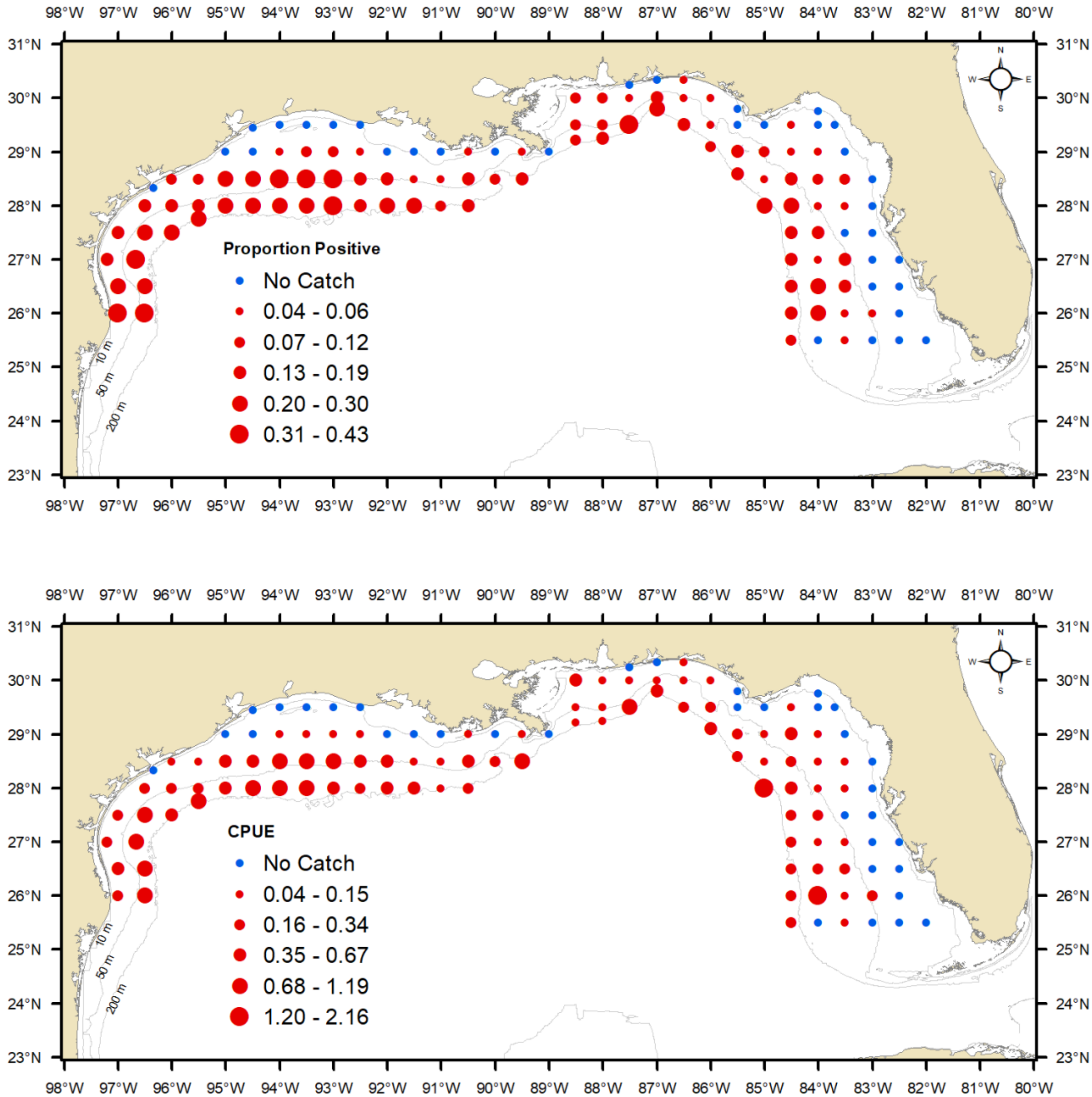


Figure 2. Gray triggerfish proportion positive (upper) and mean catch per unit effort (lower) from Fall Plankton Survey neuston net samples used to develop the current indices of abundance.

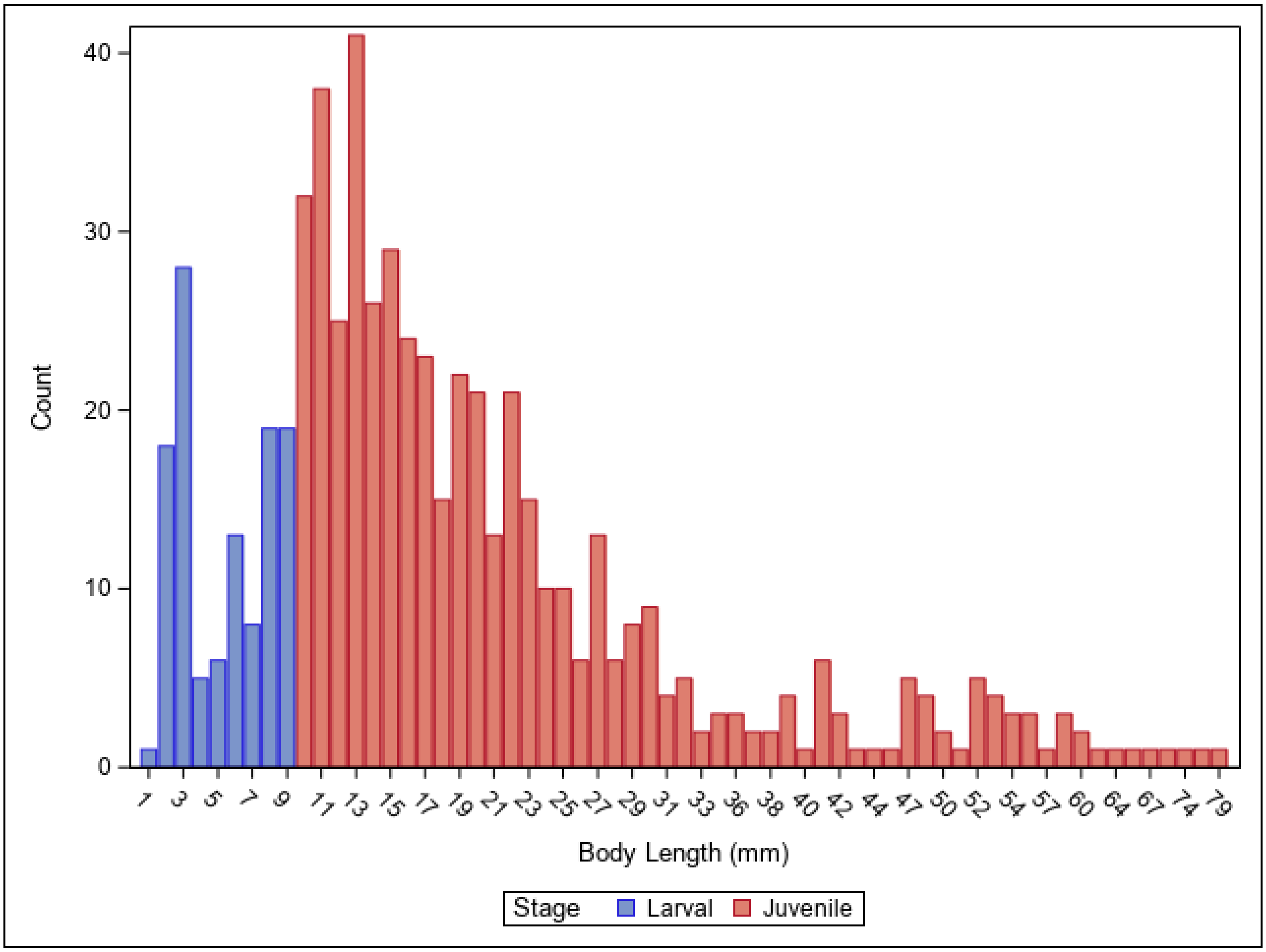


Figure 3. Length frequencies of gray triggerfish from neuston net samples collected during the SEAMAP Fall Plankton surveys. Length data is only included from samples used to generate indices of relative abundance based on current methods.

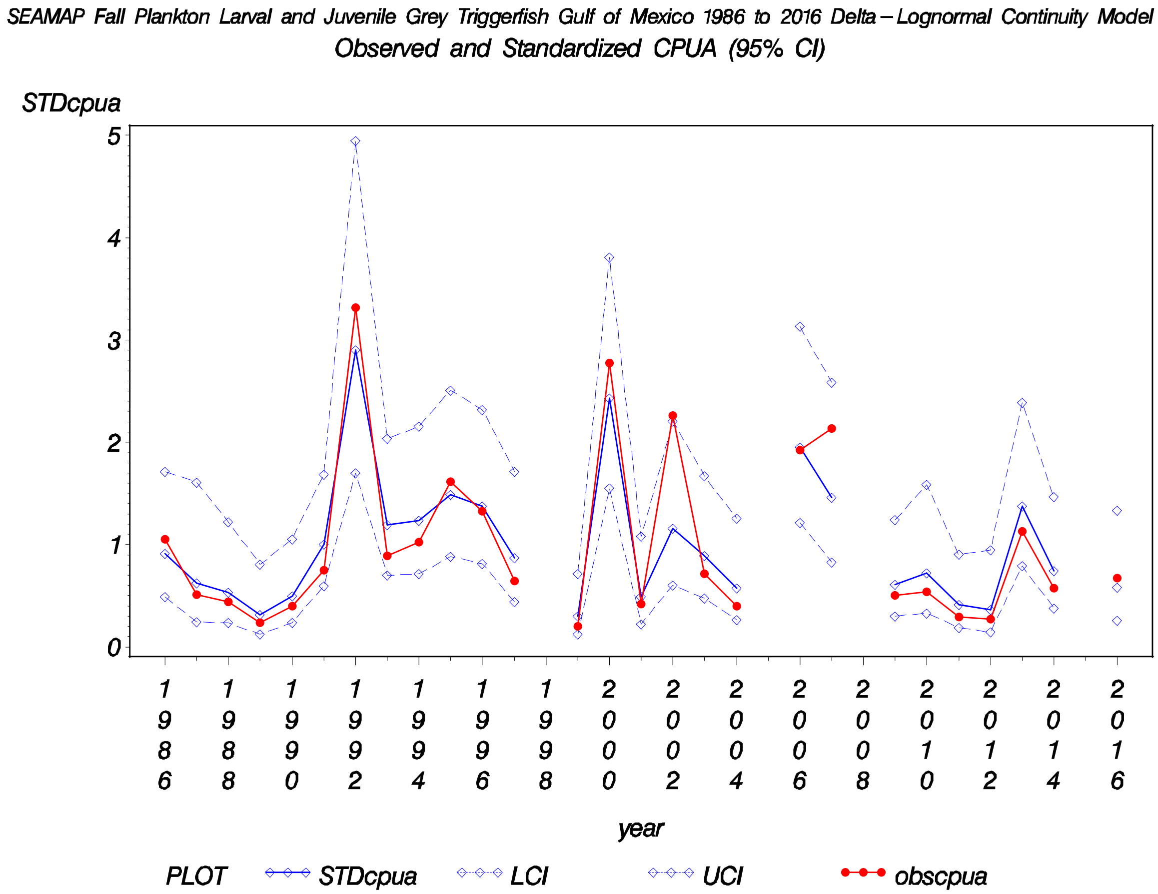


Figure 4. Delta-lognormal continuity index of relative abundance for Gulf of Mexico larval and juvenile gray triggerfish caught during SEAMAP Fall Plankton Surveys from 1986 to 2016.

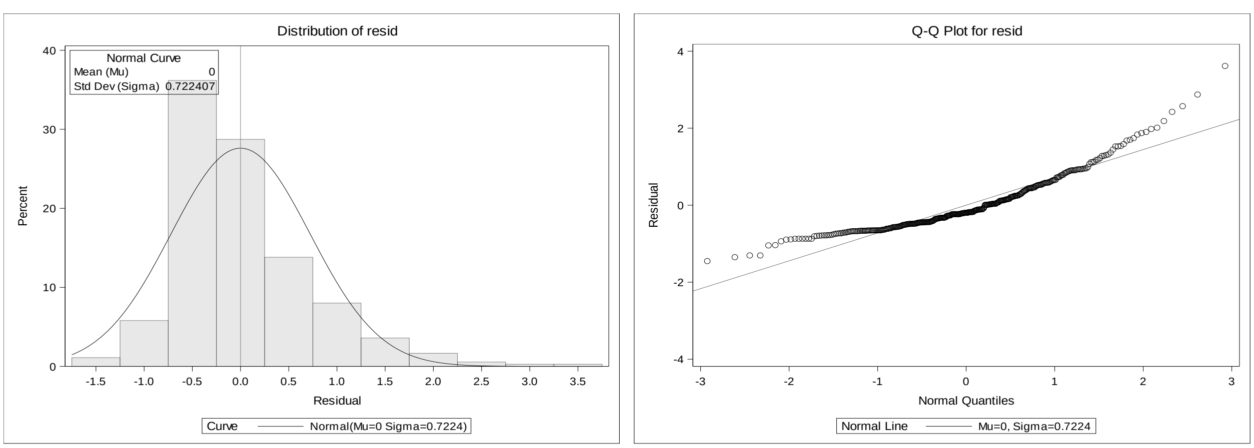


Figure 5. Distribution (left) and QQ plot (right) of residuals from the continuity delta-lognormal (top) positive catch submodel of larval and juvenile gray triggerfish CPUE from SEAMAP Fall Plankton Surveys in the Gulf of Mexico.

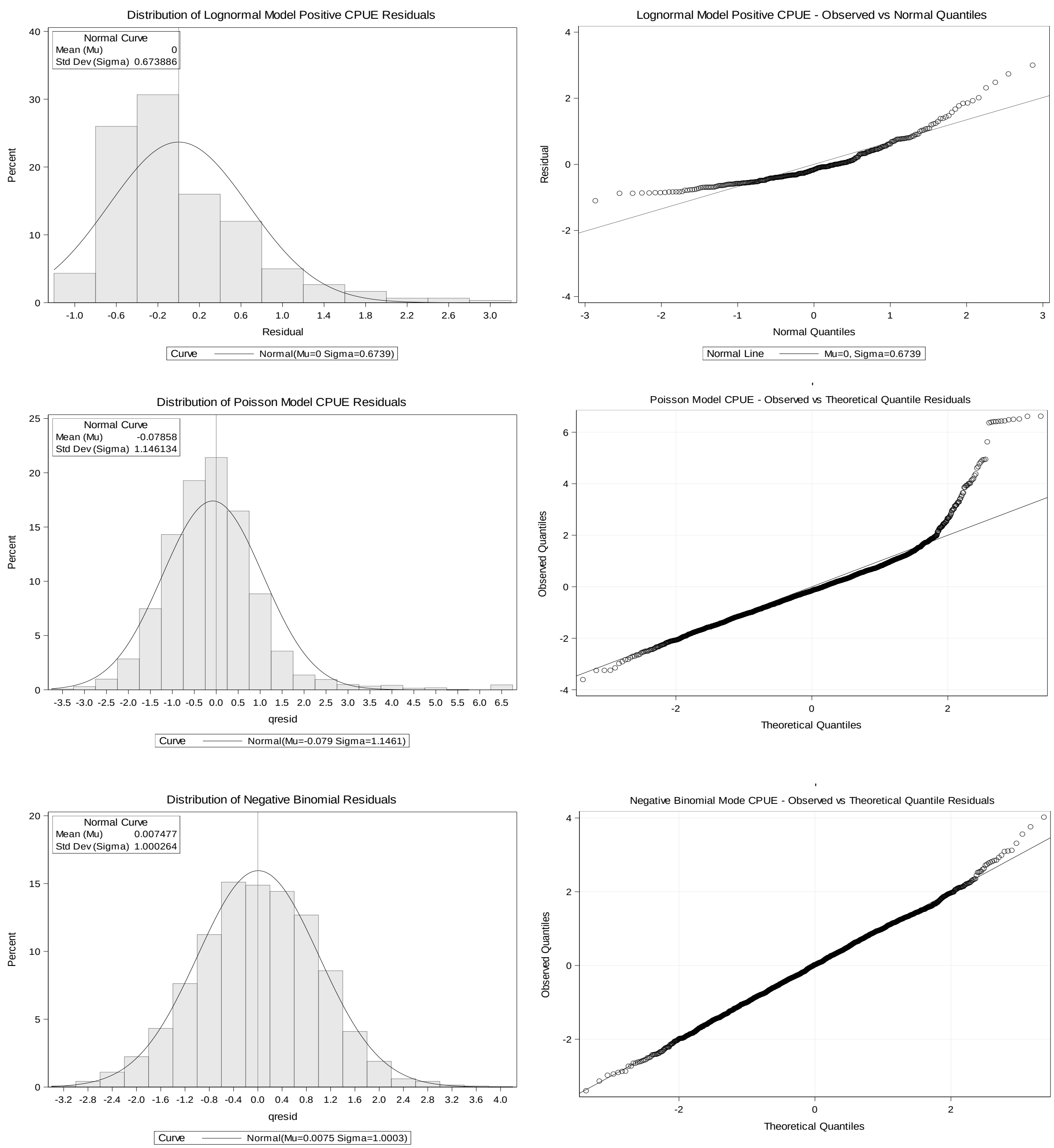


Figure 6. Distributions (left) and QQ plots (right) of residuals from the current delta-lognormal (top) positive catch submodel and Poisson (middle) and negative binomial (bottom) models of larval and juvenile gray triggerfish CPUE from SEAMAP Fall Plankton Surveys in the Gulf of Mexico.

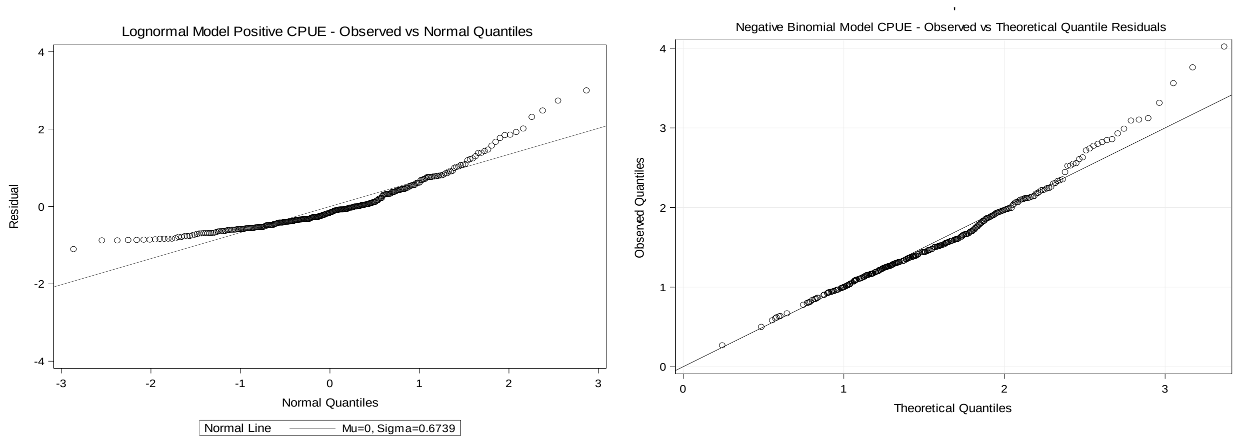


Figure 7. Comparison of QQ plots of the delta-lognormal positive CPUE submodel and negative binomial model subset to only show residuals with positive CPUE.

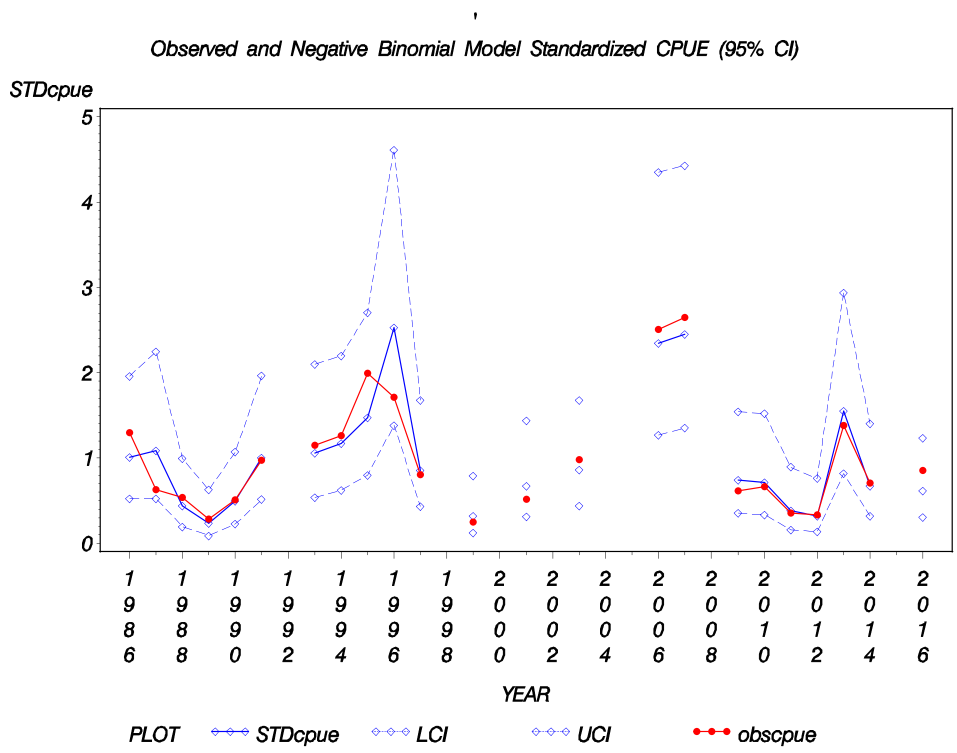


Figure 8. Negative binomial current index of relative abundance for Gulf of Mexico larval and juvenile gray triggerfish caught during SEAMAP Fall Plankton Surveys from 1986 to 2016.

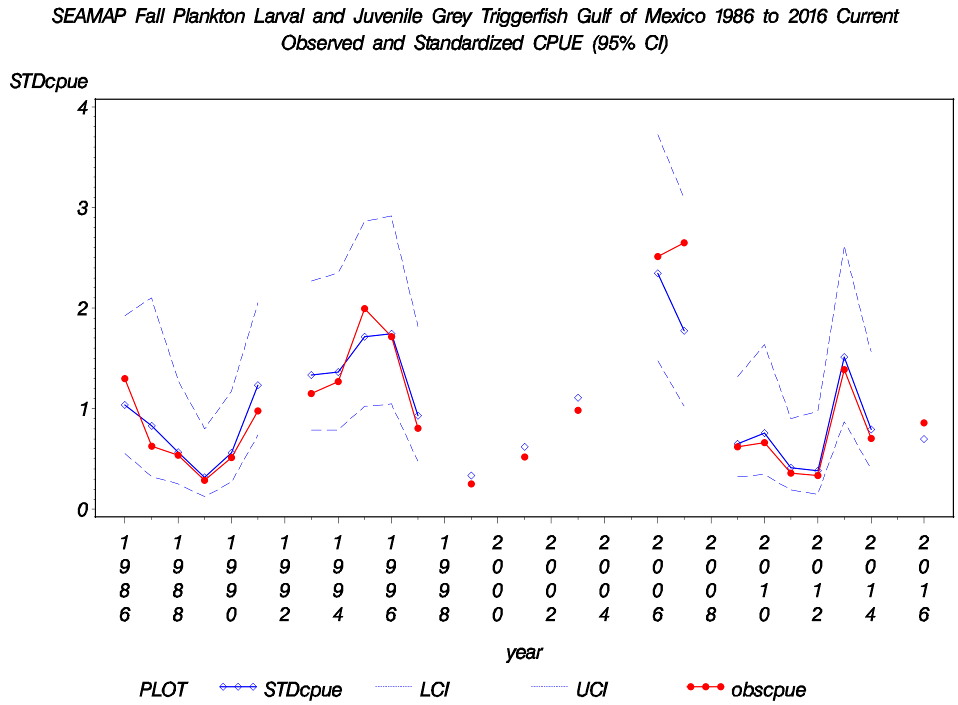


Figure 9. Delta-lognormal continuity index of relative abundance for Gulf of Mexico larval and juvenile gray triggerfish caught during SEAMAP Fall Plankton Surveys from 1986 to 2016.

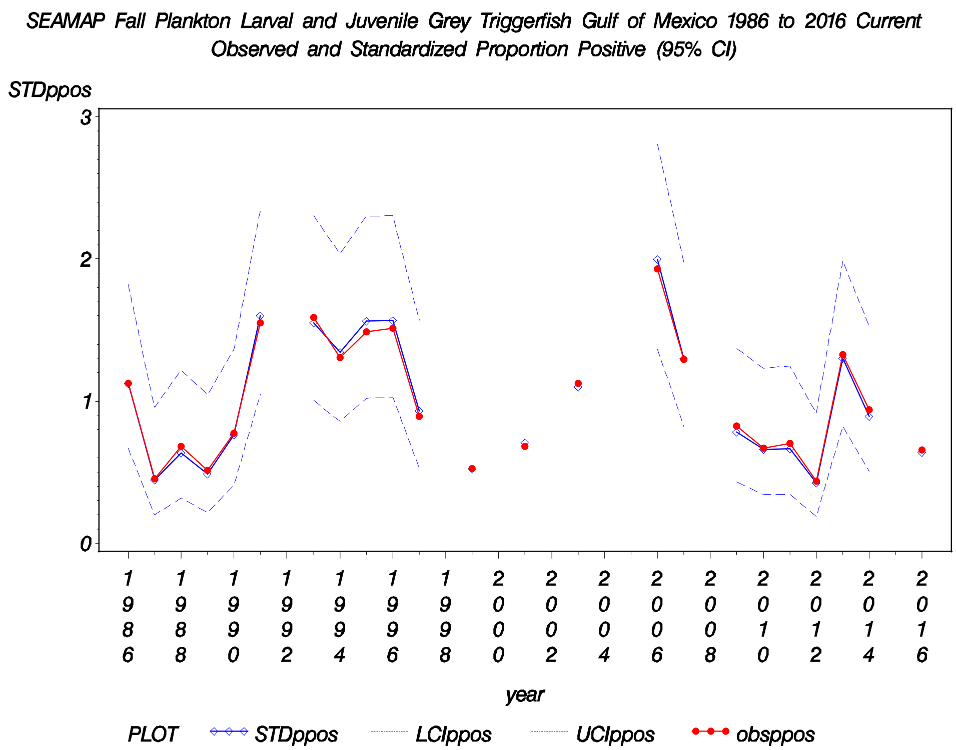


Figure 10. Delta-lognormal binomial submodel current index of relative abundance for Gulf of Mexico larval and juvenile gray triggerfish caught during SEAMAP Fall Plankton Surveys from 1986 to 2016.

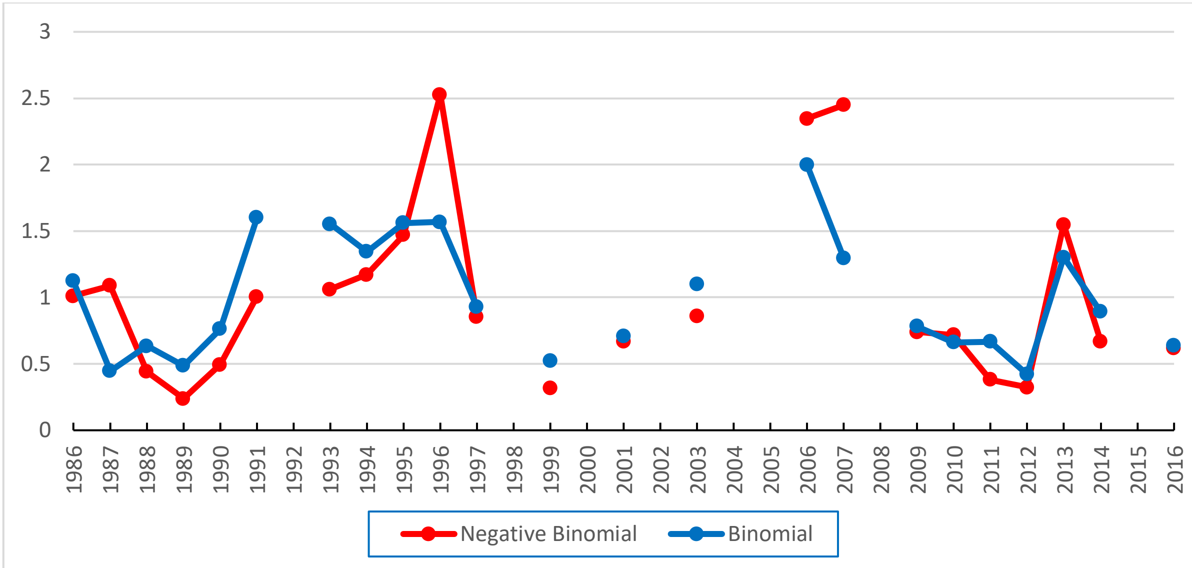


Figure 11. Comparison of the current negative binomial CPUE model and binomial proportion positive model indices of gray triggerfish relative abundance caught during SEAMAP Fall Plankton Surveys from 1986 to 2016.

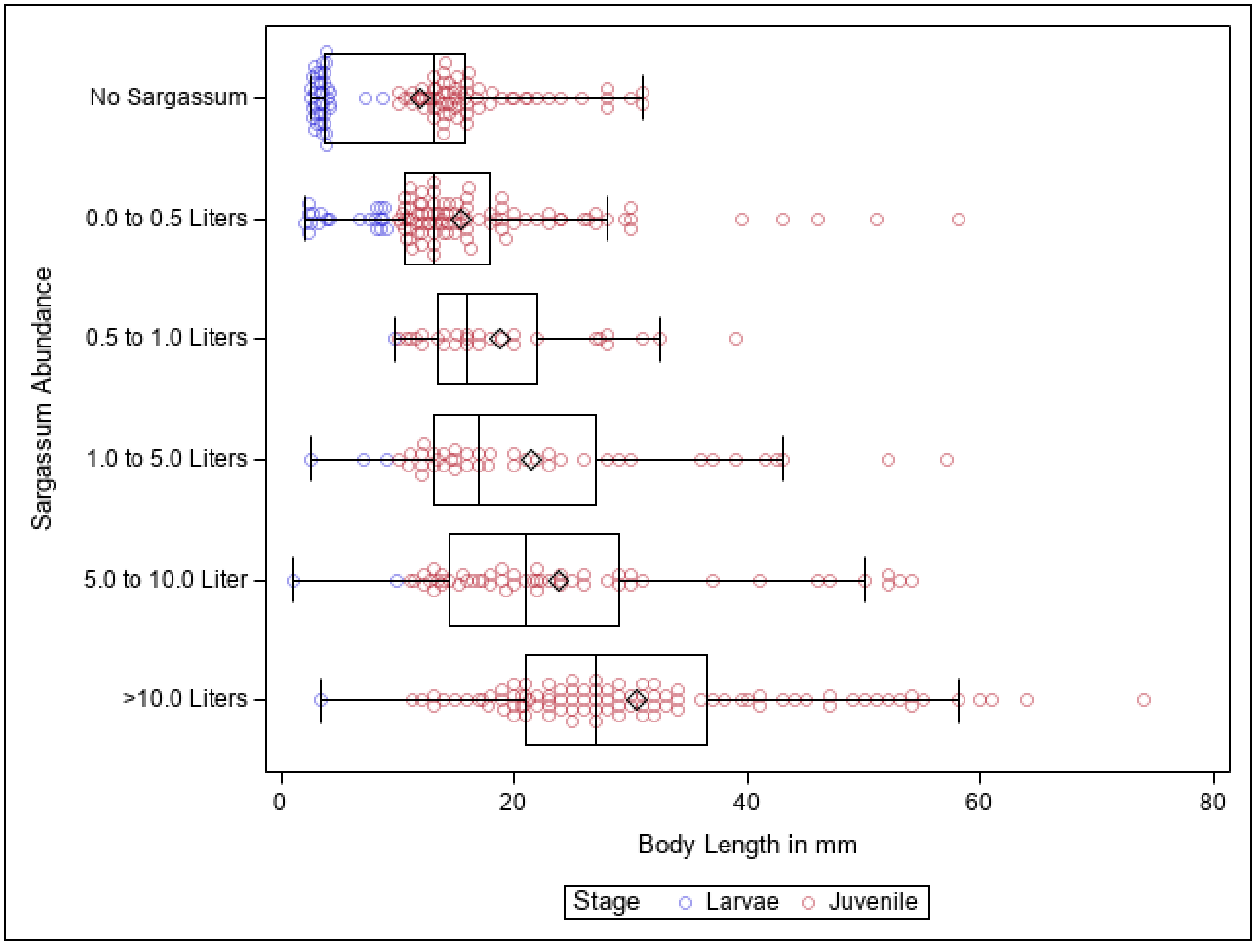
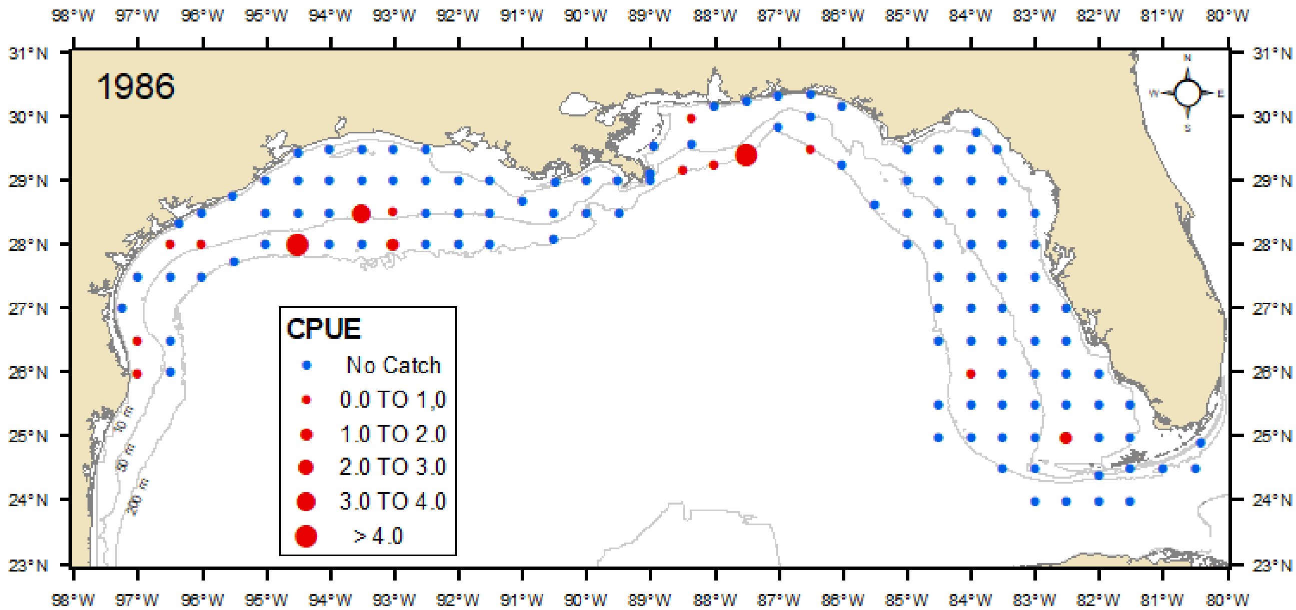
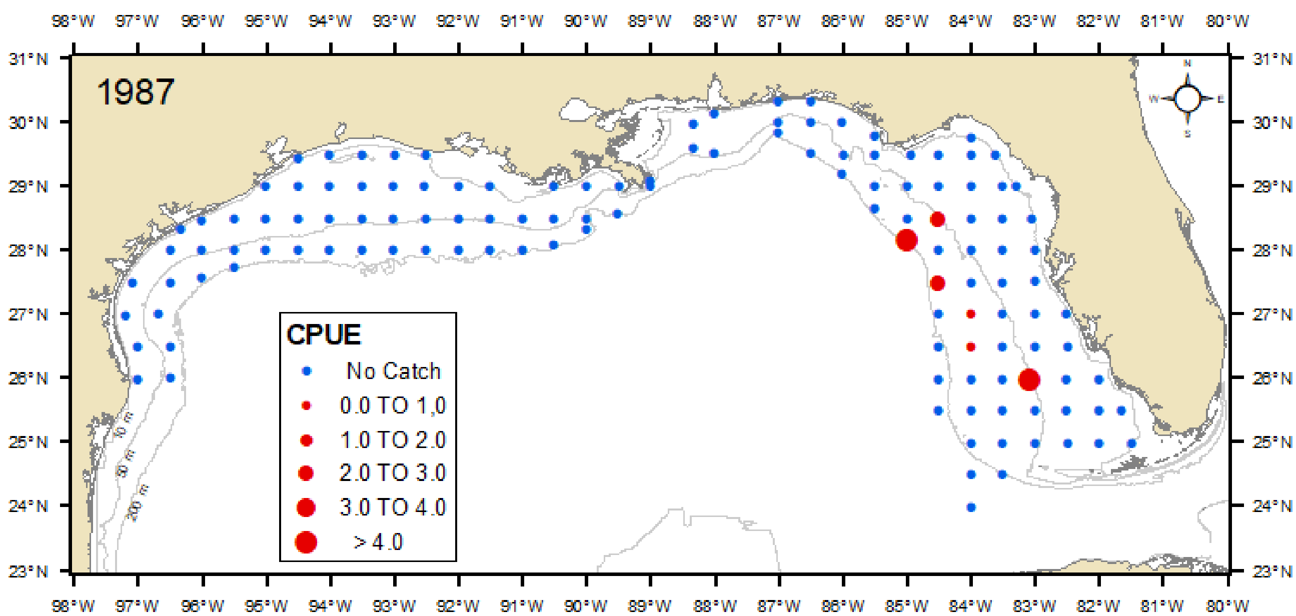
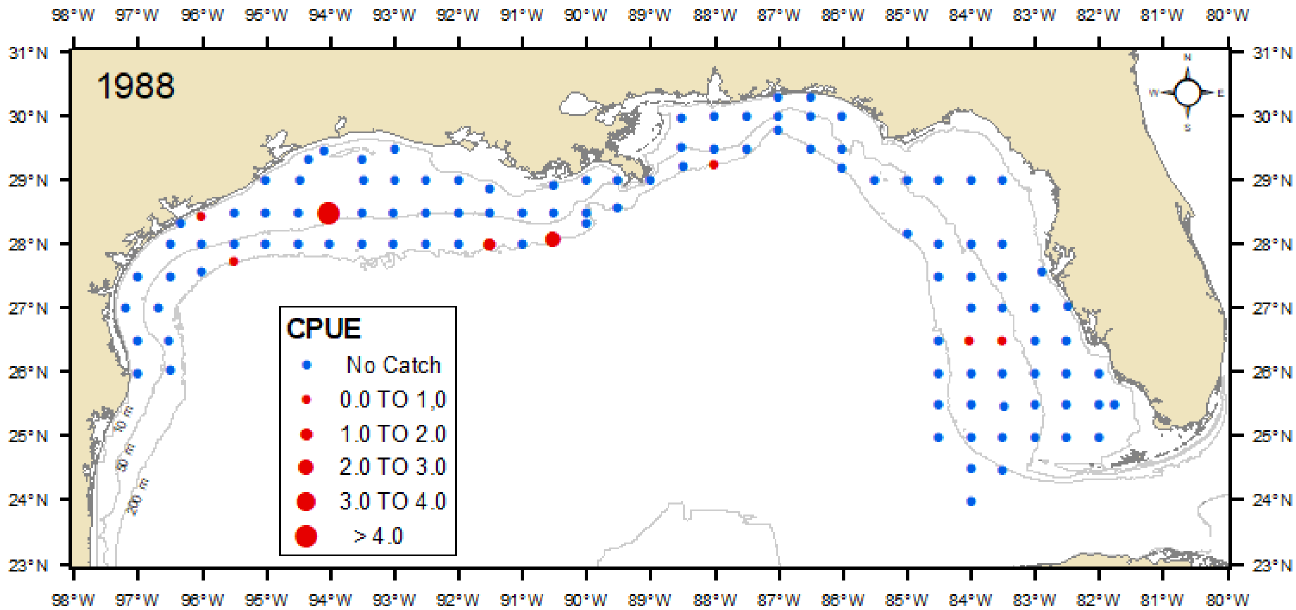


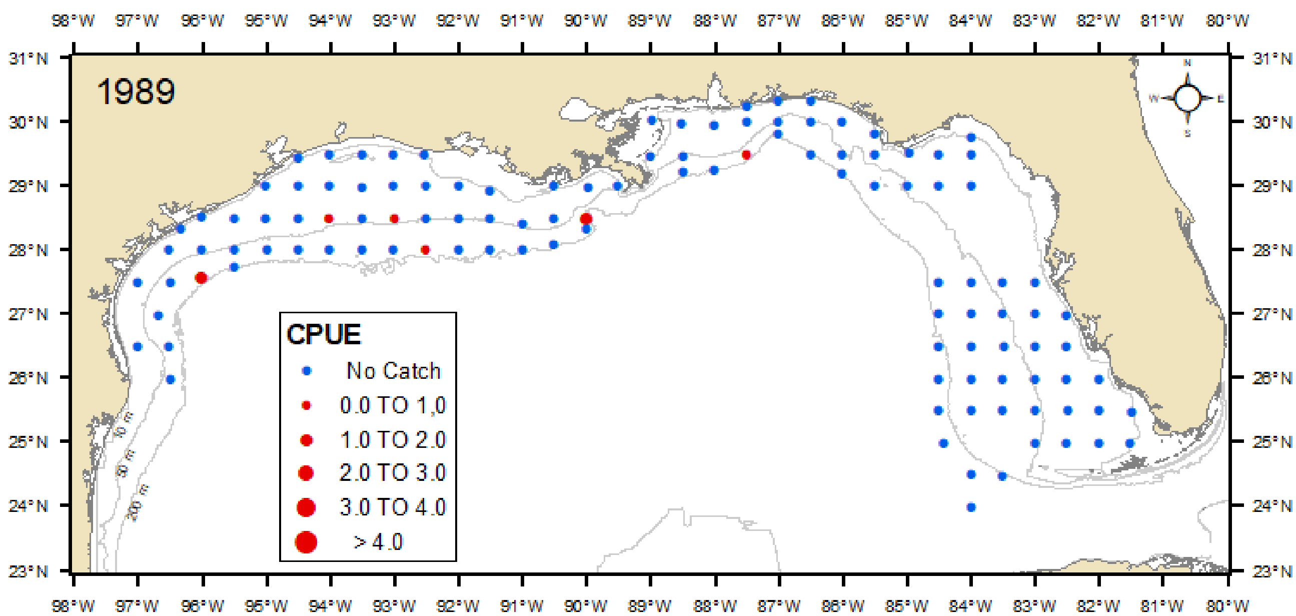
Figure 12. Scatter and boxplots of gray triggerfish (n = 545) body length by increasing levels of Sargassum abundance caught in Fall Plankton Survey neuston net (n = 1347) primary samples from 2006 to 2016.

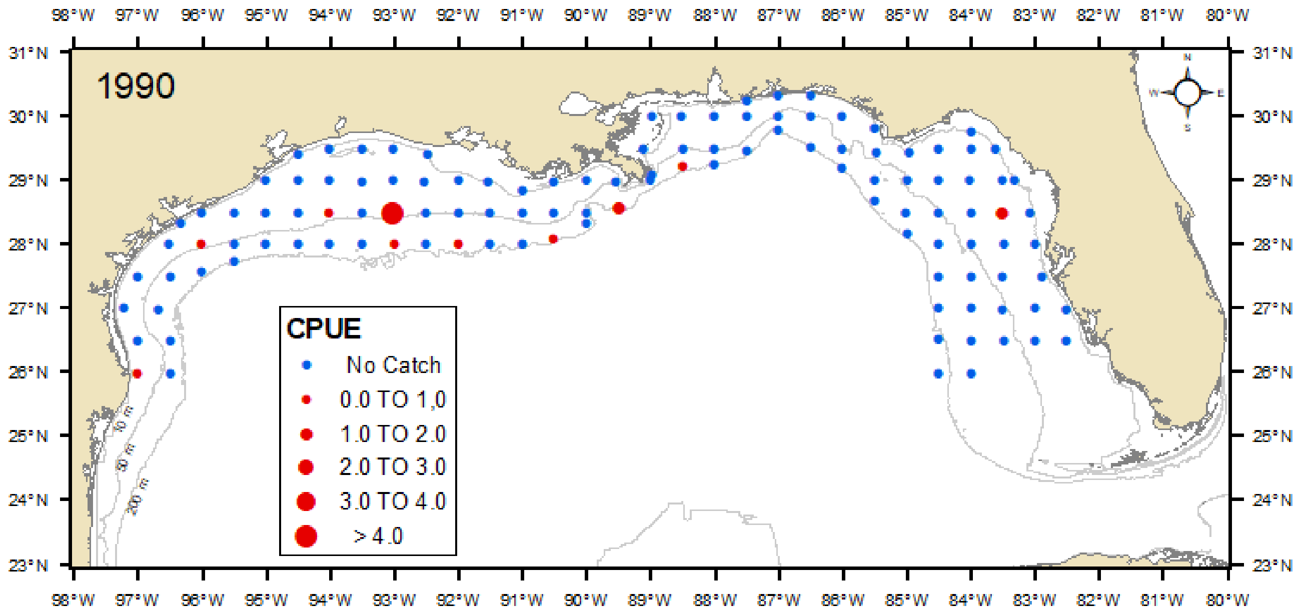
Appendix Figure 1. Annual survey effort and catch per unit effort (CPUE) of gray triggerfish larvae and juveniles from the SEAMAP Fall Plankton Survey conducted from 1986-2016. CPUE is expressed as fish per 10 minute tow.

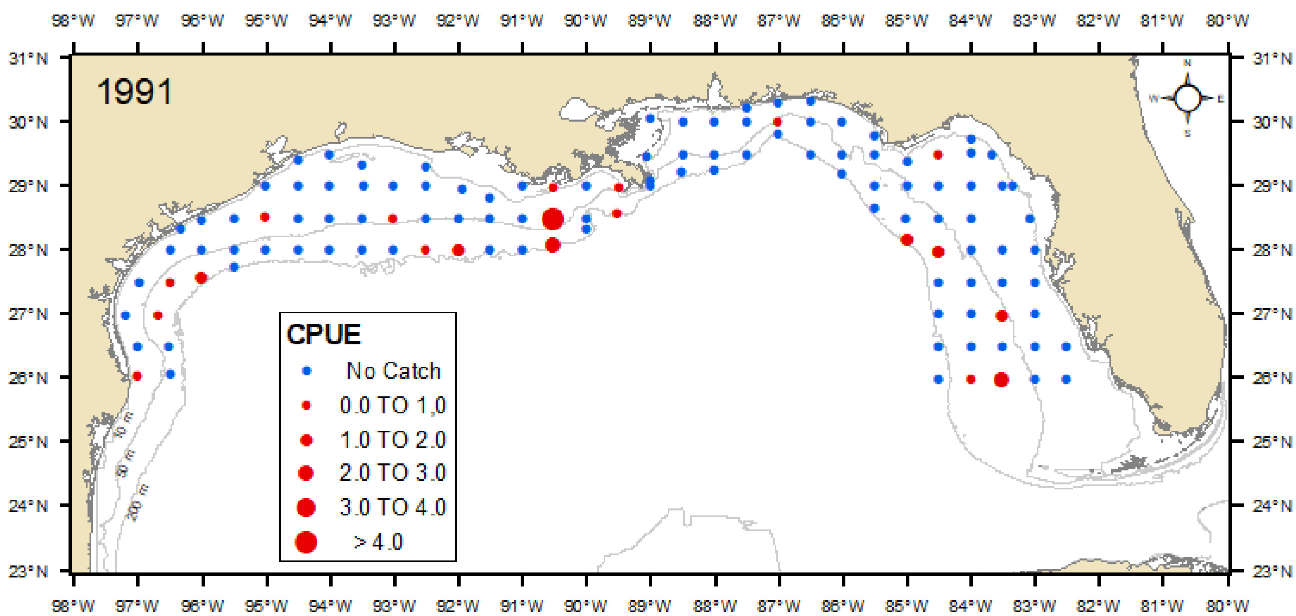


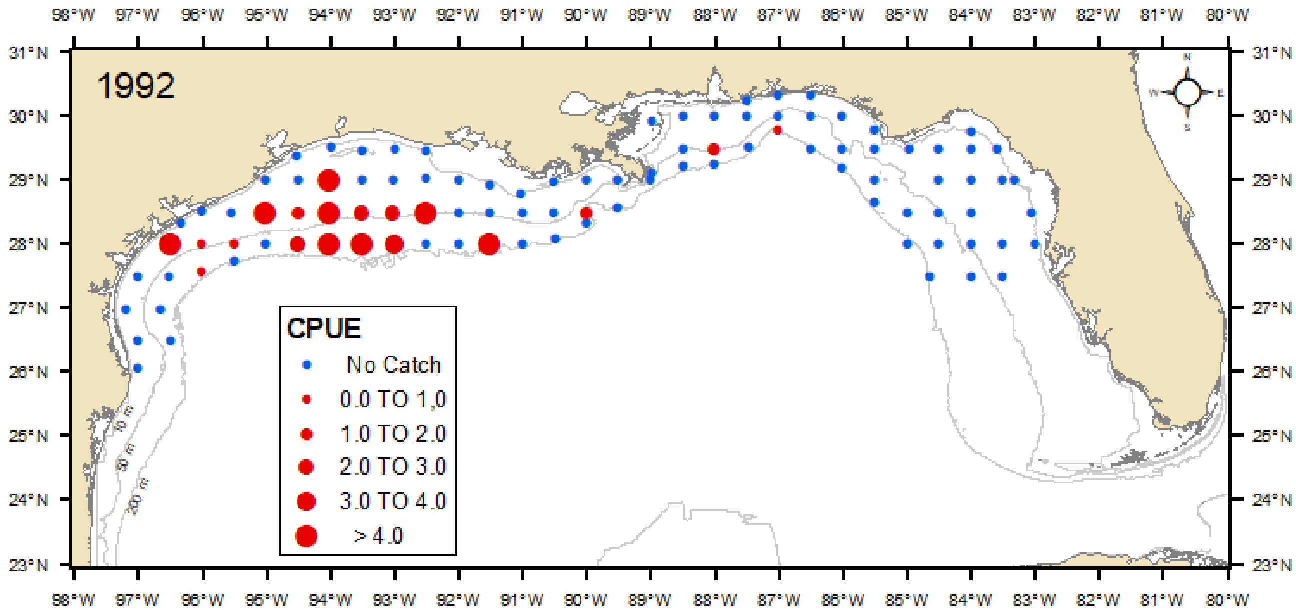


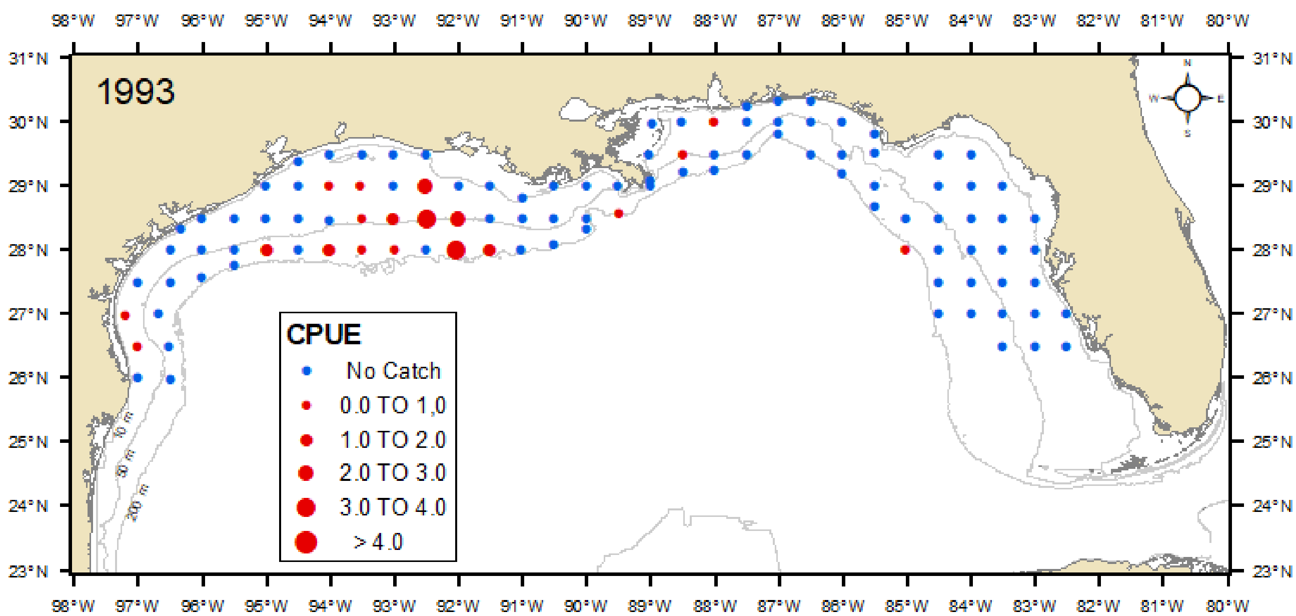

1988
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0

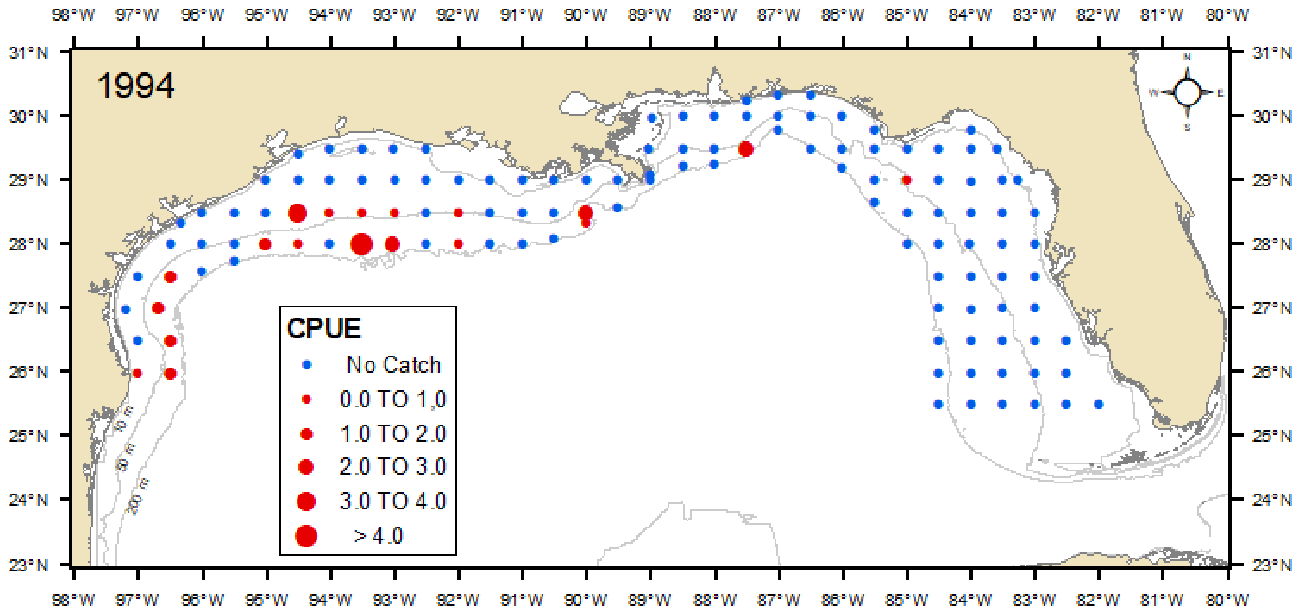

1989
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


1990
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


1991
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


1992
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W 97°W 96°W 95°W 94°W 93°W 92°W 91°W 90°W 89°W 88°W 87°W 86°W 85°W 84°W 83°W 82°W 81°W 80°W
31°N 30°N 29°N 28°N 27°N 26°N 25°N 24°N 23°N


1993
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W 97°W 96°W 95°W 94°W 93°W 92°W 91°W 90°W 89°W 88°W 87°W 86°W 85°W 84°W 83°W 82°W 81°W 80°W
31°N 30°N 29°N 28°N 27°N 26°N 25°N 24°N 23°N


1994
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W
97°W
96°W
95°W
94°W
93°W
92°W
91°W
90°W
89°W
88°W
87°W
86°W
85°W
84°W
83°W
82°W
81°W
80°W
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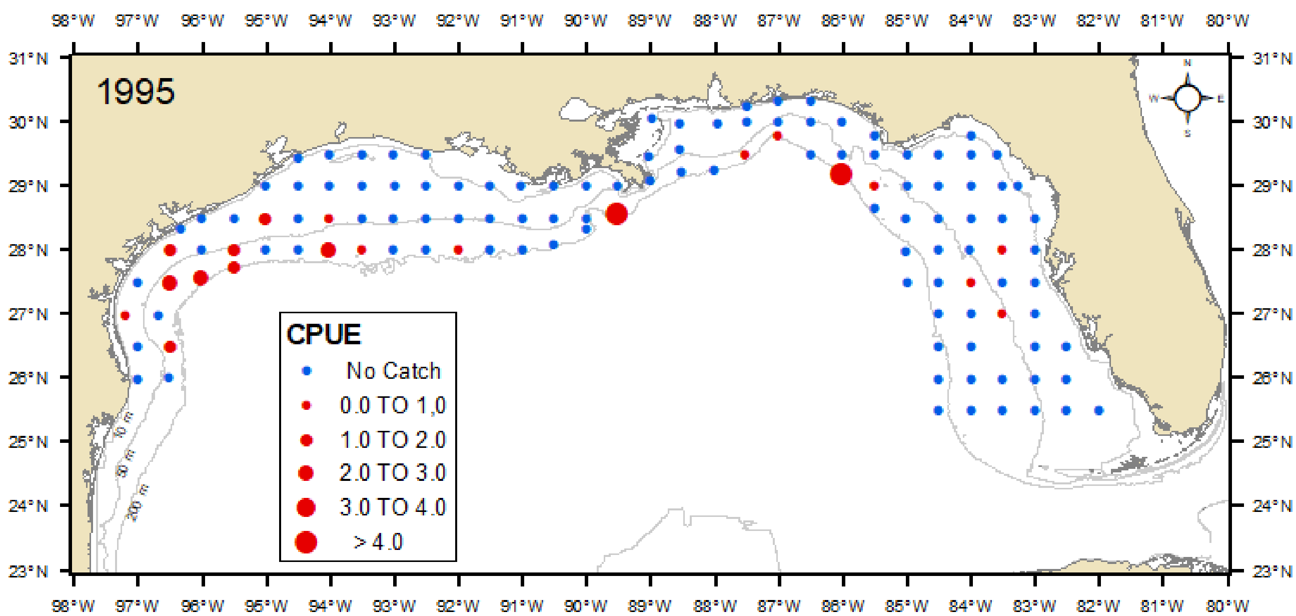
29°N
28°N
27°N
26°N
25°N
24°N
23°N
10 m
50 m
200 m


1995
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W
97°W
96°W
95°W
94°W
93°W
92°W
91°W
90°W
89°W
88°W
87°W
86°W
85°W
84°W
83°W
82°W
81°W
80°W
31°N
30°N
29°N
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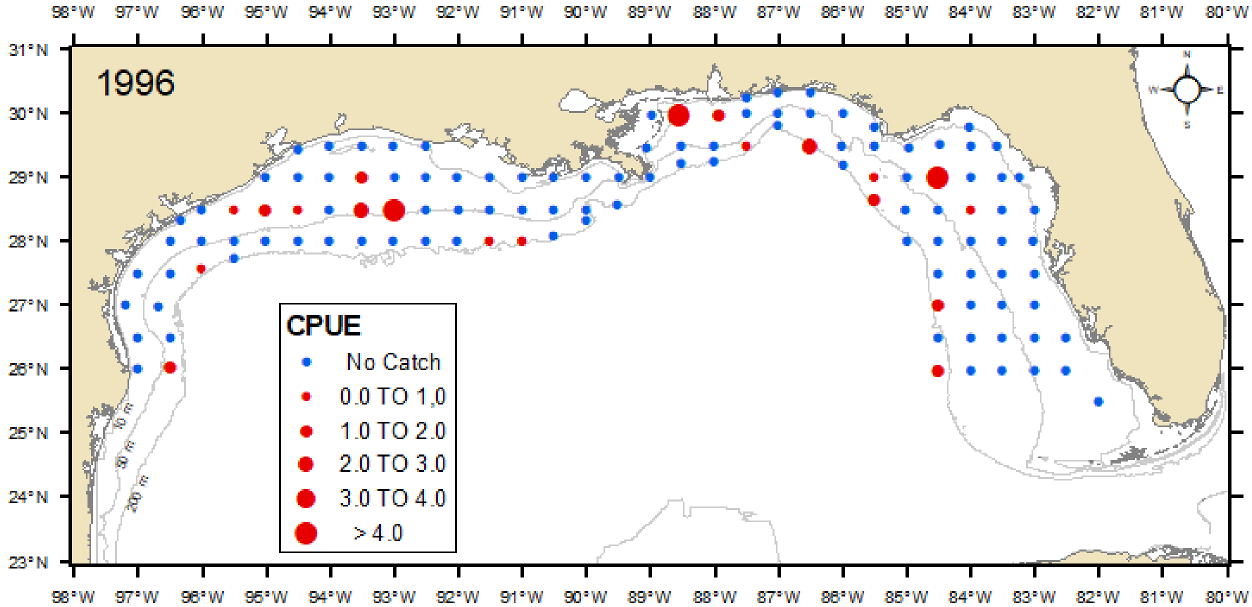
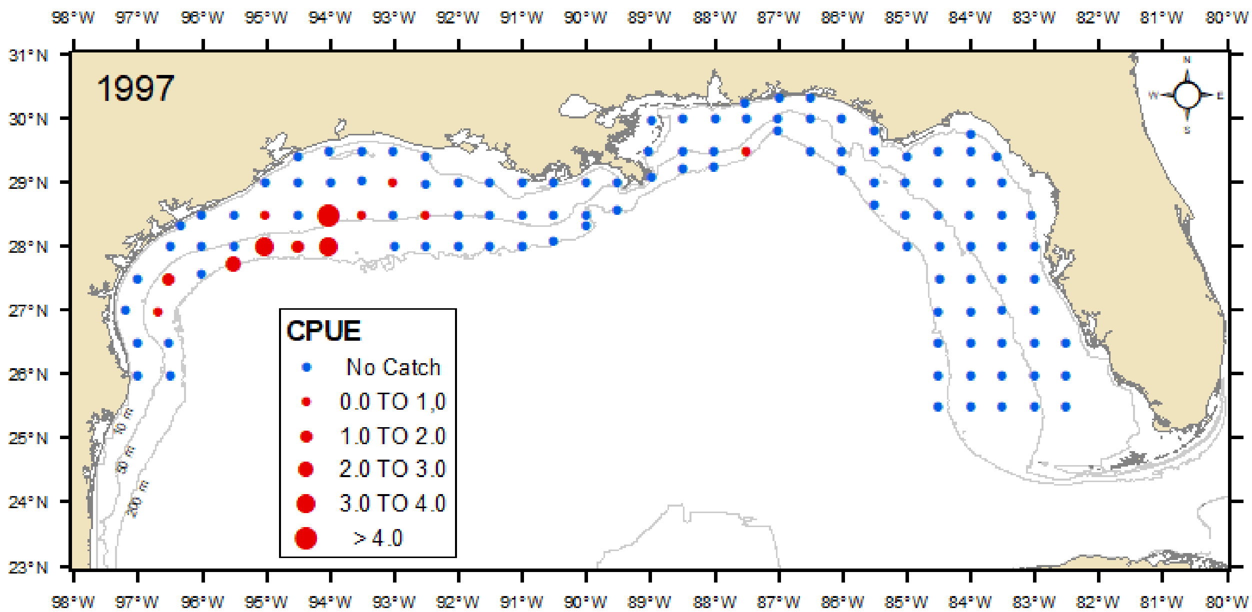
27°N
26°N
25°N
24°N
23°N
10 m
50 m
200 m


1996
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0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CPUE
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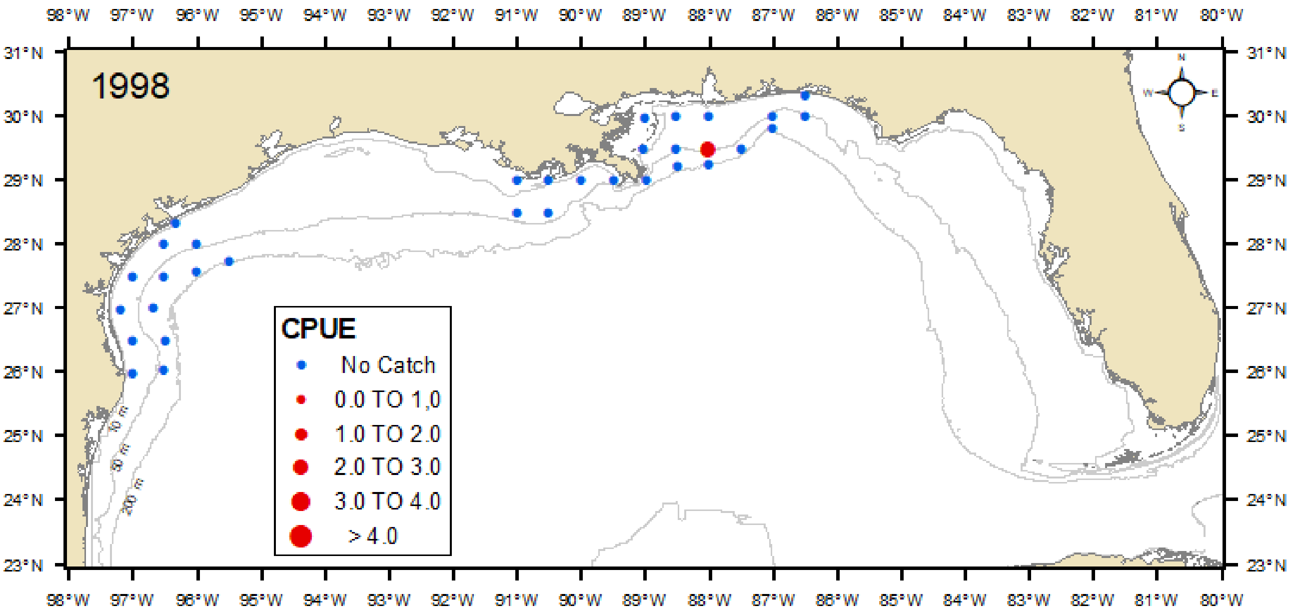
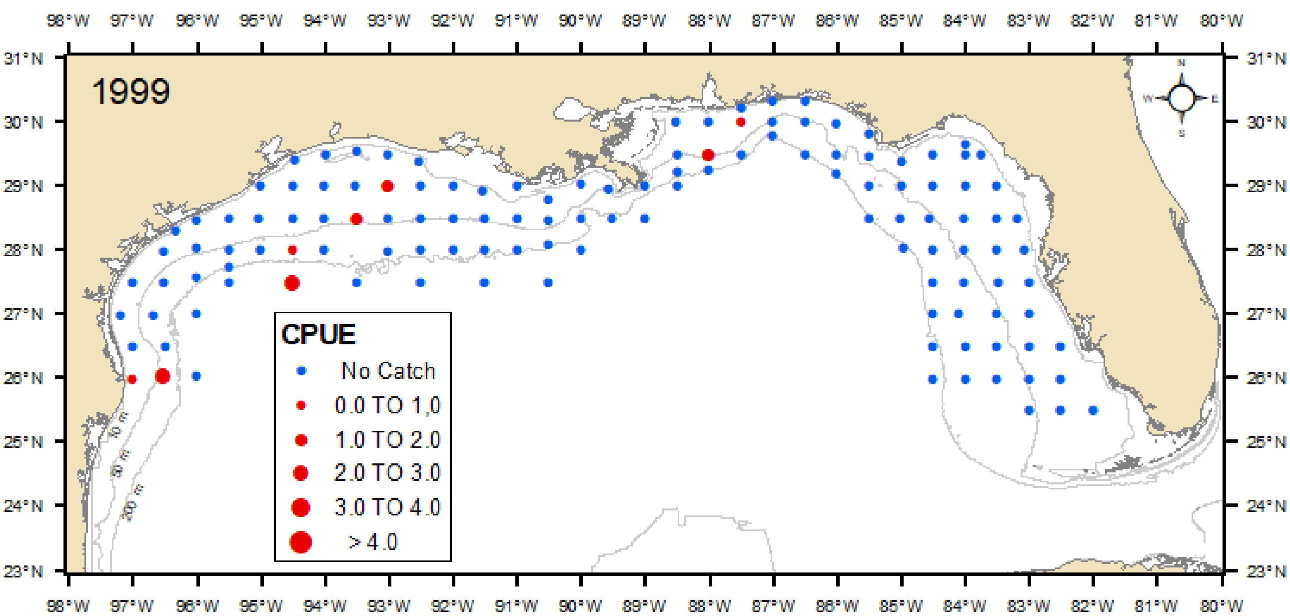
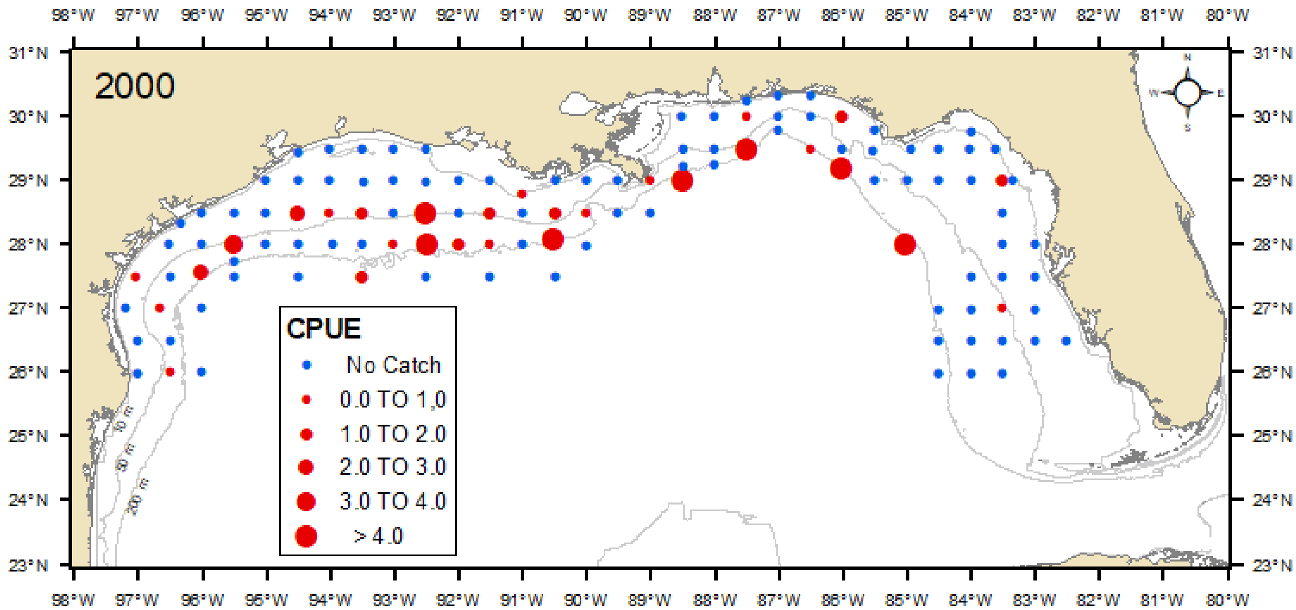
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


1998
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W 97°W 96°W 95°W 94°W 93°W 92°W 91°W 90°W 89°W 88°W 87°W 86°W 85°W 84°W 83°W 82°W 81°W 80°W
31°N 30°N 29°N 28°N 27°N 26°N 25°N 24°N 23°N
10 m
50 m
200 m


1999
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
98°W 97°W 96°W 95°W 94°W 93°W 92°W 91°W 90°W 89°W 88°W 87°W 86°W 85°W 84°W 83°W 82°W 81°W 80°W
31°N 30°N 29°N 28°N 27°N 26°N 25°N 24°N 23°N
10 m
50 m
200 m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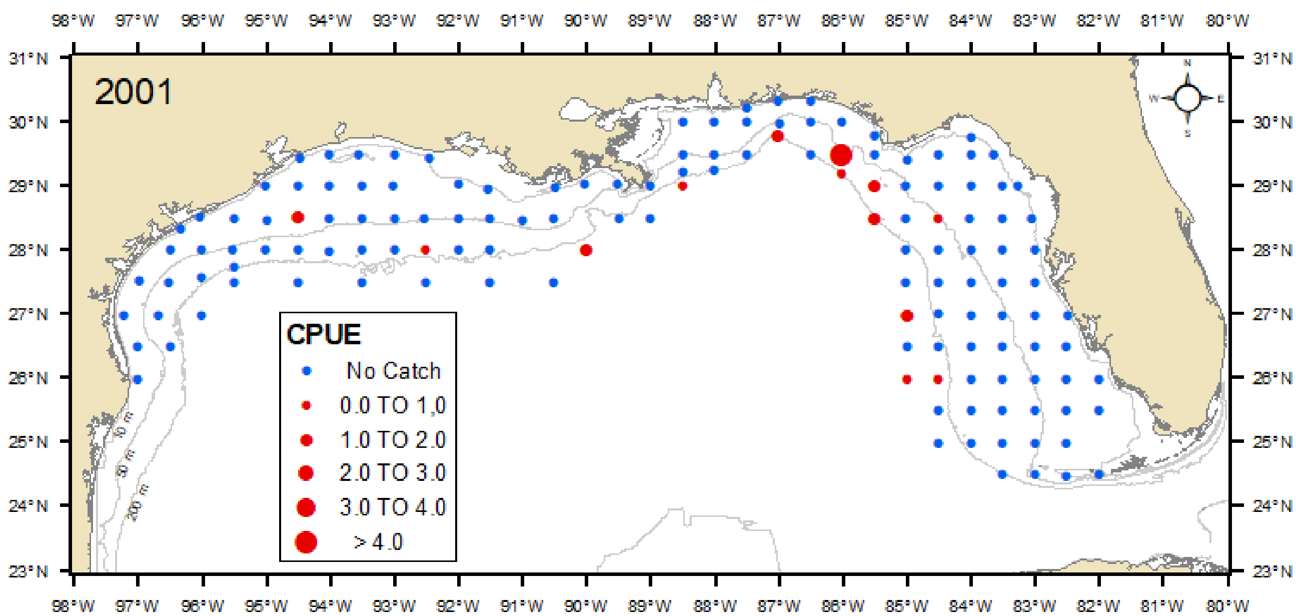
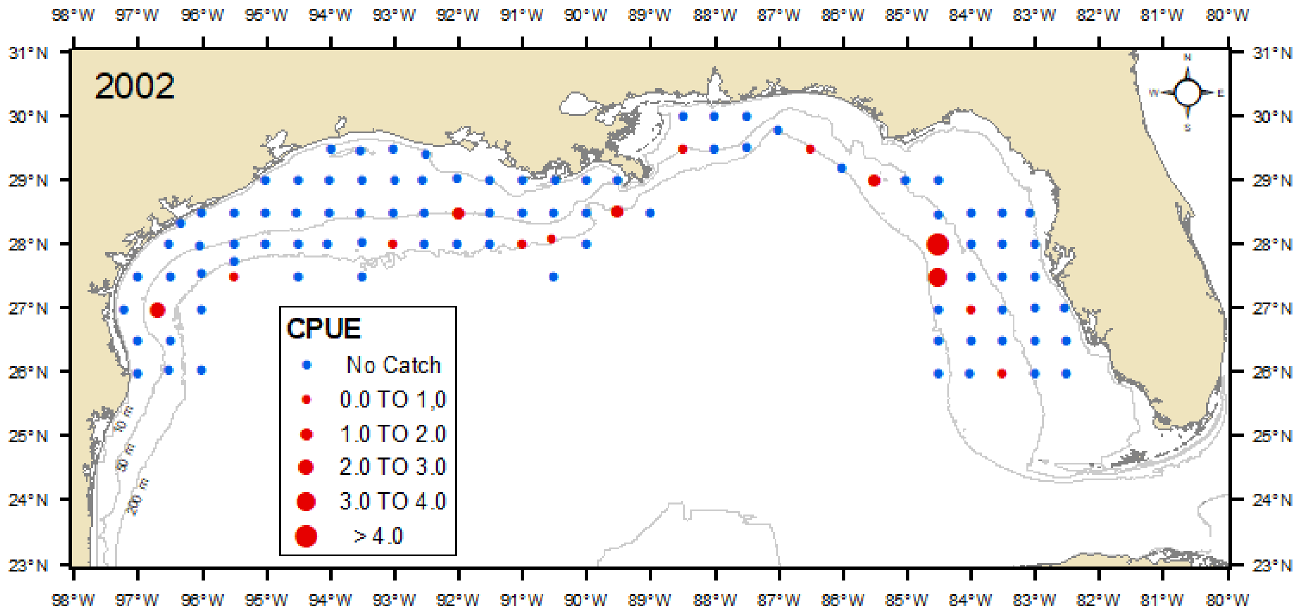
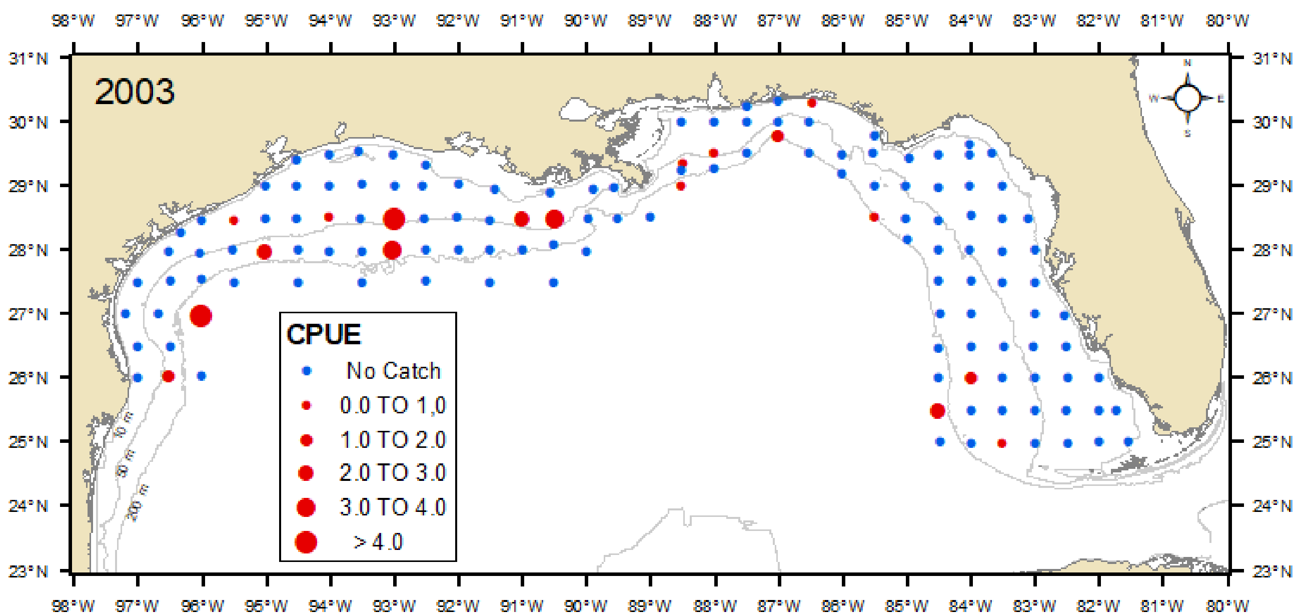
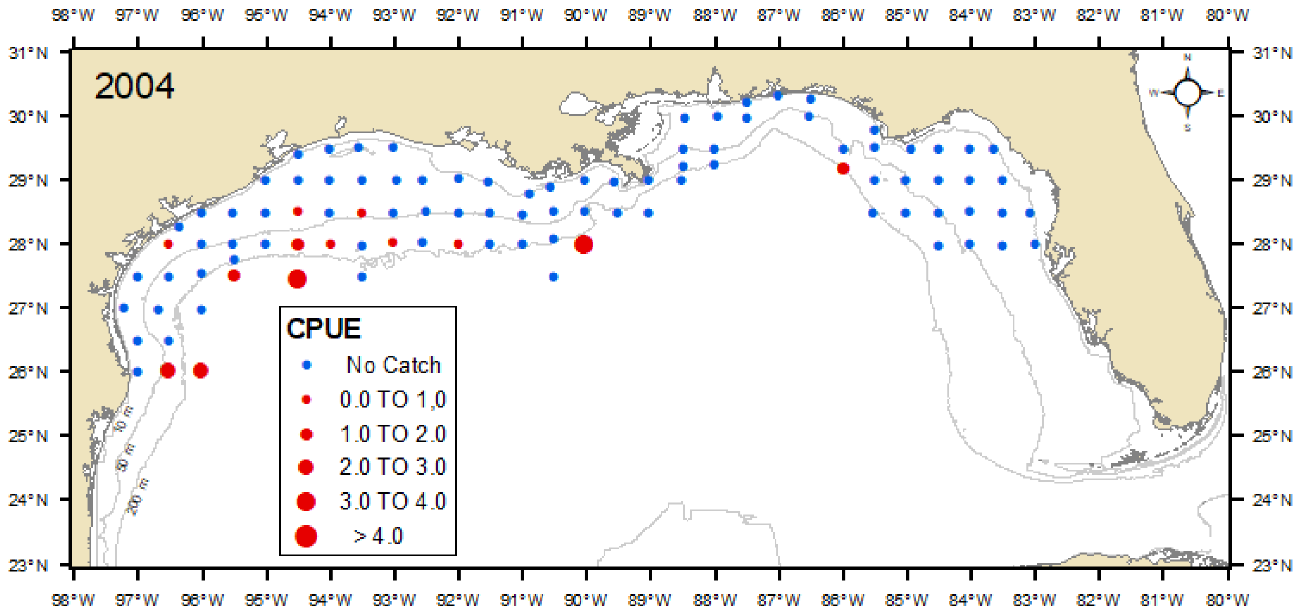
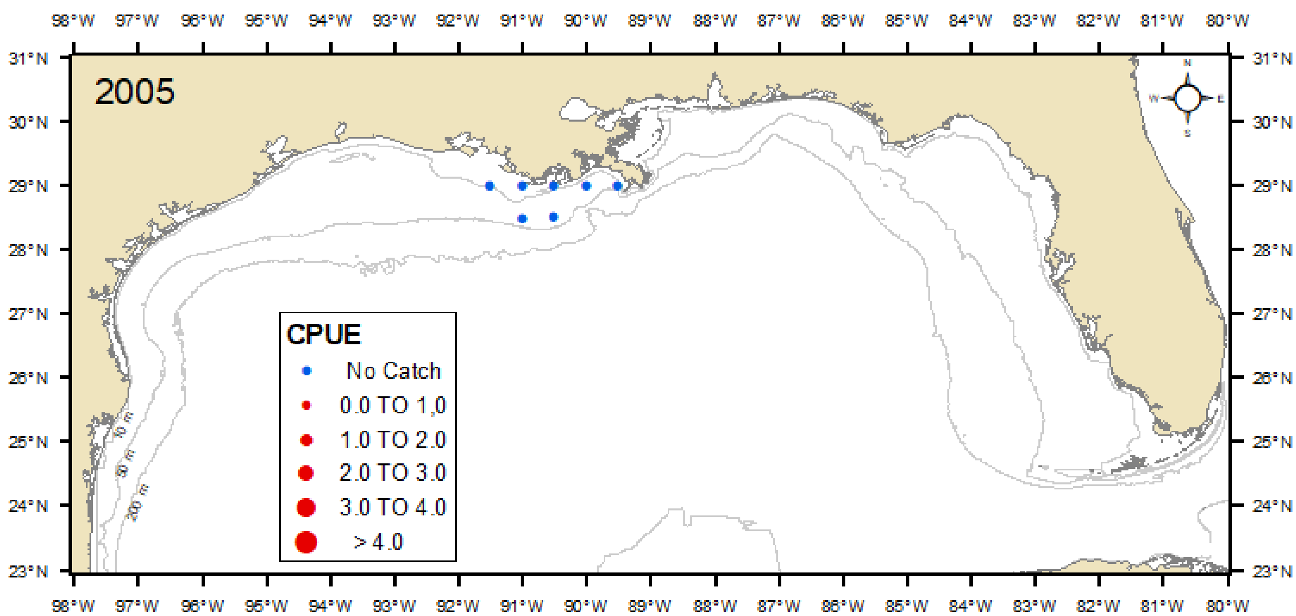
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0

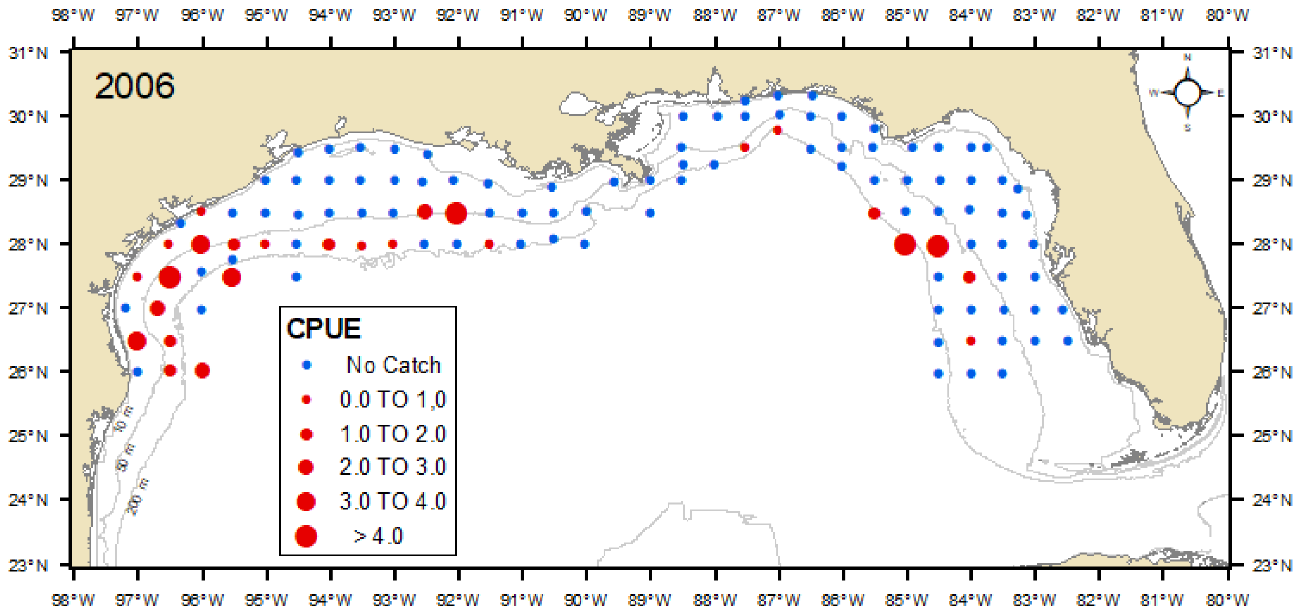

2001
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2002
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2003
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2004
CPUE
No Catch
0.0 TO 1,0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2005
CPUE
No Catch
0.0 TO 1,0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0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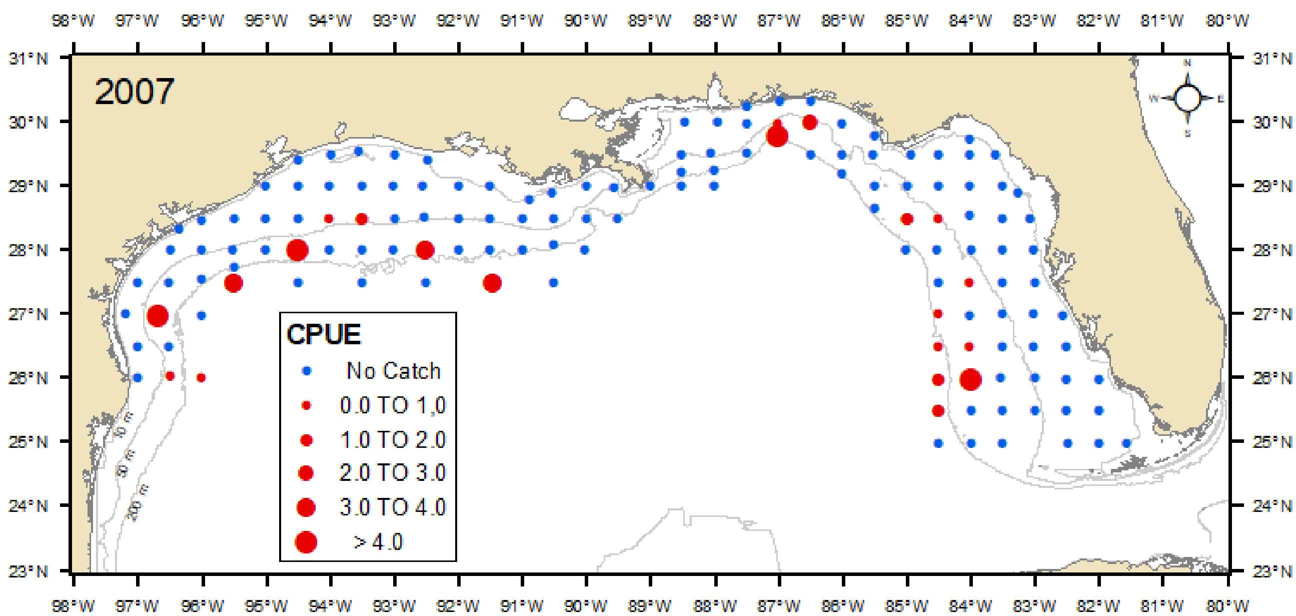
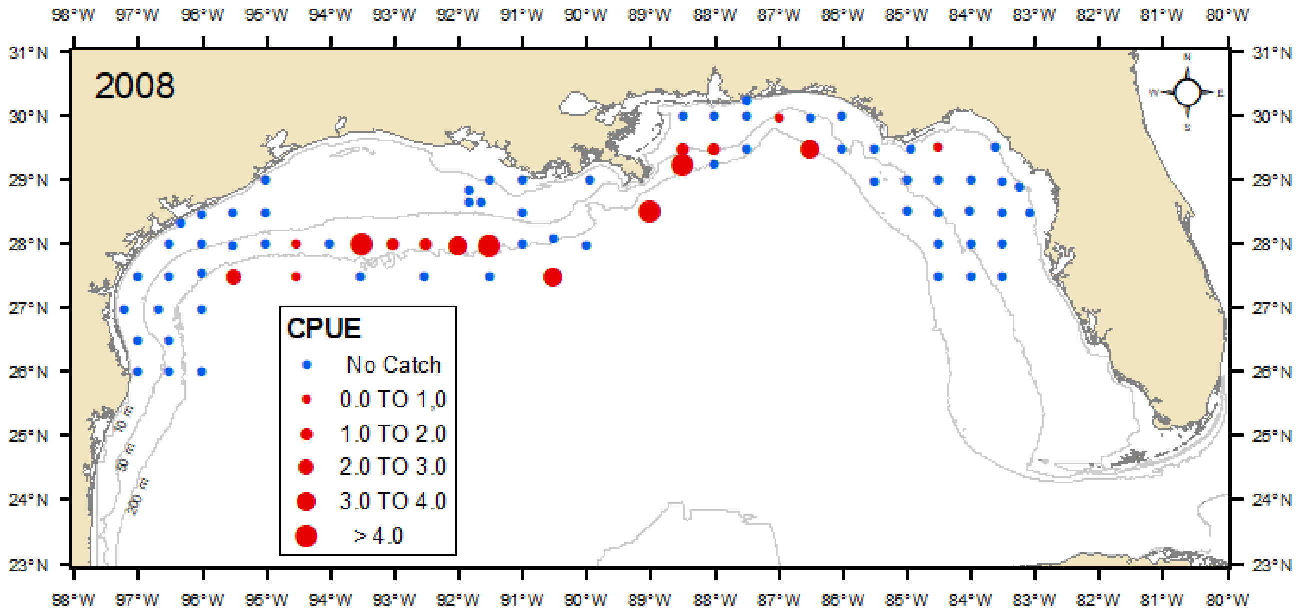
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2007
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2008
CPUE
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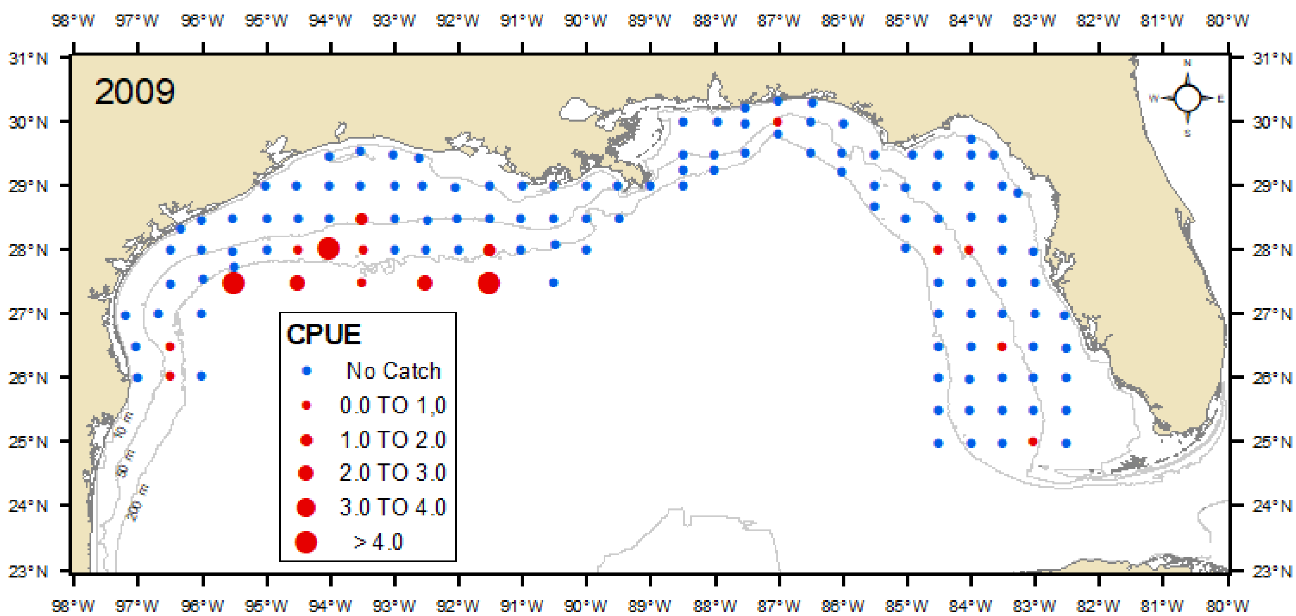
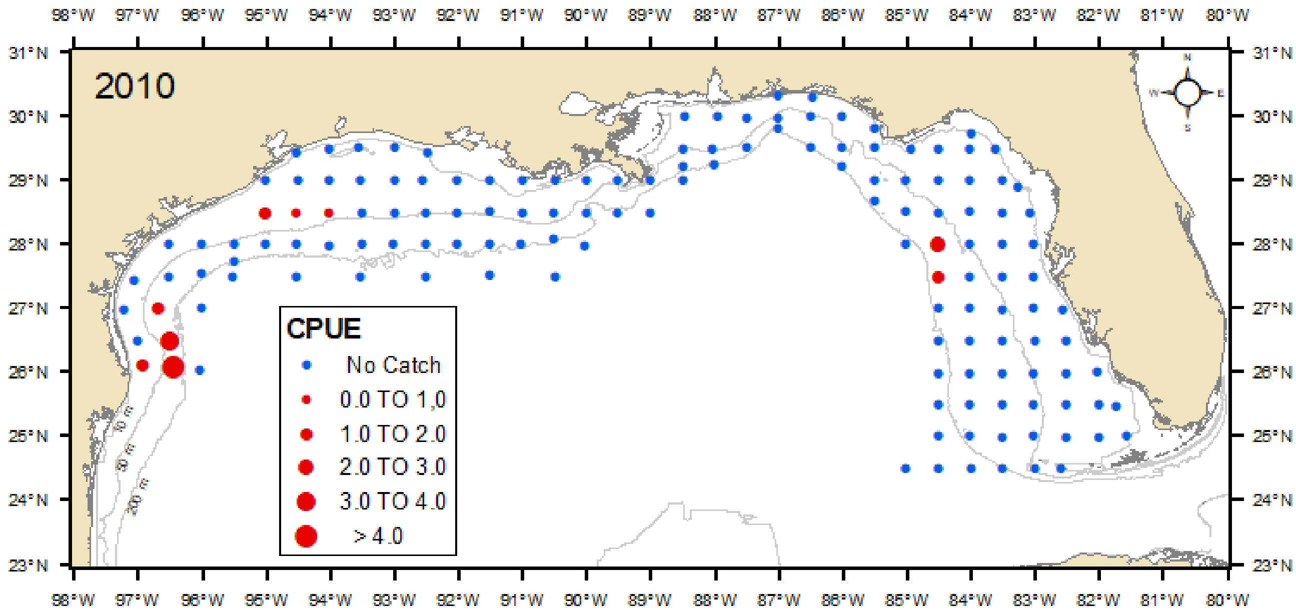
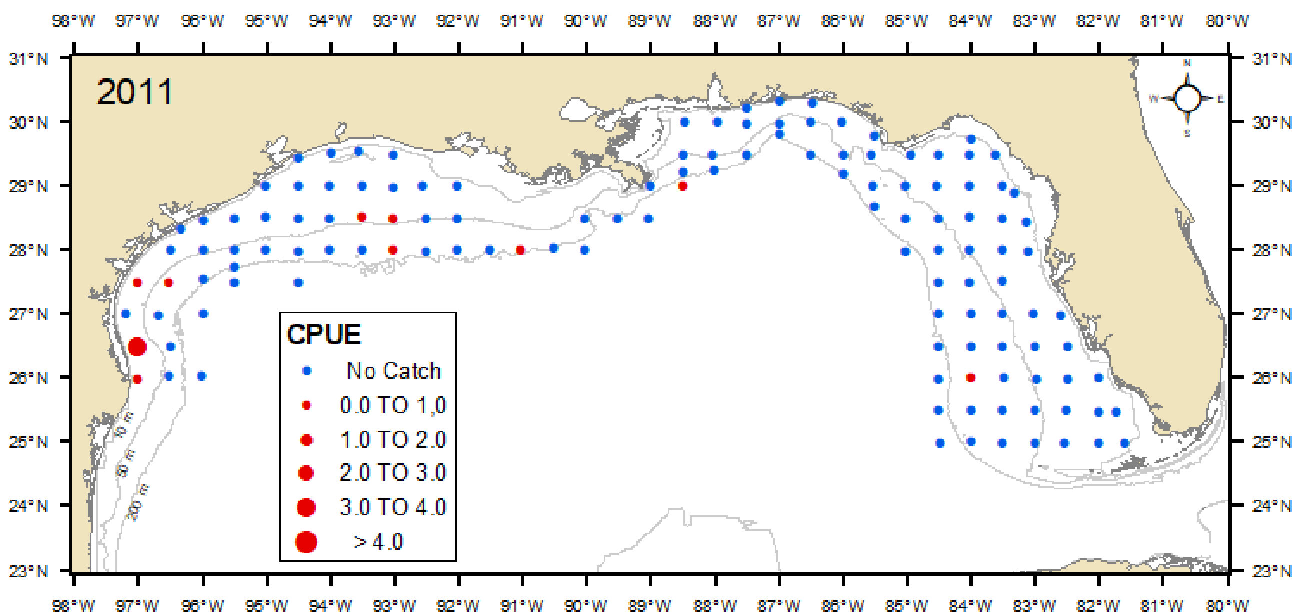
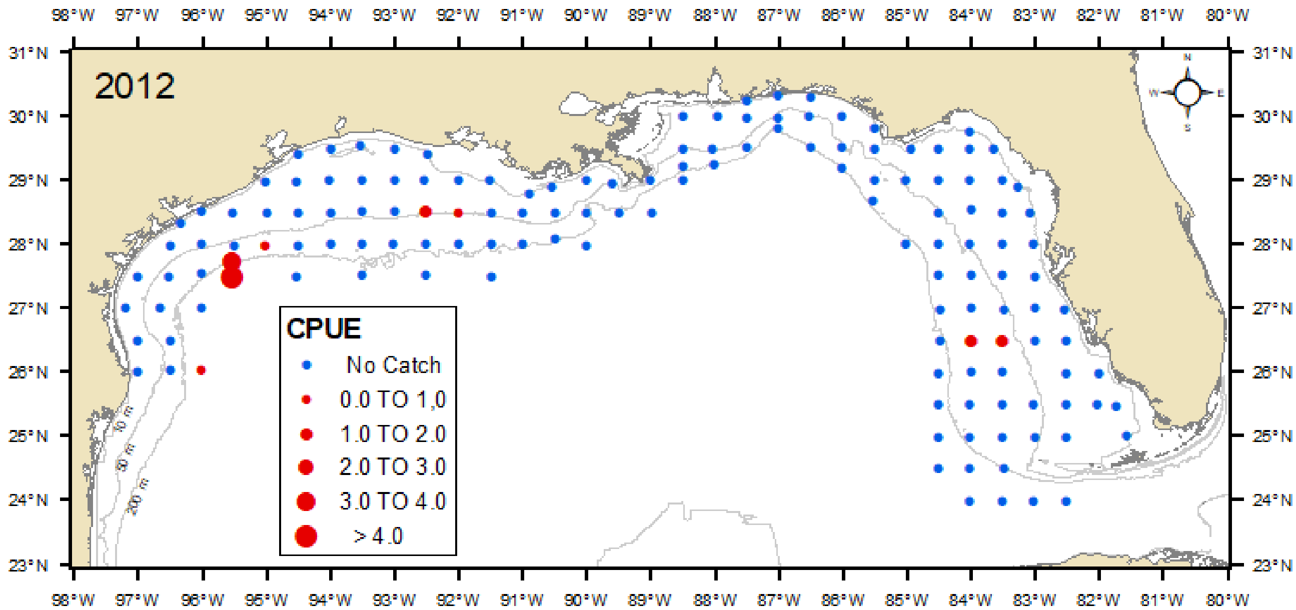
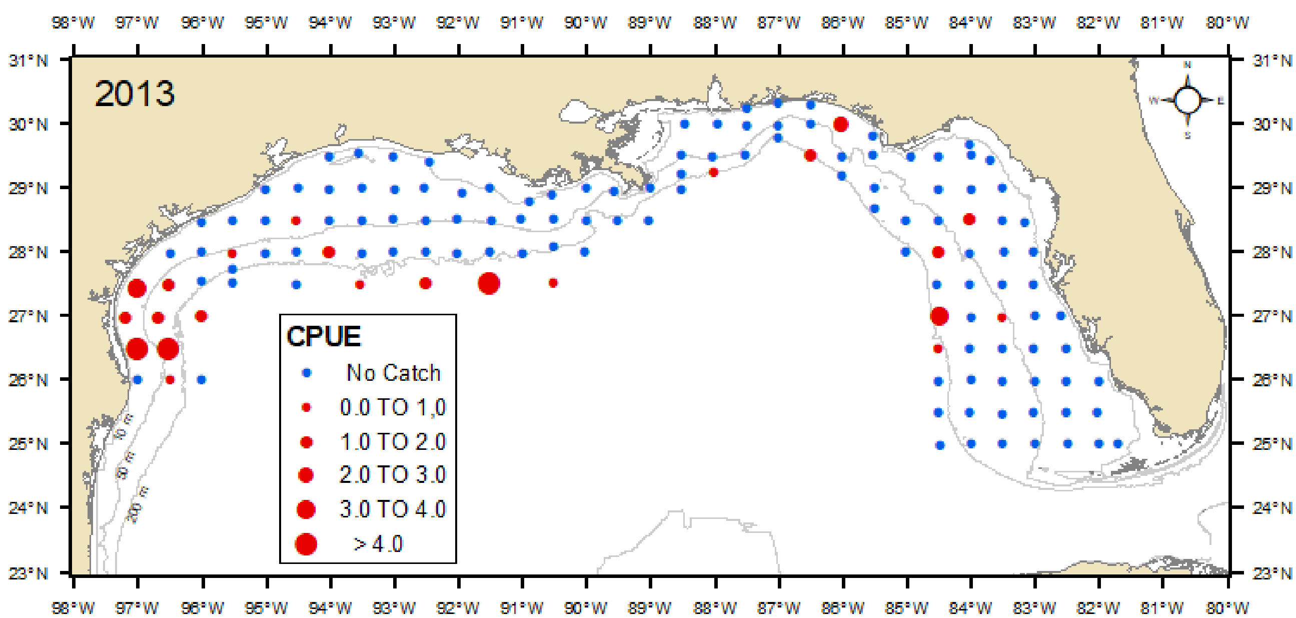
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0

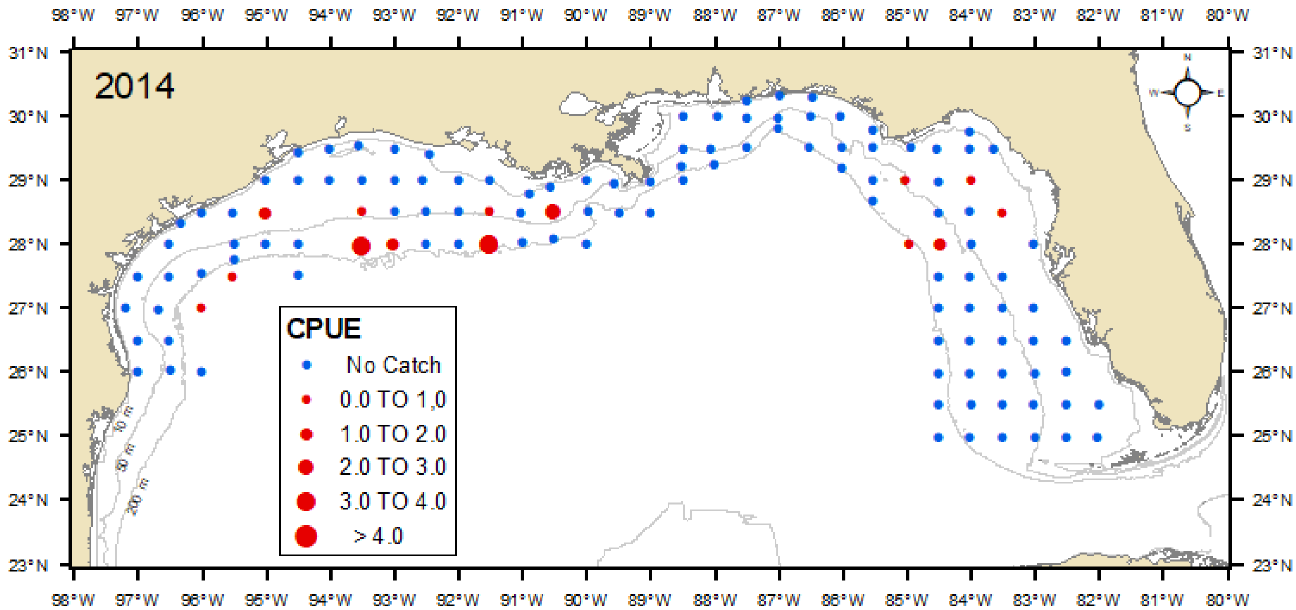

2009
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0

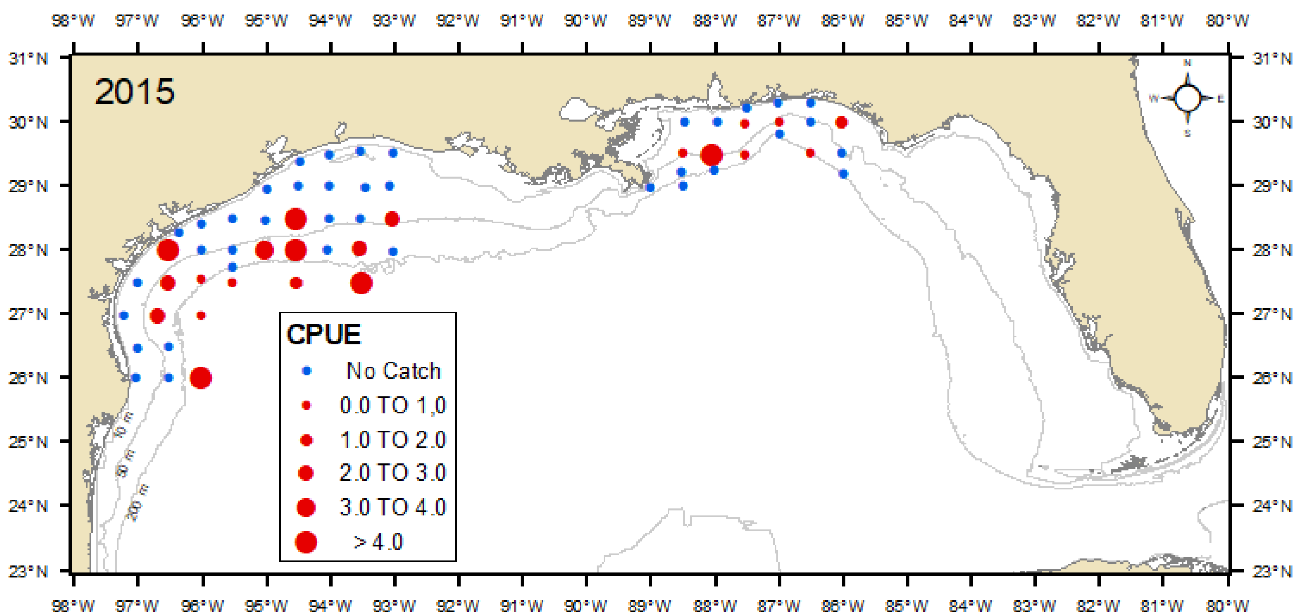

2010
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0

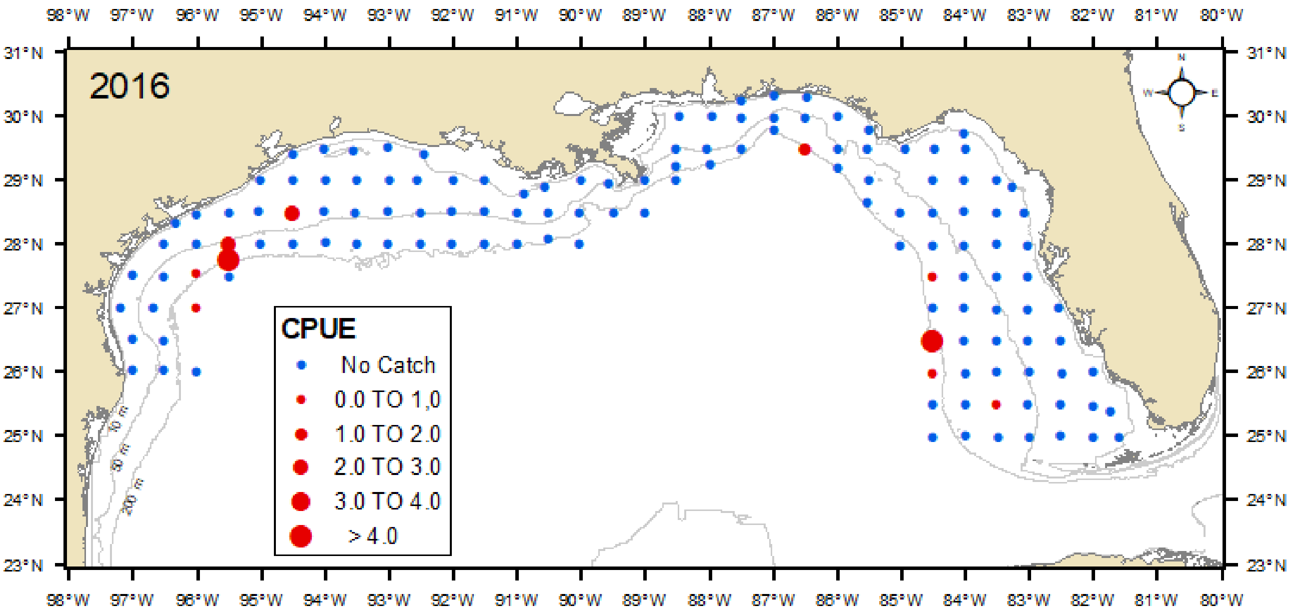

2011
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2012
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2013
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2014
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2015
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0


2016
CPUE
No Catch
0.0 TO 1.0
1.0 TO 2.0
2.0 TO 3.0
3.0 TO 4.0
> 4.0
10 m
50 m
200 m
98°W
97°W
96°W
95°W
94°W
93°W
92°W
91°W
90°W
89°W
88°W
87°W
86°W
85°W
84°W
83°W
82°W
81°W
80°W
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N