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Red Snapper (*Lutjanus campechanus*) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2019

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Abstract: *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 larvae captured during these surveys were initially reviewed as a potential fishery-independent index to reflect trends in the relative spawning stock size of Red Snapper during the Southeast Data Assessment and Review (SEDAR7) process in 2004. Indices of larval abundance as a proxy for adult spawning stock have been incorporated into the SEDAR7 (2004), SEDAR7 Update (2009), SEDAR31 (2012), SEDAR31 Update (2014), and SEDAR52 (2017). Nominal indices of proportion of positive occurrence (PPOS) and age corrected catch per unit area (CPUA) are provided for the western, northeastern and eastern GOM as defined by the SEDAR74 Stock Id Workshop. Delta-Lognormal standardized indices of age corrected CPUA were generated for the western and northeastern GOM, and a standardized index of PPOS was generated for the eastern GOM.*

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. The SEAMAP Fall Plankton Survey, conducted primarily during the month of September, is the only Gulfwide plankton survey of the U.S. continental shelf and coastal waters during the Red Snapper (*Lutjanus campechanus*) spawning season occurring from late April through October. Occurrence and abundance of larvae captured during these surveys were initially reviewed as a potential fishery-independent index to reflect trends in the relative spawning stock size of Red Snapper during the Southeast Data Assessment and Review (SEDAR7) process in 2004 (Lyczkowski-Shultz *et al.*, 2004 and Hanisko *et al.*, 2004). Indices of larval abundance as a proxy for adult spawning stock have been incorporated into the SEDAR7 (2004), SEDAR7

Update (2009), SEDAR31 (2012), SEDAR31 Update (2014) and SEDAR52 (2017) assessments. There have been several changes to the formulation of the indices over time. Detailed information concerning previous iterations of the indices is documented in Hanisko *et al.* (2004), Hanisko *et al.* (2007), Pollack *et al.* (2012), Hanisko *et al.* (2017), the SEDAR 31 – Gulf of Mexico Red Snapper Stock Assessment Report (SEDAR, 2013), the SEDAR 31 Update Assessment Report (Cass-Calay *et al.,* 2015) and the SEDAR 52 Assessment Report (SEDAR, 2018)

Currently, the time series of data from the Fall Plankton Survey available for analysis extends from 1986 to 2019. This document outlines the development of Red Snapper larval indices for the western (WGOM), northeastern (NEGOM) and eastern (EGOM) GOM continental shelf based on similar methodology used for the SEDAR 52 assessment. The development of indices for these three spatial areas follow the SEDAR 74 Stock ID Workshop definitions for the development of a three-area model for the current SEDAR 74 Research Track Assessment.

Methodology

SEAMAP Plankton Sample Methodologies

The standard sampling gear and methodology used to collect plankton samples during SEAMAP surveys were similar to those recommended by Kramer *et al.* (1972), Smith and Richardson (1977) and Posgay and Marak (1980). A 61 cm or 60 cm (inside diameter) bongo net fitted with 0.335 mm mesh netting was fished in an oblique tow path from a maximum depth of 200 m or to 2-5 m off the bottom at station depths less than 200 m. Maximum bongo tow depth was calculated using the amount of wire paid out and the wire angle at the 'targeted' maximum tow depth or measured directly using an electronic depth sensor mounted on the tow cable. A mechanical flowmeter was mounted off-center in the mouth of each bongo net to record the volume of water filtered. Water volume filtered during bongo net tows ranged from ~20 to 600 m^3 but was typically 30 to 40 m^3 at the shallowest stations and 300 to 400 m^3 at the deepest stations.

Catches of larvae in bongo net samples were standardized to account for sampling effort and expressed as number under 10 m^2 sea surface (CPUA, Catch Per Unit Area) by dividing the number of larvae by volume filtered and then multiplying the resultant by the product of 10 and maximum depth of tow. This procedure results in a less biased estimate of abundance than number per unit of volume filtered alone and permits direct comparison of abundance estimates across samples taken over a wide range of water column depths (Smith and Richardson 1977).

Sample Processing and Identification of Larvae

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 National Marine Fisheries Service (NMFS). Fish eggs and larvae were removed from bongo net samples. Fish eggs were not identified further, whereas, larvae were identified to the lowest possible taxon which in most cases was the family level. Body length (BL) in mm was measured and recorded.

In order to assure consistent identifications over the SEAMAP time series, all snapper larvae were examined and identified by ichthyoplankton specialists at the SEFSC Mississippi Laboratories using an identification protocol based on descriptions in Drass *et al.* (2000) and Lindeman *et al.* (2005). The level of identification achievable under this protocol depended on the extent of first dorsal fin development, as well as the following morphological traits: presence or absence of melanistic pigment on the throat (sternohyoideus muscle), and on the anterior surface of the visceral mass or gut; and whether preopercular spines or dorsal spines were smooth or serrated. Specimens were identified as Red Snapper only when a minimum of five dorsal spines were present, those spines were smooth, not serrated and melanistic pigmentation on the body and fins matched the description and illustrations of reared and wild caught Red Snapper larvae in Rabalais *et al.* (1980), Collins *et al.* (1980), and Drass *et al.* (2000).

Red Snapper are among six of the twelve snapper species of the subfamily Lutjaninae found in the GOM whose larvae have been described. Despite these descriptions snapper larvae can be distinguished from each other only after dorsal and pelvic spines have begun to develop using a combination of morphological characters (Lindeman et al. 2005). Red Snapper larvae prior to dorsal and pelvic spine formation are generally less than 3.5 mm BL and cannot be confidently identified in field collections because of the lack of established characteristics that permit early stage larvae of the lutjanines to be distinguished from each other. The few specimens identifiable as Red Snapper in SEAMAP collections that were less than 3.5 mm BL resulted from variability in size at developmental stage and/or shrinkage during capture and preservation. The question arises as to the potential for misidentification of Red Snapper larvae in SEAMAP collections since the larvae of all snappers found in the region have not been described. It is unlikely that this caused extensive misidentification of red snapper larvae considering how much larvae of species whose larval development has been described differ from each other and red snapper in pigmentation and body shape (Drass *et al.* 2000). Most of the snappers whose larvae remain undescribed inhabit coral reefs and reef associated ledges as adults, and clear shallow waters or mangrove areas as juveniles (Anderson 2003); biotopes of limited extent in the northern GOM (Parker *et al.* 1983). No adults or juveniles of the six snapper species whose larvae are undescribed were taken during annual summer and fall SEAMAP shrimp/bottomfish (trawl) surveys from 1982 to 2005 (G. Pellegrin, NOAA/SEFSC Mississippi Laboratories, personal communication). Fewer than five individuals per year of these species were ever observed during ten years of NMFS reef fish video surveys of reef and hard bottom habitat from Brownsville, Texas to the Florida Keys (K. Rademacher, NMFS/SEFSC Mississippi Laboratories, personal communication).

Standardized SEAMAP Station/Sample Data Set

The SEAMAP Fall Plankton sampling 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 bongo 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 and sampling effort during the Fall Plankton Surveys has at time has been impacted due to severe weather, vessel breakdowns and/or time constraints (Appendix Figure 1). Spatial coverage within the WGOM was limited during the 1998, 2005, 2008, and 2015 surveys, and sampling effort was reduced within the area during the 1988 to 1991 surveys. Spatial coverage in the NEGOM was limited during the 1998, 2002, 2005, 2015 and 2017 surveys, and sampling effort reduced during 1988 and 1989. In the EGOM, spatial coverage has been considerably more variable. Curtailed sampling during the 1992, 1998, 2004, 2005, 2008, 2015 and 2017 surveys have resulted in large portions of the EGOM remaining un-sampled. Much of the spatial variability in the EGOM 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 southeastern (Tampa, FL to Key West, FL) portion of the survey area.

Year to year variability in spatial coverage from Fall Plankton Survey data was addressed by limiting observations to samples taken at SEAMAP stations that were sampled during at least (~66%) of all years for which there was consistent spatial coverage respectively for the WGOM, NEGOM and EGOM (Figure 1). The WGOM index core data includes all samples taken during at least 20 of the 30 years of available data, the NEGOM index core data includes all samples taken during at least 19 of the 29 years of available data, and the EGOM index core data includes all samples taken during at least 18 of 27 years of available data.

Aging of Larvae, Mortality Estimates and Age Corrected Abundance

Estimates of total larval catch per unit area (CPUA) of each size class (catch curves) were developed for larval Red Snapper by summing the CPUA of each size class under 10 m^2 of sea surface. Size classes of 1.0 mm were utilized, with the midpoint of each size representing larvae lengths within ± 0.5 mm. Larvae less than 3.75 mm and greater than 9.75 mm in length were excluded from the analysis due to identification uncertainty of smaller larvae and gear avoidance of larger rarely caught larvae. All primary B-Number samples from 1986 to 2019 were used to estimate mortality.

Red Snapper larvae collected during SEAMAP collections are not aged as part of standard protocols. However, Jones (2013) has examined the age and growth of Red Snapper larvae (n=103) obtained from samples collected during the SEAMAP Summer Shrimp/Bottomfish trawl survey in 2008 and the Fall Plankton surveys in 2006, 2007, and 2008. The study established the following length-at-age relationship for Red Snapper larvae:

$$(1) \qquad l = 1.9302e^{0.0705t}$$

where l was length in mm and t is age in days. The r-squared value for this relationship was 0.8744.

Size classes were converted to age classes using the length-at-age relationship established by Jones (2013) to assign an age to the mid-points of each 1.0 mm size class. The summed abundance of each age/size class was then corrected to account for exponential growth by dividing the summed abundance of each size class by their respective duration of the size class in days (Houde, 1977). Duration was calculated by subtracting the age of the lower boundary of length of a size class from the age of the upper boundary of length of the size class. An estimate of larval Red Snapper mortality was then estimated from the descending limb of the catch curve. Subsequently, the instantaneous mortality rate (Z=-0.1841) was estimated as the slope of a non-linear least squares function relating the duration-corrected larval abundance and age (Figure 2, Ricker, 1975).

Individual larvae in each sample were then back calculated to the number of larvae at 11.2 days of age by assigning age based on their length and adjusting for daily mortality. The total number of 11.2 day old larvae was then summed and standardized to the total number of larvae per 10 m^2 of sea surface for each sample.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for Red Snapper in the WGOM and NEGOM (Pennington, 1983; Bradu and Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). 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:

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

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

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 (Christman, unpublished).

The submodels of the delta-lognormal model 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. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC.

The delta-lognormal model cannot include years with zero catch. Therefore, years in which Red Snapper were not observed, respective to the WGOM (1988) and NEGOM (1986 to 1990, 1992, 1993 and 1996) were removed prior to the calculation of delta-lognormal indices. The factors Y*ear*, *Subregion*, *Time of Day* (TOD) and *Depth* were examined as possible influences on the proportion of positive occurrence and abundance of nonzero larval abundance for the WGOM and NEGOM (Table 1).

The overall proportion of positive occurrence of Red Snapper in the EGOM is less than 5% for the 27 years of the time series with consistent spatial coverage. Only five years had larvae occurring in three or more samples, with all years occurring after 2009. Therefore, potential trends in the EGOM are examined utilizing nominal time series of proportion of positive occurrence and abundance. A binomial generalized linear mixed model including only a factor for year was also generated in an effort to determine the potential of a proportion of positive occurrence index and to baseline relative CVs for the EGOM. Data for the binomial model was restricted to years with at least one positive occurrence.

Results and Discussion

Proportion of positive occurrence (PPOS), mean age corrected larval CPUA and the percentage of total CPUA from all years with consistent spatial coverage respective to the WGOM, NEGOM and EGOM provide an overview of the difference among the three regions and within subregions[1] of the WGOM and NEGOM (Table 2). Red Snapper larvae were captured throughout the gulfwide survey area but occurred 2.3 and 5.3 times more often and at 2.4 and 10.2 times greater CPUA in the WGOM than in the NEGOM and EGOM respectively. The WGOM accounted for 77.3 percent of the total gulfwide CPUA, the NEGOM accounted for 18.3 percent and the EGOM accounted for 4.3 percent. In the WGOM, the Louisiana subregion accounted for 66.1 percent of the total abundance in the region with larvae occurring 1.2 time more often and at 1.8 times greater CPUA than the Texas subregion. In the NEGOM, the Mississippi/Alabama subregion accounted for 60.8 percent of the total abundance in the region with larvae occurring 2.5 times more often and at 3.1 times greater CPUA than the Florida subregion.

Nominal PPOS and CPUA of Red Snapper larvae have been steadily increasing throughout the SEAMAP Fall Plankton survey area over the time series (Figure 3, Table 3). The WGOM has seen a steady increase in PPOS since the late 1980s. In the NEGOM, PPOS was at or near zero until the early 1990s, has steadily increased from 2000 to 2009, and has seen a rapid increase since 2010. PPOS in the EGOM remained at or near zero from 1986 until 2010 but has been increasing over the latter part of the time series. Nominal CPUA in both the WGOM and NEGOM has shown a marked increase over time. Distinct Shifts in increasing CPUA are evident from 1986 to 1999, 2000 to 2009/2010 and after 2000/2010 in both regions. In the EGOM, CPUA was at or near zero until 2010 but has increased during the latter part of the time series.

Delta-lognormal indices of larval Red Snapper age corrected CPUA were generated for the WGOM and NEGOM. The WGOM index is presented in Table 4 and Figure 4. The backward selection procedure retained year and TOD in the binomial submodel, and year, TOD and subregion in the lognormal submodel (Table 5). The AIC for the binomial and lognormal submodels were 1505.4 and 877.9, respectively. The diagnostic plots for the lognormal submodels are show in Figure 5, and indicated the distribution of the residuals is approximately normal. The NEGOM index is presented in Table 6 and Figure 4. The backward selection procedure retained year and subregion in the binomial submodel, and year, subregion and depth in the lognormal submodel (Table 5). The AIC for the binomial and lognormal

[1] See Table 1 and Figure 1 for the designations of spatial subregions.

submodels were 483.7 and 236.5, respectively. The diagnostic plots for the lognormal submodels are show in Figure 5, and indicated the distribution of the residuals is approximately normal.

The current WGOM delta-lognormal index of abundance was developed utilizing similar methods and spatial extents as the WGOM index generated for SEDAR52. The WGOM index exhibits a variable but steadily increasing trend over the entire time series. The trend is relatively gradual until 2014, but shows a sharp increase in CPUA in 2016 and 2019. CPUA in these years is two times greater than the 2011 to 2014 average. CVs have continued to improve and typically have been less than 30% over the past decade. The WGOM (Table 4) relative index of abundance is recommended for consideration as a tuning index in the SEDAR74 assessment model.

The development of a three area model for the SEDAR 74 assessment required the splitting of SEAMAP Fall Plankton survey eastern GOM (> -89.25 Degrees of Longitude) sampling effort between the NEGOM and EGOM regions as defined by the stock identification process, effectively allocating a small number of samples (<35) within each region. The NEGOM delta-lognormal index of abundance indicates a slowly increasing population from 1986 to 2009 and a marked increase in the population after 2010 with the 2019 terminal year posting the highest abundance recorded during the time series. However, due to low sample sizes and low catch rates early in the time series, there is little precision to the trend. CVs are typically greater that 50% for all but the most recent years of the time series.

Although sample sizes in the EGOM were similar to those in the NEGOM, mean PPOS (0.04) in the EGOM was less than half of the mean PPOS (.09) in the NEGOM. Our exploratory binomial model successfully converge with an AIC of 223.75. The factor year was not significant. Nominal data, annual least squared means (LSMEANS) estimates of PPOS and other parameters are presented in Table 6. The binomial model indicates a relative increase in PPOS over the time series. CVs on annual estimates indicate little precision with which to assess trend. Only a single year of the PPOS index was below 50%. Low catch rates in the EGOM will require greater sampling effort within the region to assess the feasibility of a larval index for this area.

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Table 1. Factors considered for inclusion into the binomial and lognormal sub-models of the Delta-lognormal approach for the western GOM (top) and northeastern GOM (bottom) indices. Note there was no delta-lognormal model for the eastern GOM.

Western Gulf of Mexico (WGOM)

Factors	Levels	Description
Year	*29*	*1986-1987, 1989-1997,1999-2004,2006-2007,2009-2014 and 2016-2019*
Subregion	*2*	*TX = Texas (>93.75 Degrees W Longitude)* *LA = Louisiana (> 89.25 and <= 93.75 Degrees W Longitude)*
Time of Day (TOD)	*2*	*D = Day (Sunrise to Sunset)* *N = Night (Sunset to Sunrise)*
Depth		*Water Depth*

Northeastern Gulf of Mexico (NEGOM)

Factors	Levels	Description
Year	*21*	*1991, 1994-1995, 1997, 1999-2001, 2003-2004, 2006-2014, 2016 and 2018-2019*
Subregion	*2*	*MS/LA = Mississippi and Alabama (> 87.25 and <= 89.25)* *FL = Florida (<= 87.25)*
Time of Day (TOD)	*2*	*D = Day (Sunrise to Sunset)* *N = Night (Sunset to Sunrise)*
Depth		*Water Depth*

Table 2. Number of samples (N), number of positive occurrences (NPOS), proportion of positive occurrence (PPOS), standard error of PPOS (PPOS SE), catch per unit area (CPUA), standard error of CPUA (CPUA SE), total CPUA and percentage of total CPUA (Percent Total CPUA) by region and subregion. Asterisk (*) indicates that percentage of total abundance is based on gulfwide Total CPUA. TX and LA are subregions within the west region and MS/AL and FL are subregions within the northeastern region.

Region SubRegion	N	NPOS	PPOS	PPOS SE	CPUA	CPUE SE	Total CPUA	Percent Total CPUA	
GOM	3549	469	0.13	0.01	2.34		8322.09		
West	1650	343	0.21	0.01	3.90	0.33	6436.60	77.34	*
TX	806	153	0.19	0.01	2.71	0.57	2184.41	33.94	
LA	844	190	0.23	0.01	5.04	0.32	4252.18	66.06	
Northeast	947	89	0.09	0.01	1.61	0.24	1525.76	18.33	*
MS/AL	314	48	0.15	0.01	2.95	0.56	927.07	60.76	
FL	633	41	0.06	0.02	0.95	0.21	598.69	39.24	
East	952	37	0.04	0.01	0.38	0.09	359.73	4.32	*

Table 3. Sampling effort, nominal proportion of positive occurrence (PPOS) and nominal catch per unit effort (CPUA) for the western (WGOM), northeastern (NEGOM) and eastern (EGOM) Gulf of Mexico. Only years with consistent spatial coverage for each region are included.

	WGOM			NEGOM			EGOM		
YEAR	**N**	**PPOS**	**CPUA**	**N**	**PPOS**	**CPUA**	**N**	**PPOS**	**CPUA**
1986	49	0.082	1.012	27	0.000	0.000	32	0.031	0.163
1987	55	0.073	1.904	30	0.000	0.000	33	0.061	0.254
1988	28	0.000	0.000	13	0.000	0.000	25	0.040	0.226
1989	28	0.143	1.796	15	0.000	0.000	25	0.000	0.000
1990	31	0.194	1.666	19	0.000	0.000	20	0.000	0.000
1991	31	0.097	1.435	18	0.056	0.345	25	0.040	0.164
1992	55	0.127	0.925	35	0.000	0.000			
1993	55	0.127	1.377	30	0.000	0.000	20	0.000	0.000
1994	55	0.073	1.092	35	0.029	0.105	32	0.000	0.000
1995	55	0.236	3.025	32	0.031	0.156	32	0.031	0.093
1996	55	0.164	1.876	35	0.000	0.000	27	0.000	0.000
1997	54	0.259	3.171	33	0.030	0.246	31	0.032	0.060
1998									
1999	55	0.145	1.194	35	0.086	0.921	27	0.000	0.000
2000	55	0.273	5.495	35	0.114	1.500	24	0.000	0.000
2001	47	0.149	3.418	33	0.091	0.278	32	0.000	0.000
2002	54	0.222	2.533				27	0.074	0.418
2003	54	0.296	6.215	33	0.121	1.234	33	0.000	0.000
2004	54	0.222	2.493	33	0.030	0.296			
2006	52	0.231	5.018	34	0.088	2.980	25	0.000	0.000
2007	55	0.291	3.413	35	0.171	2.679	33	0.000	0.000
2008				26	0.038	0.130			
2009	55	0.309	4.113	35	0.086	0.997	32	0.094	1.043
2010	53	0.151	1.552	34	0.235	5.657	33	0.030	0.200
2011	53	0.245	8.214	35	0.086	2.679	33	0.212	3.371
2012	55	0.309	7.752	29	0.172	1.339	33	0.061	0.327
2013	54	0.296	3.187	34	0.147	2.316	33	0.030	0.059
2014	52	0.269	7.022	33	0.152	5.229	31	0.032	0.239
2015									
2016	55	0.345	15.120	35	0.200	2.596	33	0.091	0.674
2017	53	0.226	3.333						
2018	53	0.340	7.255	33	0.242	3.212	33	0.061	0.831
2019	47	0.468	13.099	29	0.414	10.176	32	0.094	1.159

Table 4. SEAMAP Fall Plankton Survey index of western Gulf of Mexico (WGOM) larval Red Snapper age corrected abundance developed using the delta-lognormal (DL) model. The number of samples (N), proportion of positive occurrence (PPos), observed catch per unit area (CPUA), the DL index (Index), the DL index scaled to a mean of one (StdIndex) for the time series, the lower and upper confidence limits (StdLCL and StdUCL) for StdIndex and the coefficient of variation of the mean (CV) are listed. Years with zero PPos represent true zero abundance for years with consistent spatial coverage. These years are not included in the delta-lognormal model.

Year	N	PPos	CPUA	Index	StdIndex	StdLCL	StdUCL	CV
1986	49	0.0816	1.0123	1.0607	0.2823	0.0885	0.8999	0.6320
1987	55	0.0727	1.9036	1.6500	0.4391	0.1375	1.4026	0.6333
1988	28	0.0000	0.0000					
1989	28	0.1429	1.7960	2.0644	0.5494	0.1757	1.7181	0.6198
1990	31	0.1936	1.6662	1.6729	0.4452	0.1713	1.1567	0.5060
1991	31	0.0968	1.4349	0.8076	0.2149	0.0588	0.7849	0.7220
1992	55	0.1273	0.9245	0.9528	0.2536	0.1025	0.6272	0.4771
1993	55	0.1273	1.3765	1.0116	0.2692	0.1088	0.6660	0.4772
1994	55	0.0727	1.0917	0.7416	0.1973	0.0619	0.6295	0.6324
1995	55	0.2364	3.0247	2.8520	0.7589	0.3928	1.4662	0.3384
1996	55	0.1636	1.8758	2.0067	0.5340	0.2407	1.1848	0.4148
1997	54	0.2593	3.1715	3.3526	0.8922	0.4743	1.6782	0.3240
1998								
1999	55	0.1455	1.1938	1.4300	0.3805	0.1635	0.8856	0.4419
2000	55	0.2727	5.4946	4.5804	1.2189	0.6566	2.2627	0.3169
2001	47	0.1489	3.4180	3.1821	0.8468	0.3455	2.0756	0.4718
2002	54	0.2222	2.5333	2.4186	0.6436	0.3251	1.2743	0.3517
2003	54	0.2963	6.2154	4.5353	1.2069	0.6713	2.1696	0.2997
2004	54	0.2222	2.4926	2.5736	0.6848	0.3422	1.3704	0.3575
2005								
2006	52	0.2308	5.0182	4.4871	1.1941	0.5997	2.3775	0.3548
2007	55	0.2909	3.4125	3.9348	1.0471	0.5844	1.8761	0.2979
2008								
2009	55	0.3091	4.1131	4.7935	1.2756	0.7222	2.2532	0.2903
2010	53	0.1509	1.5520	1.9576	0.5209	0.2240	1.2114	0.4415
2011	53	0.2453	8.2136	7.9067	2.1040	1.0946	4.0444	0.3357
2012	55	0.3091	7.7521	7.4400	1.9798	1.1195	3.5013	0.2910
2013	54	0.2963	3.1865	3.9595	1.0537	0.5866	1.8926	0.2992
2014	52	0.2692	7.0223	5.8265	1.5505	0.8282	2.9026	0.3214
2015								
2016	55	0.3455	15.1199	11.9410	3.1776	1.8757	5.3832	0.2682
2017	53	0.2264	3.3325	3.1520	0.8388	0.4232	1.6623	0.3522
2018	53	0.3396	7.2546	5.9857	1.5928	0.9236	2.7471	0.2777
2019	47	0.4681	13.0993	10.7012	2.8477	1.7785	4.5596	0.2387

Table 5. Summary of the final delta-lognormal models from the backward selection procedure for the western Gulf of Mexico (WGOM) and northeastern Gulf of Mexico (NEGOM) indices of abundance. Note: There was no delta-lognormal model generated for the eastern GOM.

Western Gulf of Mexico (WGOM)

	Binomial Submodel Type 3 Tests(AIC=1505.43)						*Lognormal Submodel Type 3 Tests (AIC=877.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	28	1448	69.17	2.47	<.0001	<.0001	28	298	2.08	0.0015
TOD	1	1448	43.56	43.56	<.0001	<.0001	1	298	34.02	<.0001
SUBREGION	1	1448	5.49	5.49	0.0192	0.0193	1	298	12.2	0.0006
DEPTH				Dropped					Dropped	

Northeastern Gulf of Mexico (NEGOM)

	Binomial Submodel Type 3 Tests(AIC=483.7)						*Lognormal Submodel Type 3 Tests (AIC=236.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	20	657	40.81	2.04	0.0039	0.0048	20	62	1.47	0.1267
TOD				Dropped					Dropped	
SUBREGION	1	657	26.42	26.42	<.0001	<.0001	1	62	8.75	0.0044
DEPTH				Dropped			1	62	4.82	0.0318

Table 6. SEAMAP Fall Plankton Survey index of northeastern Gulf of Mexico (NEGOM) larval Red Snapper age corrected abundance developed using the delta-lognormal (DL) model. The number of samples (N), proportion of positive occurrence (PPos), observed catch per unit effort (CPUA), the DL index (Index), the DL index scaled to a mean of one (StdIndex) for the time series, the lower and upper confidence limits (StdLCL and StdUCL) for the scaled index and the coefficient of variation of the mean (CV) are listed. Years with zero PPos represent true zero abundance for years with consistent spatial coverage. These years are not included in the delta-lognormal model

Year	N	PPos	CPUA	Index	StdIndex	StdLCL	StdUCL	CV
1986	27	0.0000	0.0000					
1987	30	0.0000	0.0000					
1988	13	0.0000	0.0000					
1989	15	0.0000	0.0000					
1990	19	0.0000	0.0000					
1991	18	0.0556	0.3445	0.2980	0.1256	0.0188	0.8397	1.2108
1992	35	0.0000	0.0000					
1993	30	0.0000	0.0000					
1994	35	0.0286	0.1052	0.0872	0.0367	0.0055	0.2472	1.2168
1995	32	0.0313	0.1561	0.1604	0.0676	0.0101	0.4543	1.2153
1996	35	0.0000	0.0000					
1997	33	0.0303	0.2458	0.2283	0.0962	0.0143	0.6469	1.2160
1998								
1999	35	0.0857	0.9206	0.9603	0.4048	0.1112	1.4728	0.7194
2000	35	0.1143	1.4998	2.3624	0.9957	0.3156	3.1413	0.6253
2001	33	0.0909	0.2782	0.4080	0.1720	0.0479	0.6176	0.7106
2002								
2003	33	0.1212	1.2343	1.1481	0.4839	0.1549	1.5121	0.6192
2004	33	0.0303	0.2959	0.4630	0.1951	0.0290	1.3141	1.2177
2005								
2006	34	0.0882	2.9798	1.6452	0.6934	0.1922	2.5023	0.7138
2007	35	0.1714	2.6791	2.3037	0.9710	0.3770	2.5010	0.5008
2008	26	0.0385	0.1296	0.2100	0.0885	0.0131	0.5965	1.2183
2009	35	0.0857	0.9971	1.2963	0.5464	0.1510	1.9772	0.7157
2010	34	0.2353	5.6567	7.0149	2.9566	1.3249	6.5981	0.4181
2011	35	0.0857	2.6785	2.5883	1.0909	0.2987	3.9840	0.7219
2012	29	0.1724	1.3390	2.2364	0.9426	0.3466	2.5632	0.5332
2013	34	0.1471	2.3158	2.2627	0.9537	0.3430	2.6519	0.5467
2014	33	0.1515	5.2290	3.8132	1.6072	0.5672	4.5537	0.5581
2015								
2016	35	0.2000	2.5962	2.6906	1.1340	0.4761	2.7008	0.4552
2017								
2018	33	0.2424	3.2116	4.7175	1.9883	0.8789	4.4982	0.4258
2019	29	0.4138	10.1764	12.9304	5.4499	2.9429	10.0924	0.3156

Table 7. SEAMAP Fall Plankton Survey index of eastern Gulf of Mexico (EGOM) larval Red Snapper proportion of positive occurrence (PPos) developed using a binomial model. The number of samples (N), observed PPos, the PPos index estimate (Index), the Index lower and upper confidence limits (LCL and UCL) and the coefficient of variation of the mean (CV). Years with zero PPos represent true zero abundance for years with consistent spatial coverage. These years are not included in the binomial model.

Year	N	NPos	PPos	Index	LCL	UCL	CV
1986	32	1	0.0313	0.0313	0.0042	0.1971	1.0005
1987	33	2	0.0606	0.0606	0.0148	0.2169	0.6966
1988	25	1	0.0400	0.0400	0.0054	0.2424	0.9959
1989	25	0	0.0000				
1990	20	0	0.0000				
1991	25	1	0.0400	0.0400	0.0054	0.2424	0.9959
1992							
1993	20	0	0.0000				
1994	32	0	0.0000				
1995	32	1	0.0313	0.0313	0.0042	0.1971	1.0005
1996	27	0	0.0000				
1997	31	1	0.0323	0.0323	0.0044	0.2025	0.9999
1998							
1999	27	0	0.0000				
2000	24	0	0.0000				
2001	32	0	0.0000				
2002	27	2	0.0741	0.0741	0.0181	0.2577	0.6916
2003	33	0	0.0000				
2004							
2005							
2006	25	0	0.0000				
2007	33	0	0.0000				
2008							
2009	32	3	0.0938	0.0938	0.0299	0.2578	0.5587
2010	33	1	0.0303	0.0303	0.0041	0.1919	1.0009
2011	33	7	0.2121	0.2121	0.1032	0.3866	0.3410
2012	33	2	0.0606	0.0606	0.0148	0.2169	0.6966
2013	33	1	0.0303	0.0303	0.0041	0.1919	1.0009
2014	31	1	0.0323	0.0323	0.0044	0.2025	0.9999
2015							
2016	33	3	0.0909	0.0909	0.0290	0.2510	0.5595
2017							
2018	33	2	0.0606	0.0606	0.0148	0.2169	0.6966
2019	32	3	0.0938	0.0938	0.0299	0.2578	0.5587

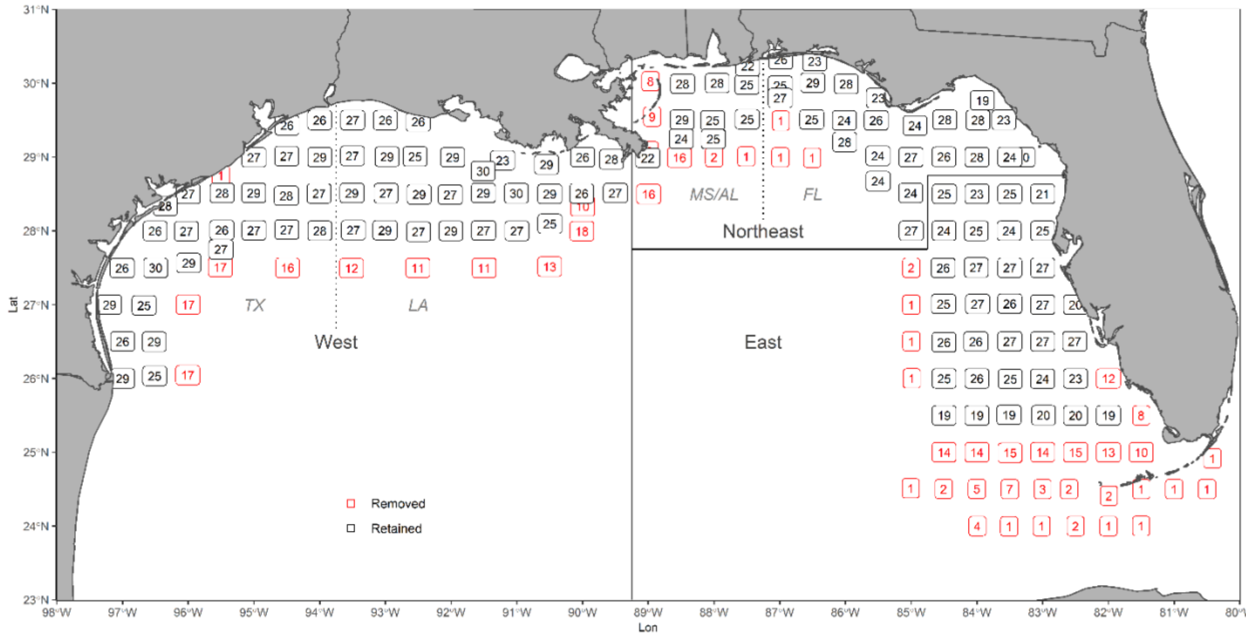


Figure 1. Number of primary bongo net samples taken at each SEAMAP B-Number location during SEAMAP Fall Plankton Surveys 1986 to 2019 with consistent spatial coverage respective to the western (WGOM), northeastern (NEGOM) and eastern (EGOM) Gulf of Mexico. Only locations with primary samples equal to or exceeding 20 were included in the WGOM, only locations with primary samples equal to or exceeding 19 were included in the NEGOM, and only locations with primary samples equal to or exceeding 18 were included in the EGOM. Solid lines indicate spatial breaks of the western, northeastern and eastern Gulf of Mexico. Vertical dotted lines indicate spatial breaks of the Texas (TX) and Louisiana (LA) subregions within the WGOM and the Mississippi/Alabama (MS/AL) and Florida (FL) subregions of the NEGOM.

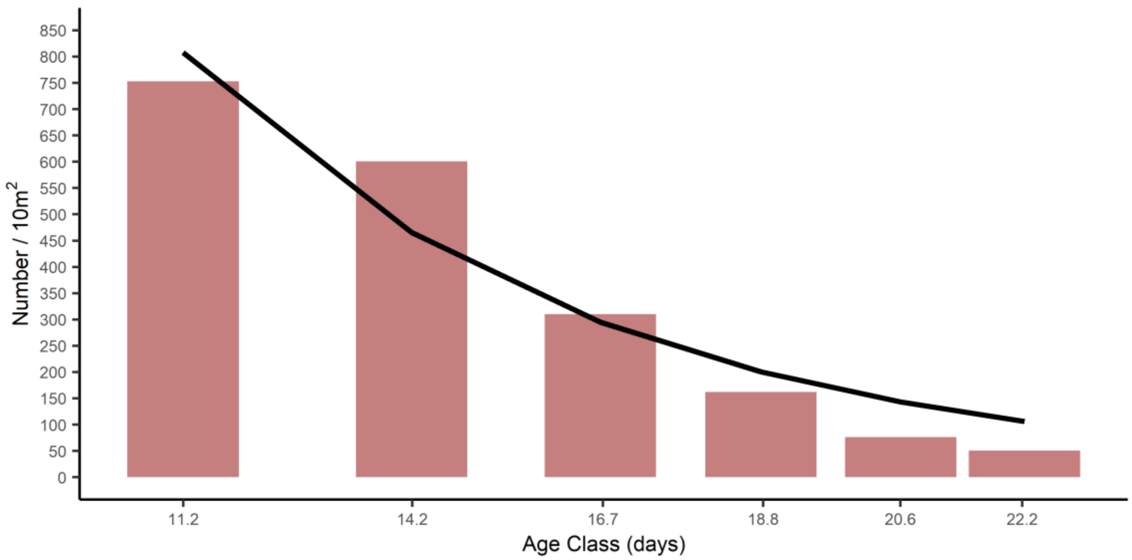


Figure 2. Age distribution (age at size class midpoint) of larval Red Snapper catch and the resulting daily loss rate curve (Z = -0.1841).

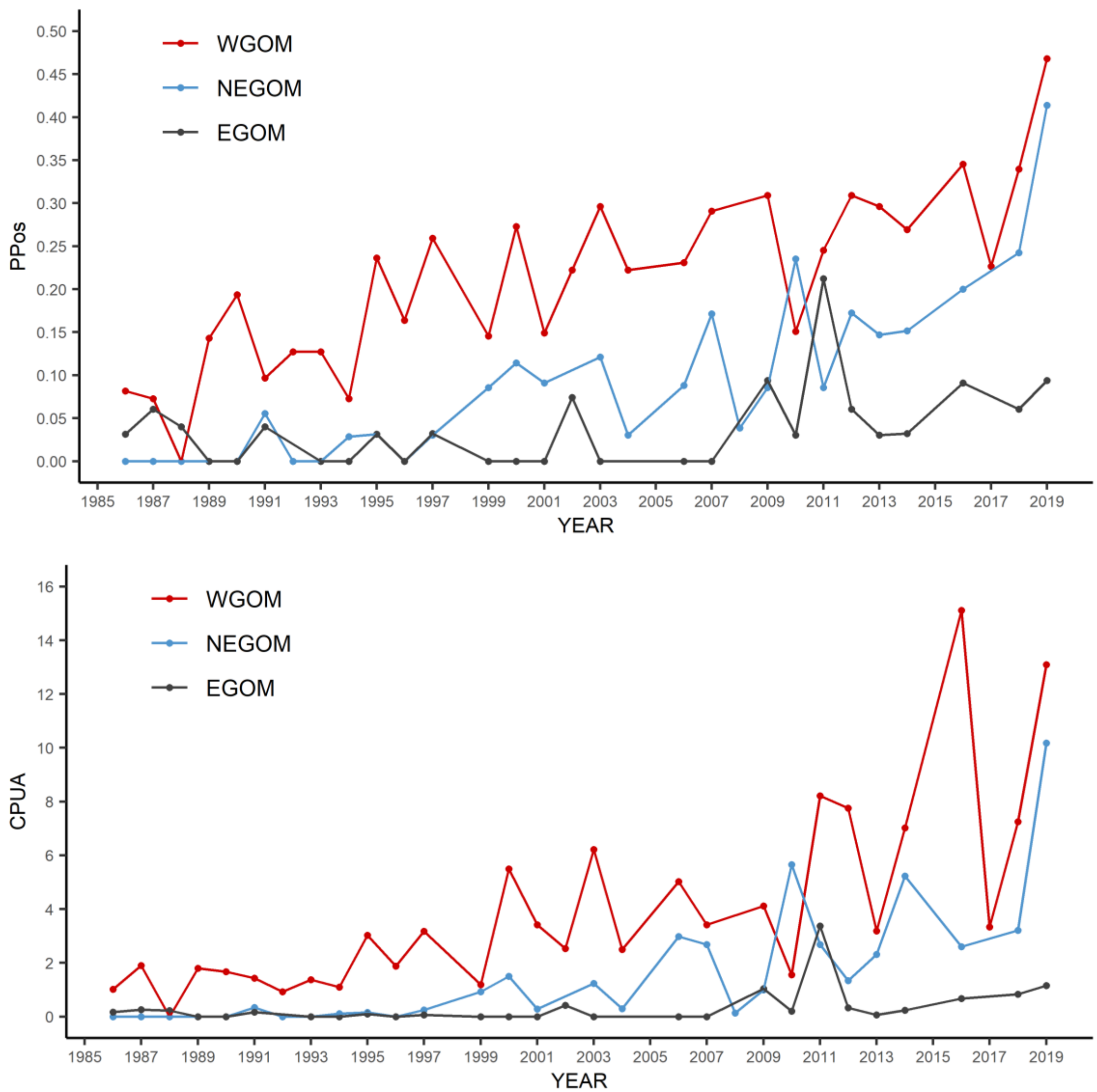


Figure 3. Nominal proportion of positive occurrence (PPos, top) and age corrected catch per unit area (CPUA, bottom) for the western (WGOM), northeastern (NEGOM) and eastern (EGOM) Gulf of Mexico.

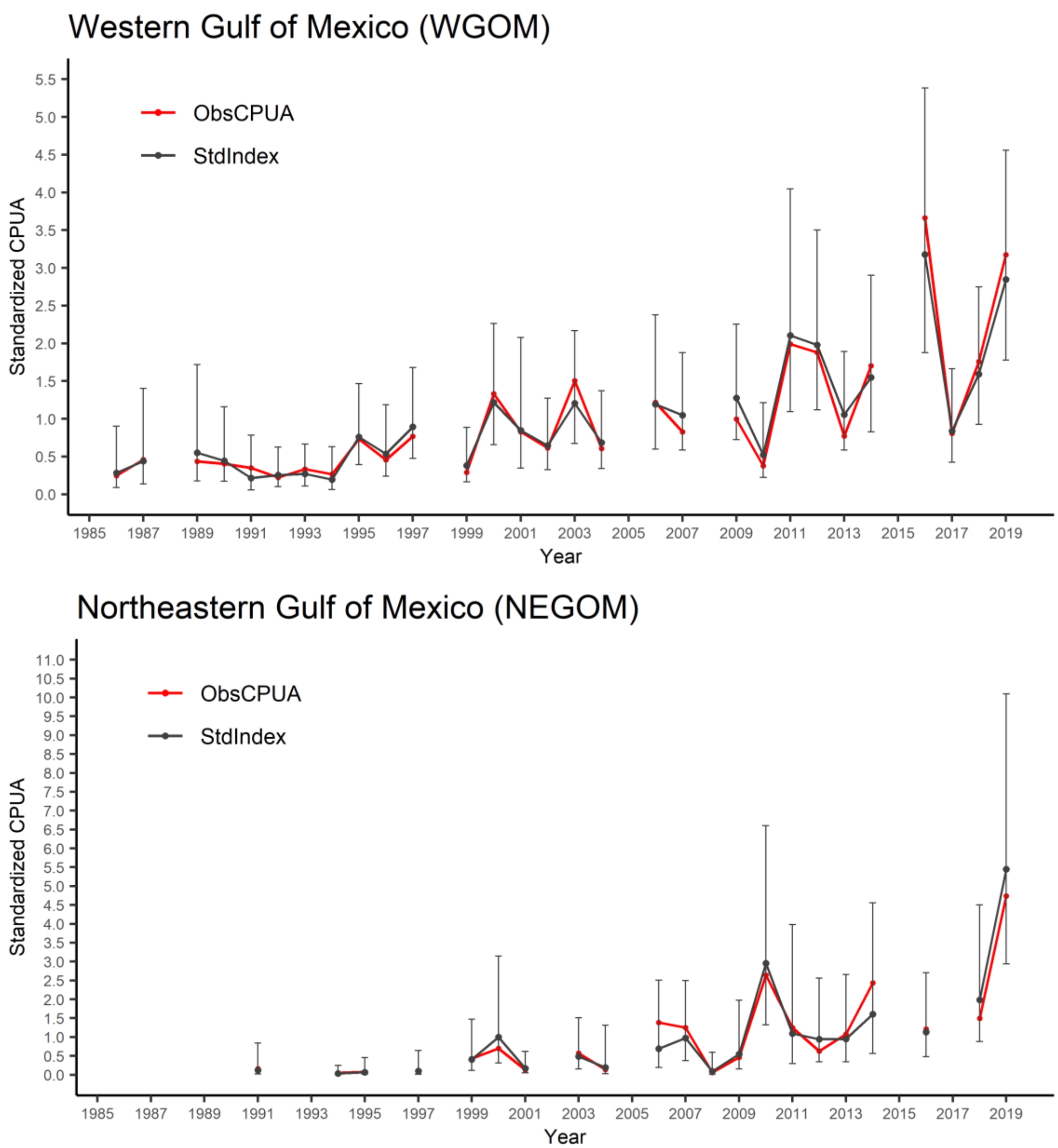
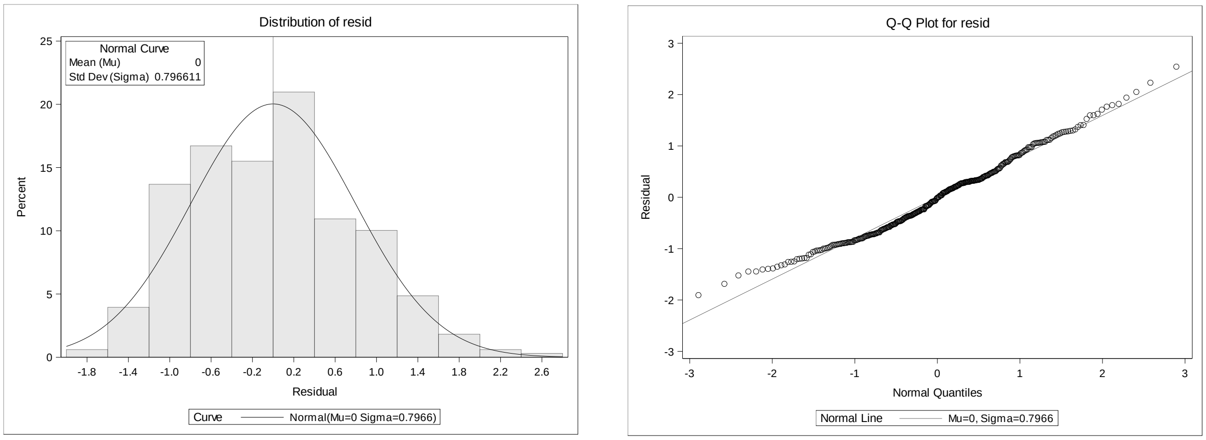


Figure 4. Annual index of larval Red Snapper age corrected abundance from SEAMAP Fall Plankton Surveys from 1986 to 2019 for the western (WGOM) and northeastern (NEGOM) Gulf of Mexico.

Western Gulf of Mexico (WGOM)



Northeastern Gulf of Mexico (NEGOM)

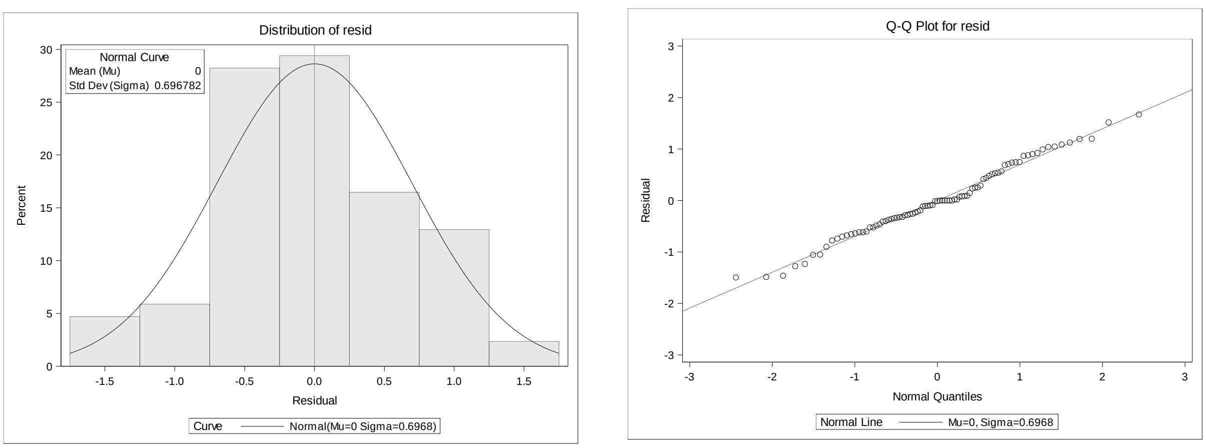
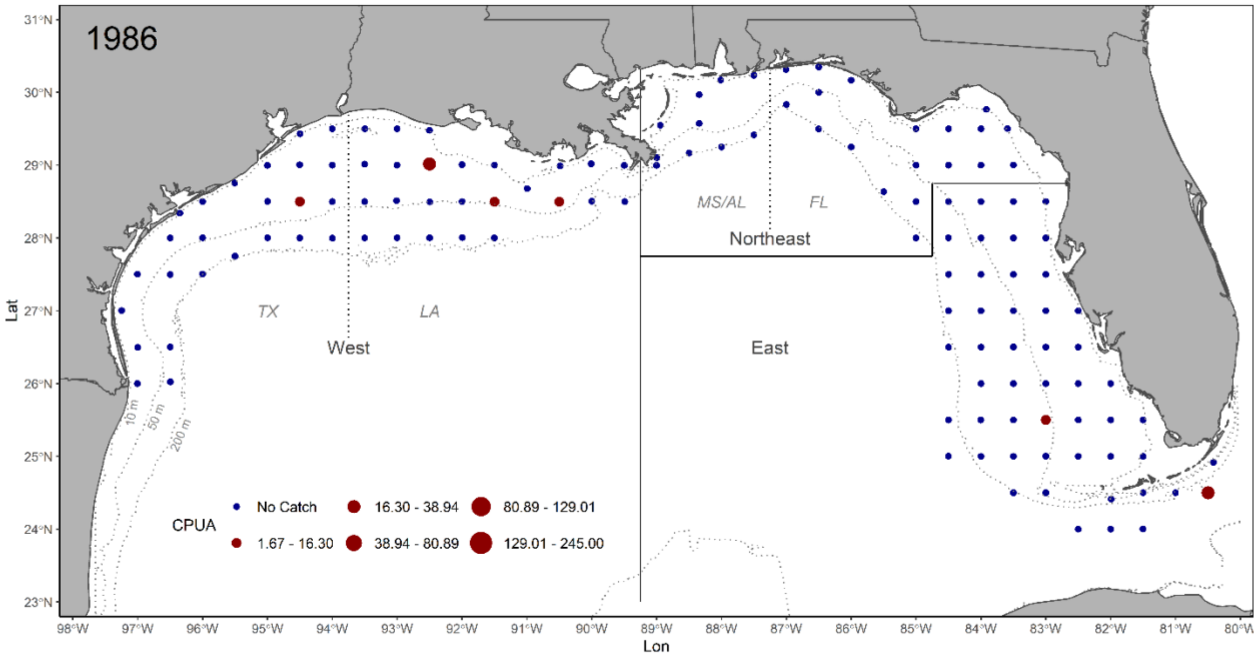
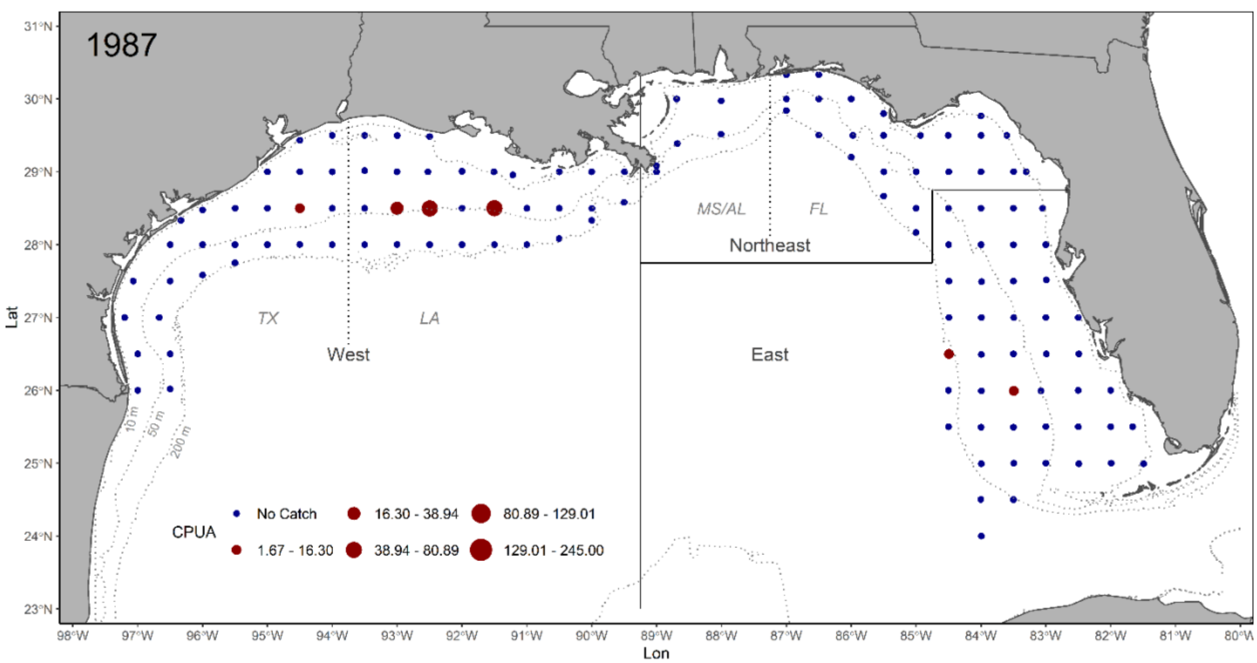
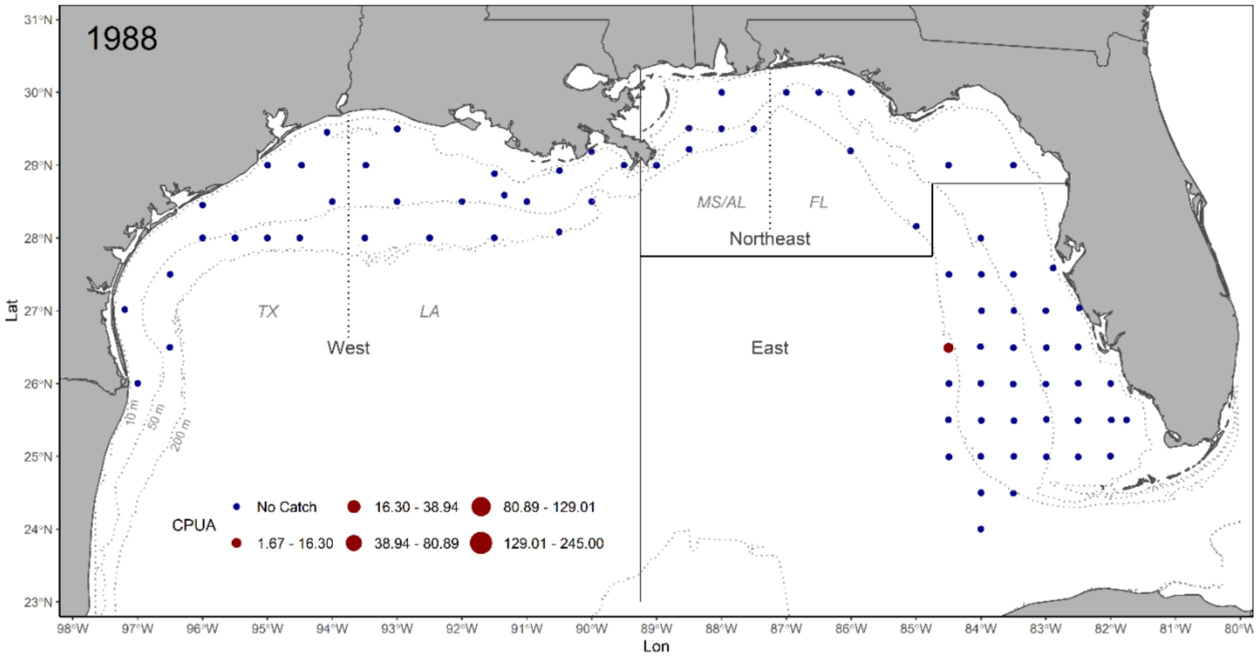


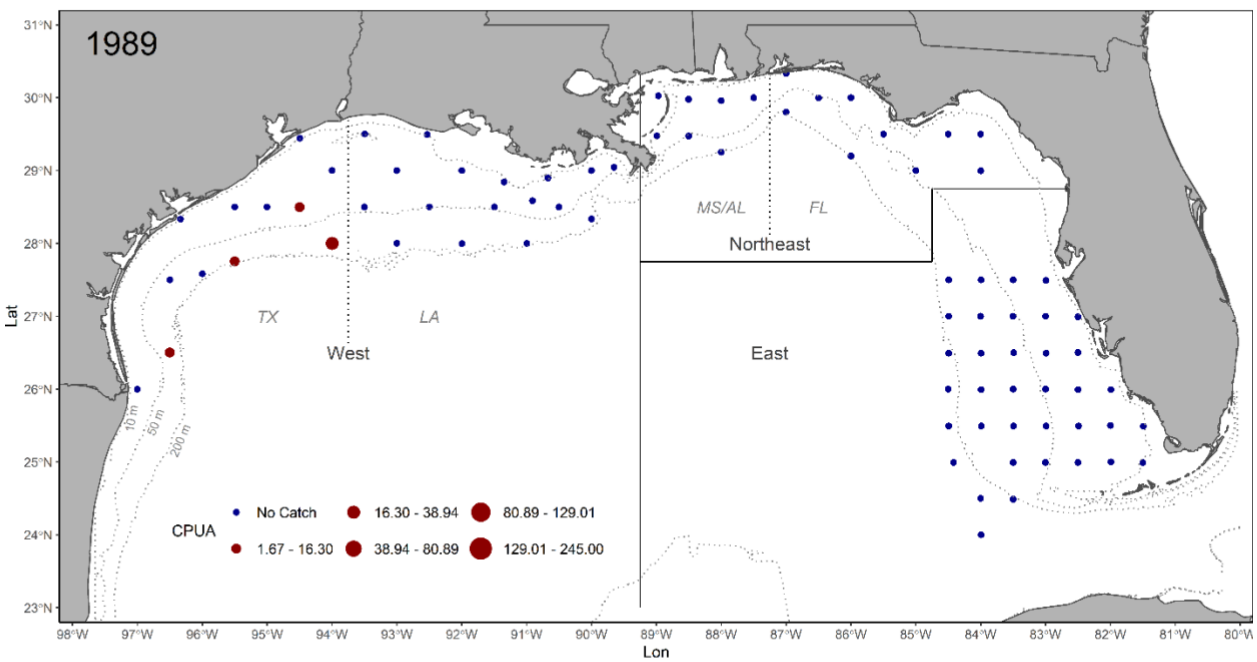
Figure 5. Diagnostic plots for the lognormal submodels of the western (WGOM, top) and northeastern (NEGOM, bottom) indices of abundance: Left column shows the frequency distribution of log (CPUA) on positive stations and the right column the cumulative normalized residuals (QQ plot).

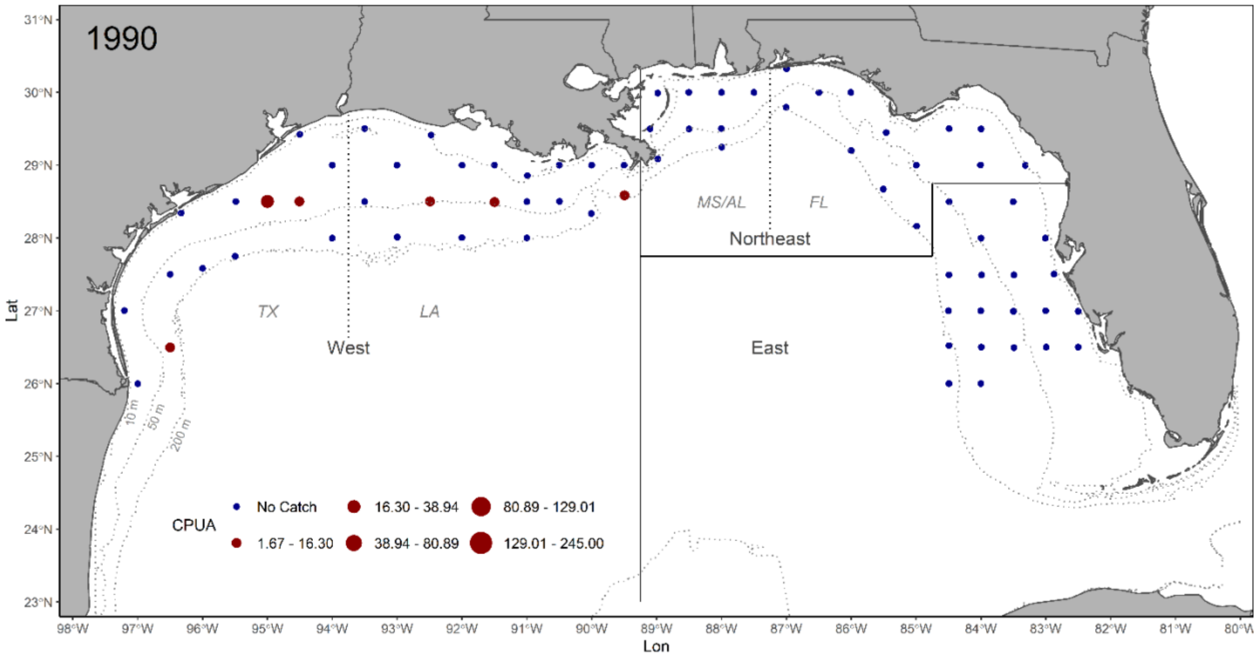
Appendix Figure 1. Annual survey effort and nominal catch per unit area (CPUA) of Red Snapper from the SEAMAP Fall Plankton Survey conducted from 1986-2019. CPUA is expressed as the number of 11.2 day old larvae under 10 m^2. Solid lines indicate spatial breaks of the western, northeastern and eastern Gulf of Mexico. Vertical dotted lines indicate spatial breaks of the Texas (TX) and Louisiana (LA) subregions within the western Gulf of Mexico and the Mississippi/Alabama (MS/AL) and Florida (FL) subregions of the northeastern Gulf of Mexico. The 10m, 50m and 200m depth contours are includes for reference.






1988
Lat
Lon
West
East
Northeast
TX
LA
MS/AL
FL
10 m
50 m
200 m
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00


1989
Lat
Lon
West
East
Northeast
TX
LA
MS/AL
FL
10 m
50 m
200 m
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00



1990
West
East
Northeast
TX
LA
MS/AL
FL
10 m
50 m
200 m
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
Lat
Lon
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
98°W
97°W
96°W
95°W
94°W
93°W
92°W
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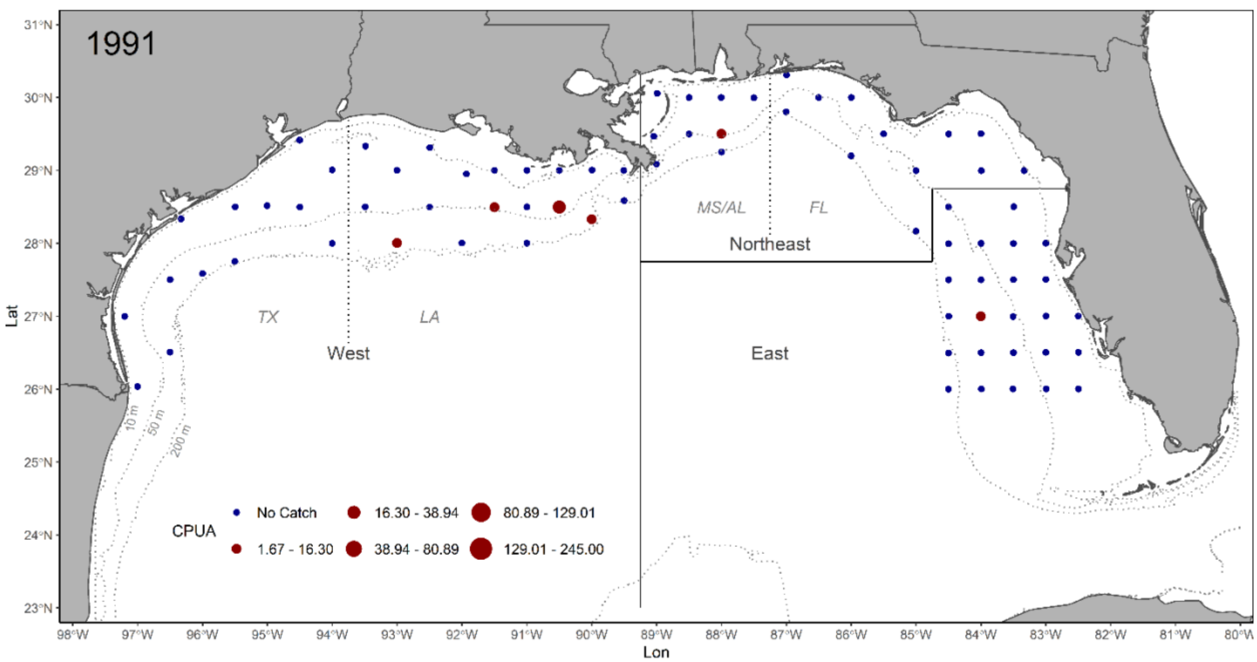
82°W
81°W
80°W



1991
West
East
Northeast
TX
LA
MS/AL
FL
10 m
50 m
200 m
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
Lat
Lon
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
98°W
97°W
96°W
95°W
94°W
93°W
92°W
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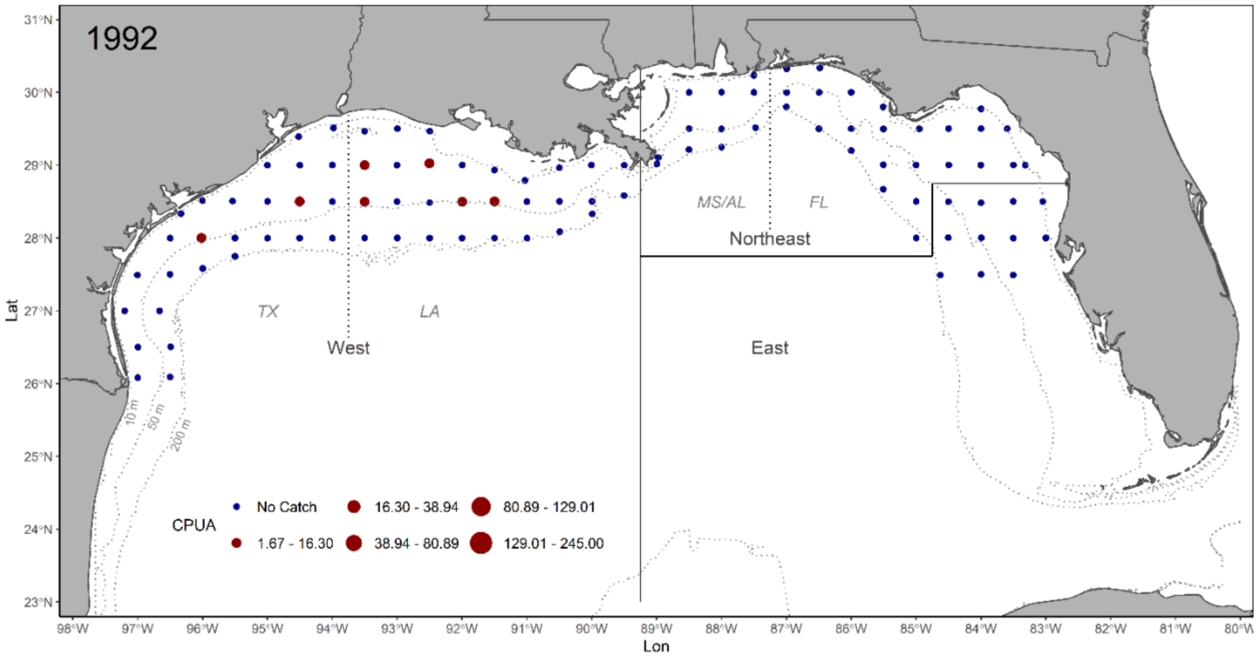
82°W
81°W
80°W


1992
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
TX
LA
MS/AL
FL
West
East
Northeast
10 m
50 m
200 m
Lat
Lon
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
98°W
97°W
96°W
95°W
94°W
93°W
92°W
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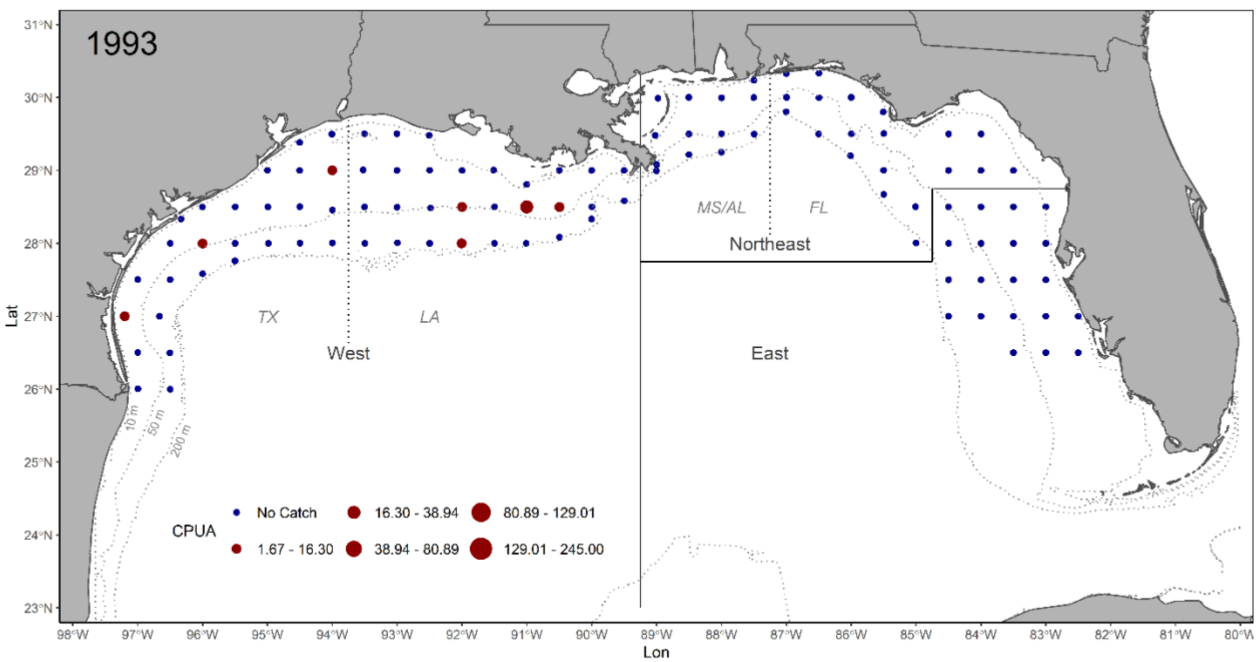
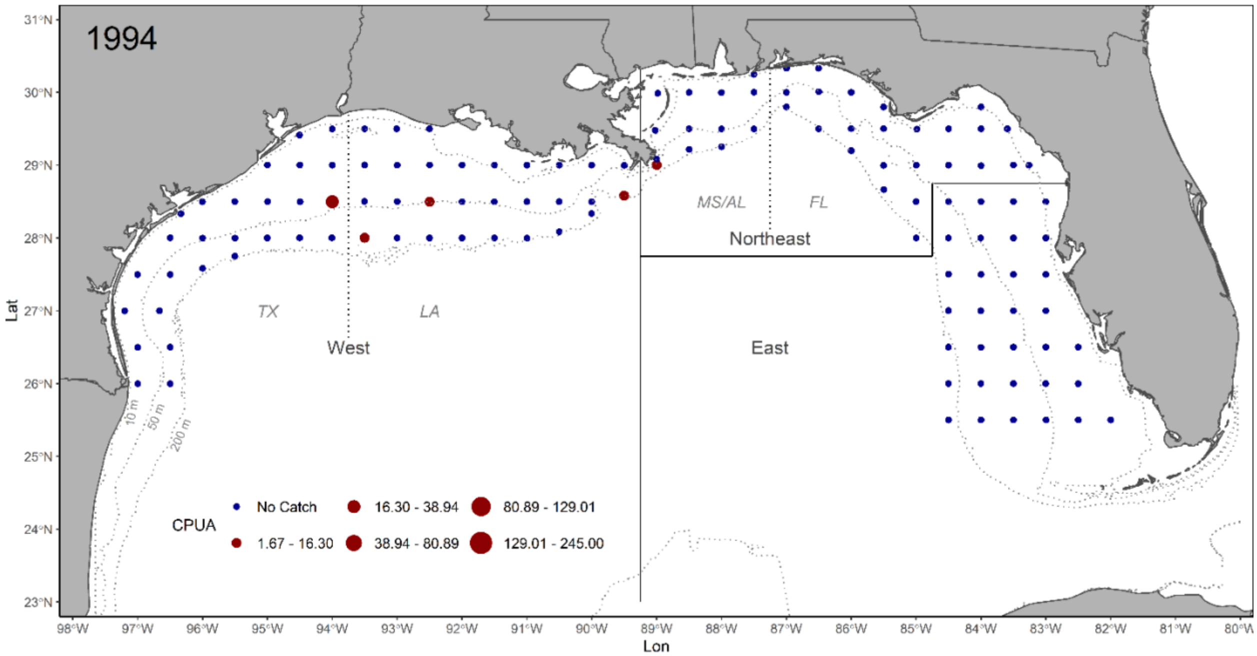
82°W
81°W
80°W


1993
CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
TX
LA
MS/AL
FL
West
East
Northeast
10 m
50 m
200 m
Lat
Lon
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
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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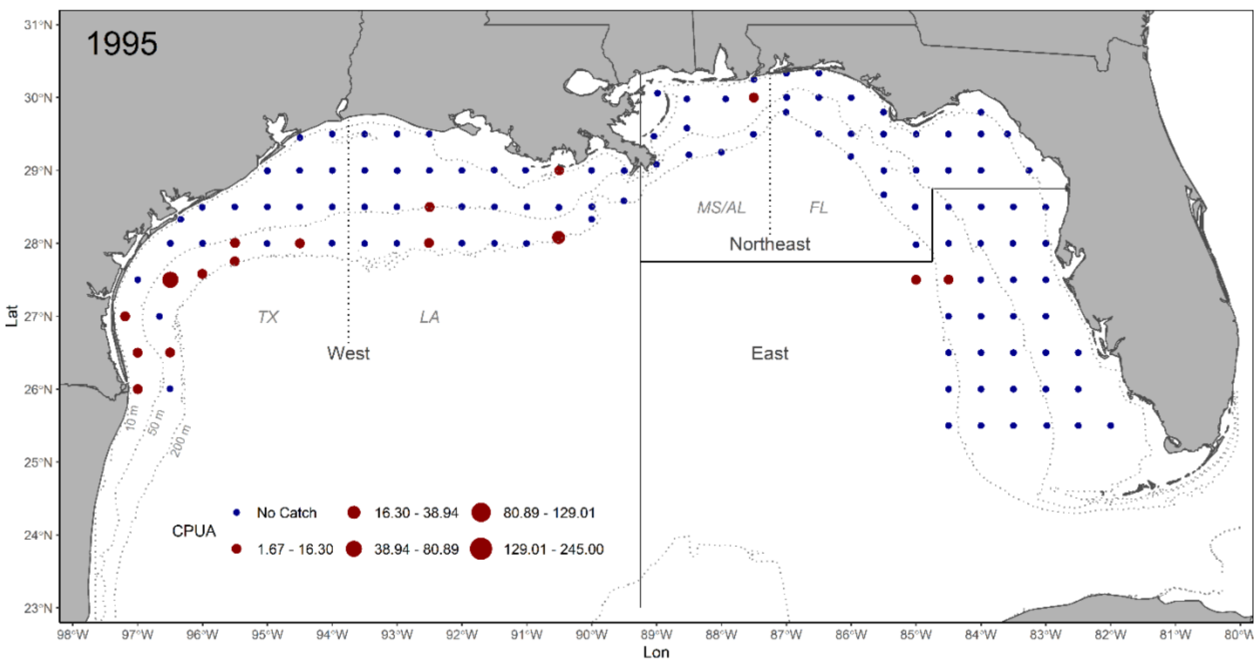
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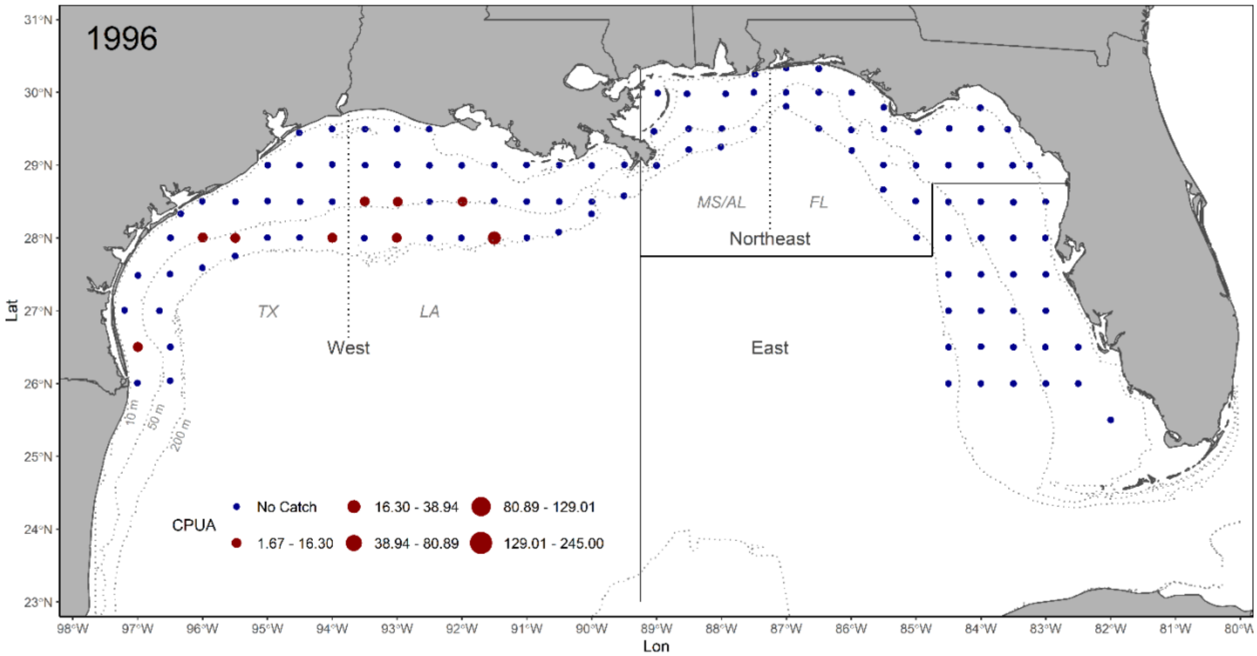
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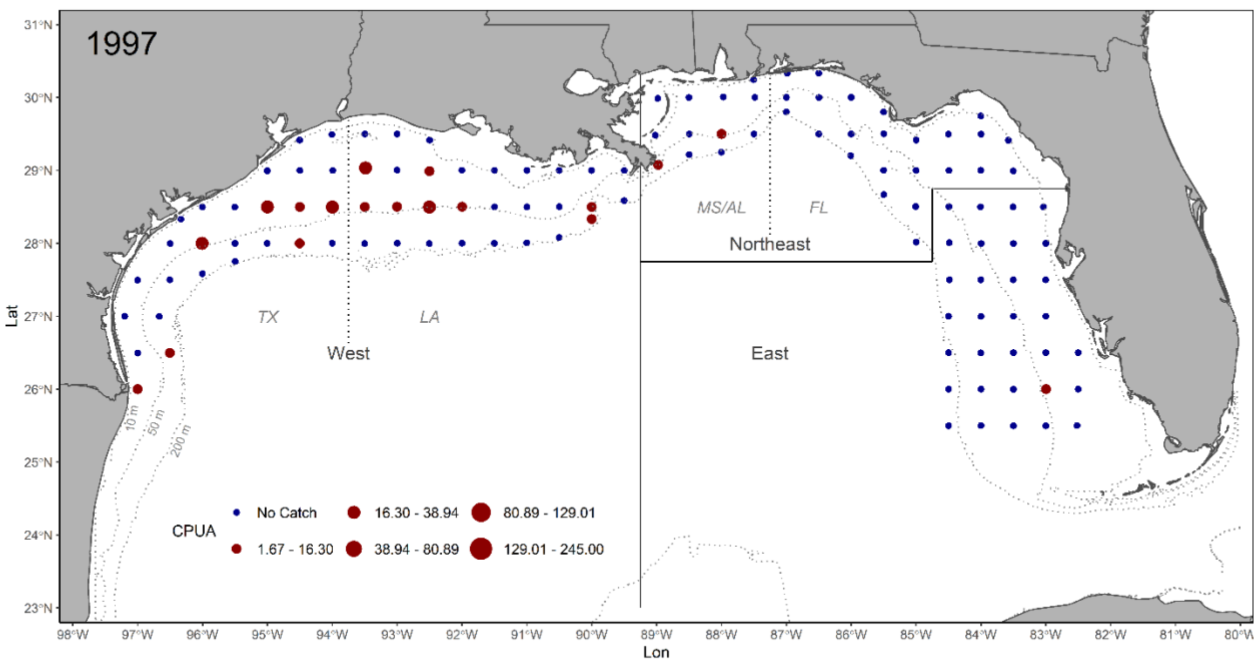
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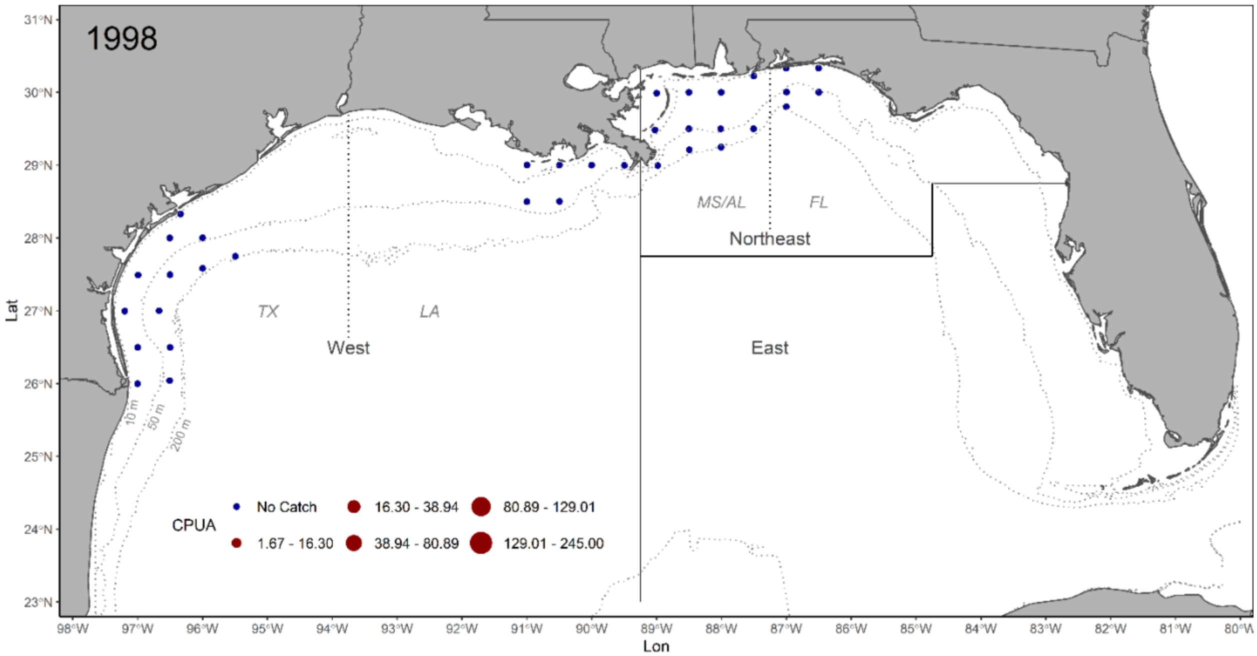
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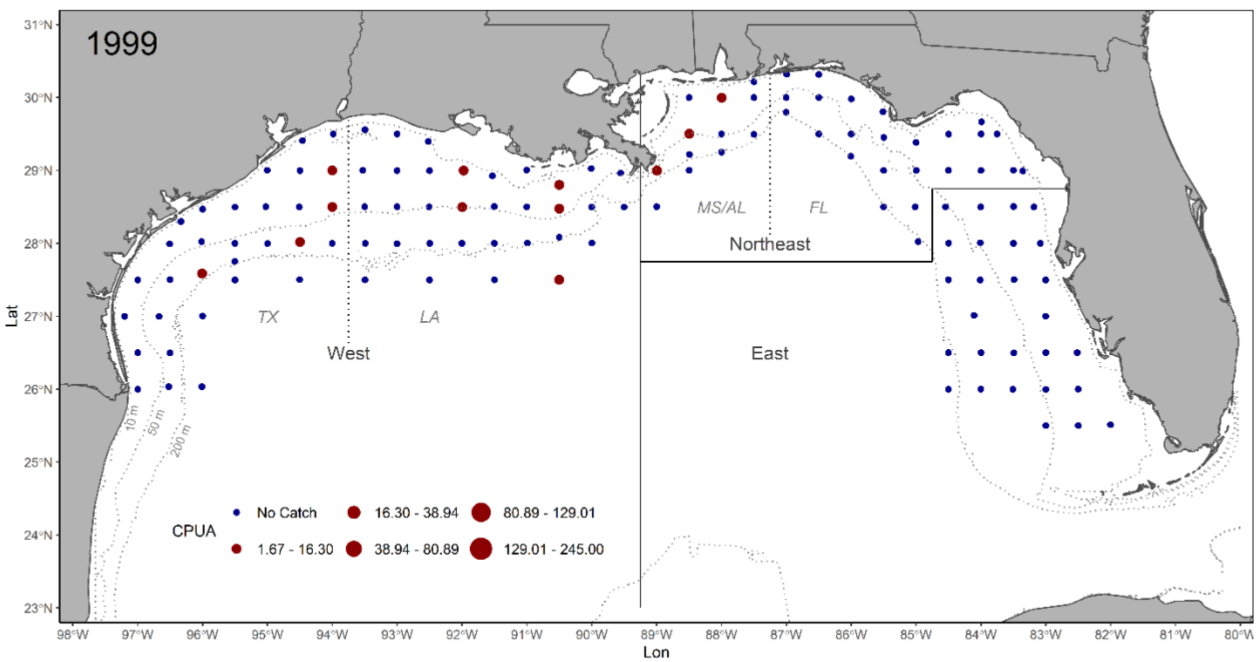
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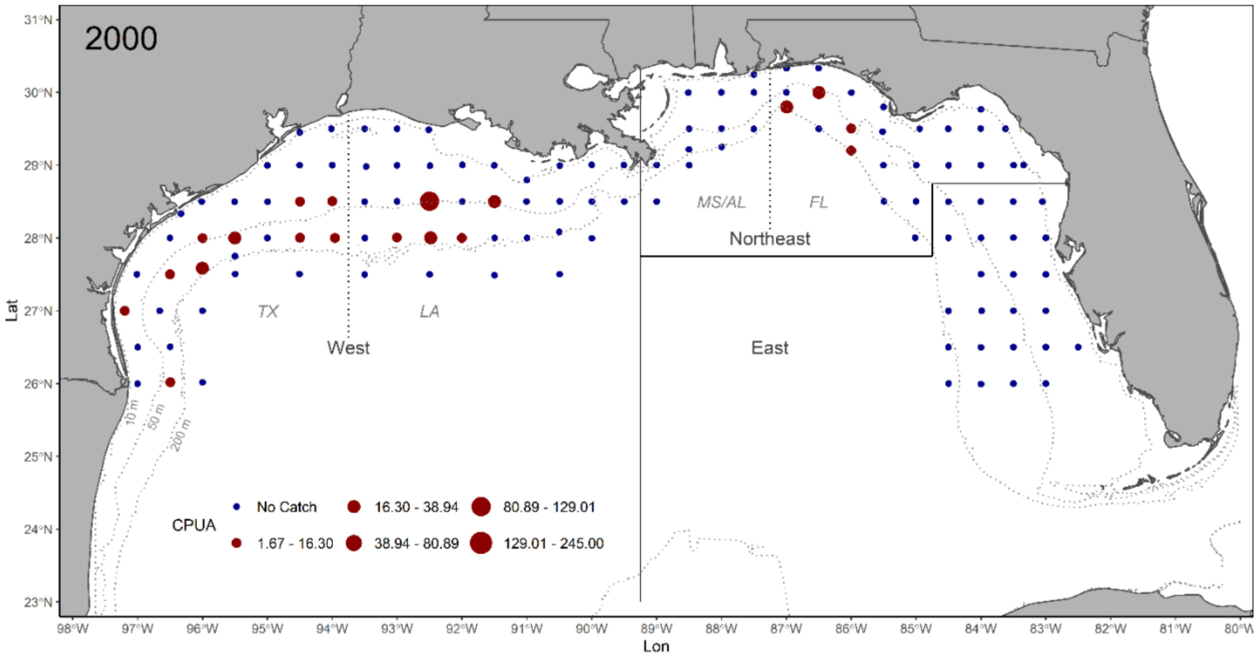
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129.01 - 245.00
Lat
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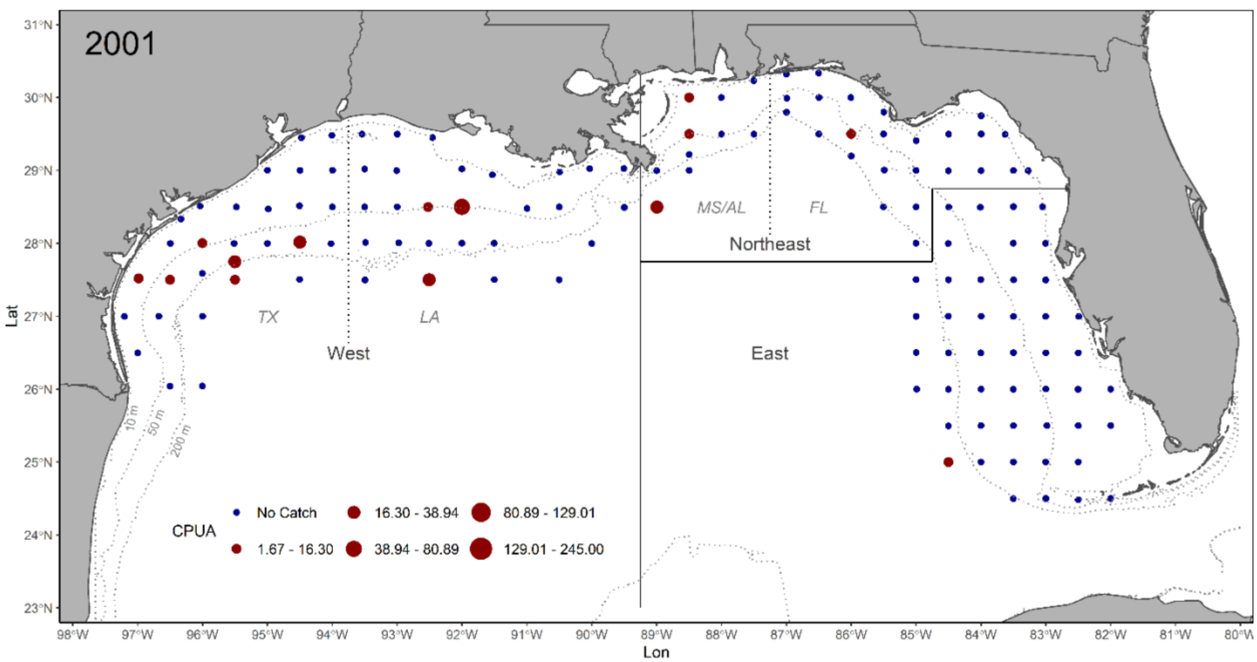
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Lat
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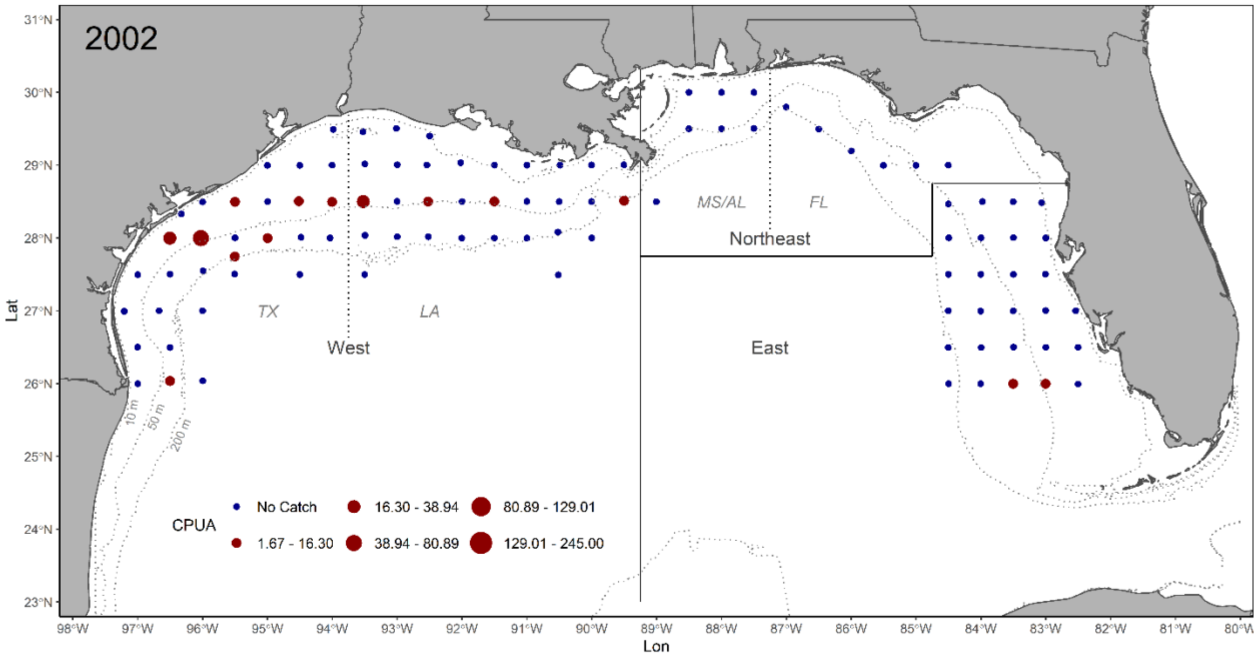
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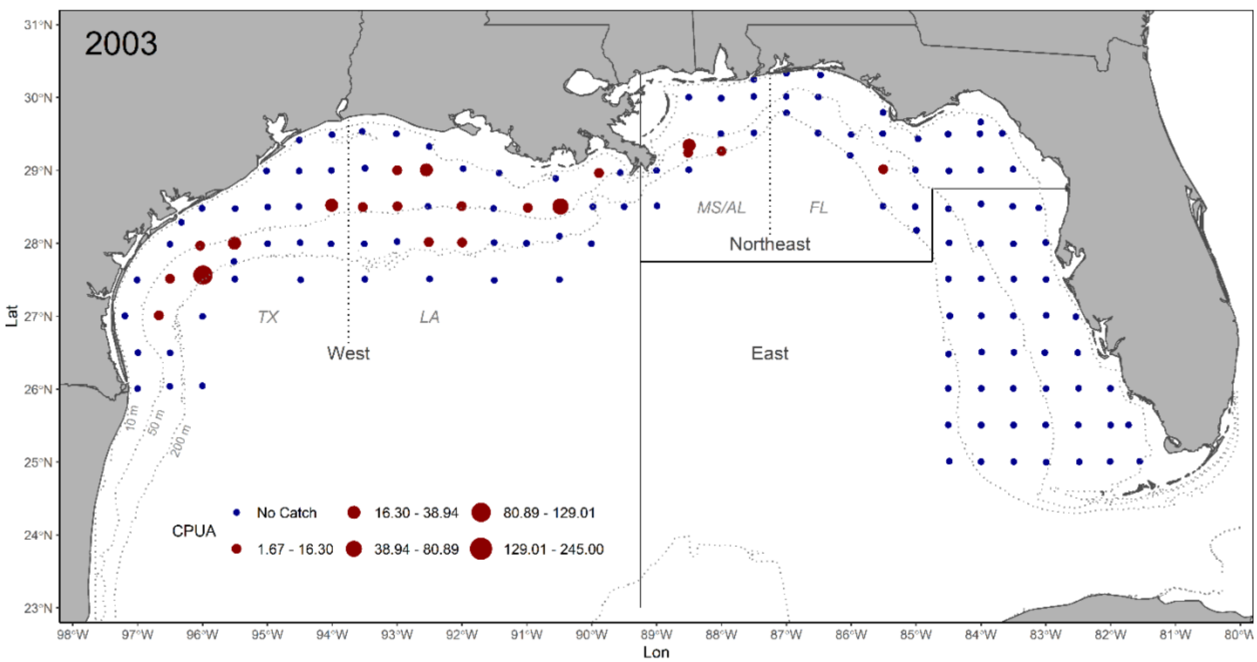
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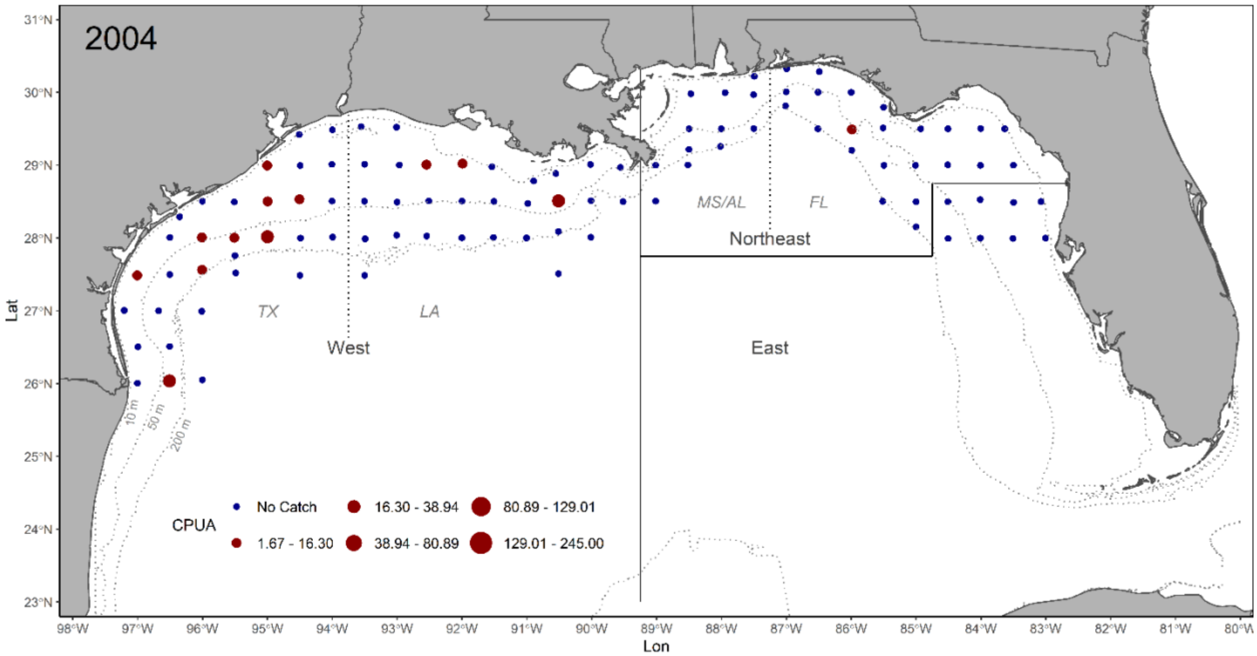
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Northeast
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East
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200 m
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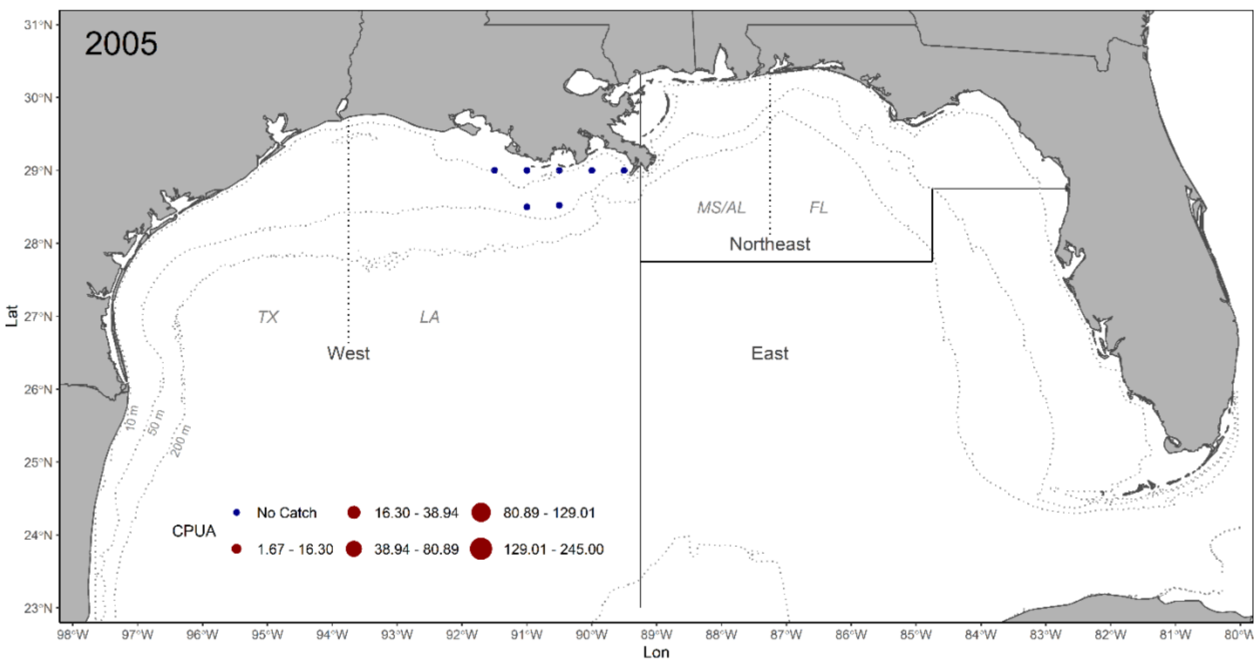
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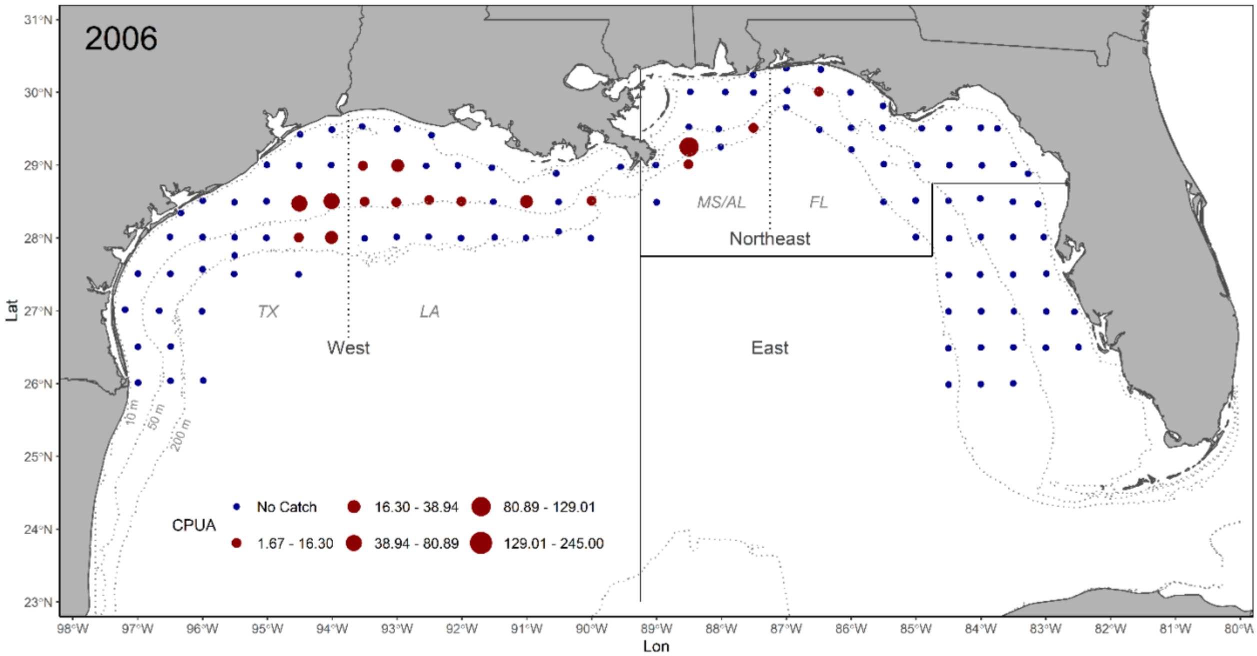
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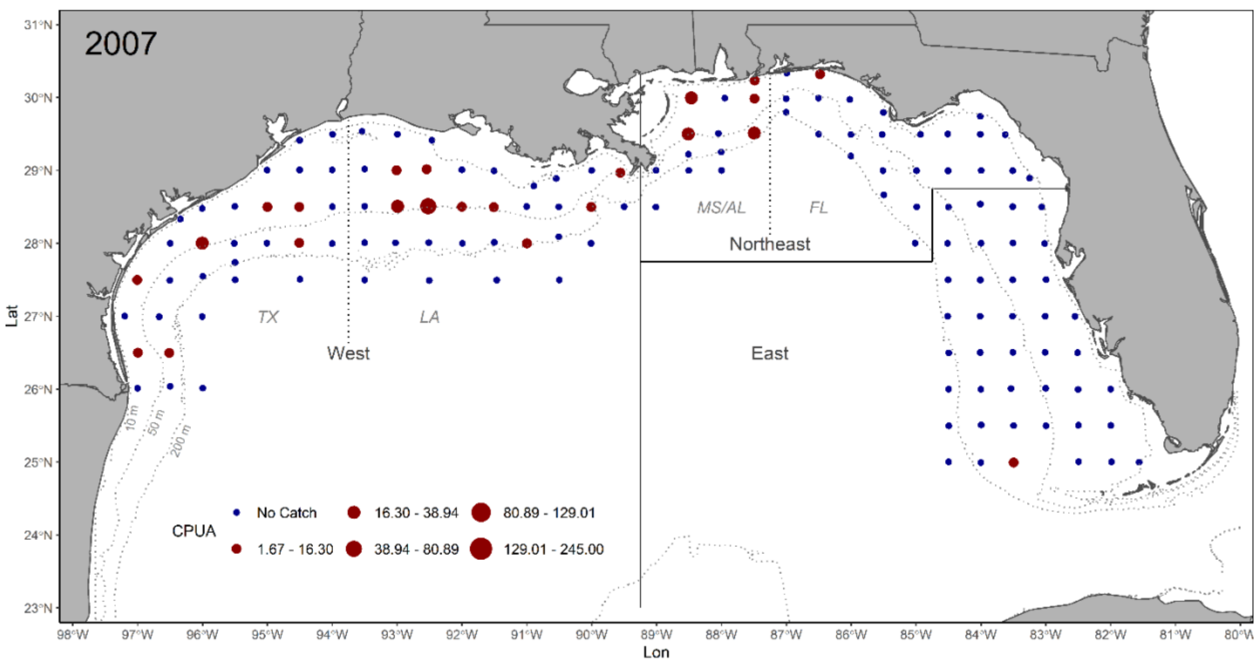
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10 m
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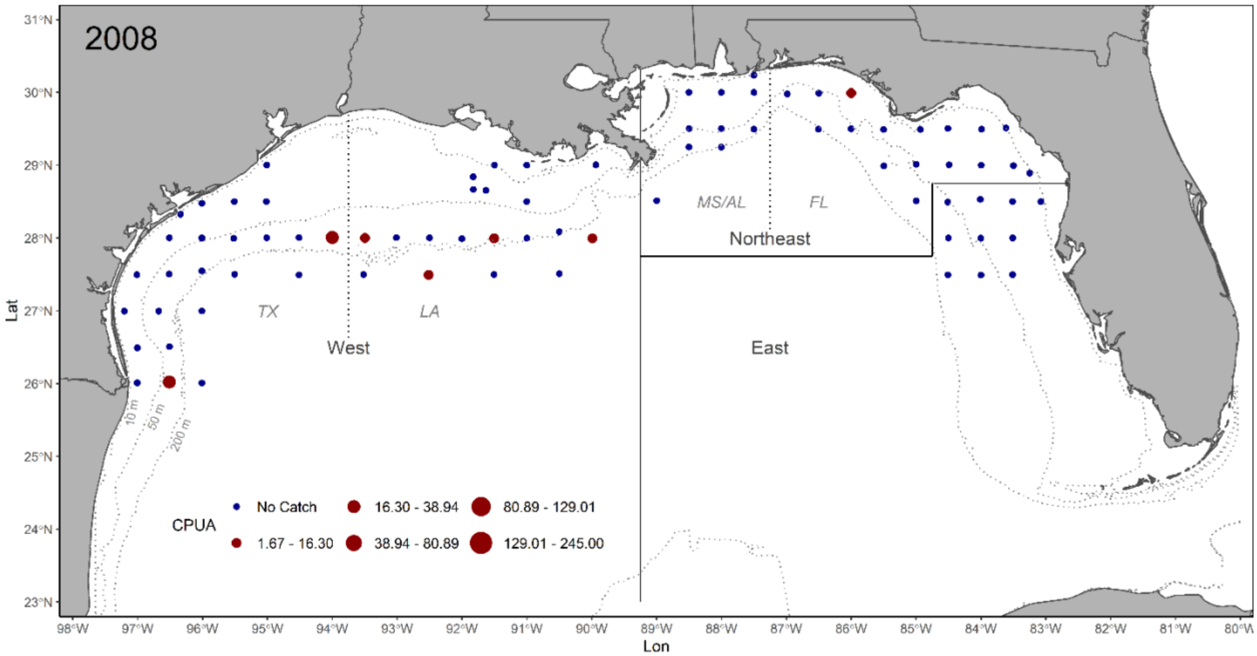

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FL
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East
CPUA
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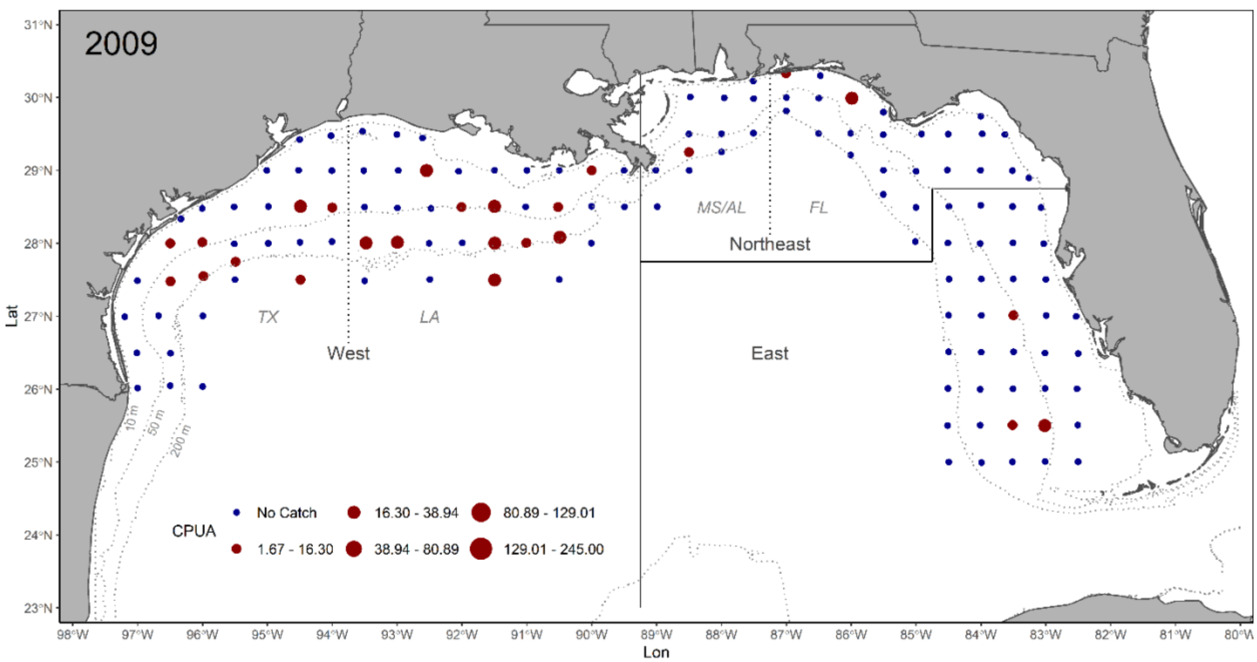

2009
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MS/AL
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Northeast
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CPUA
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Lat
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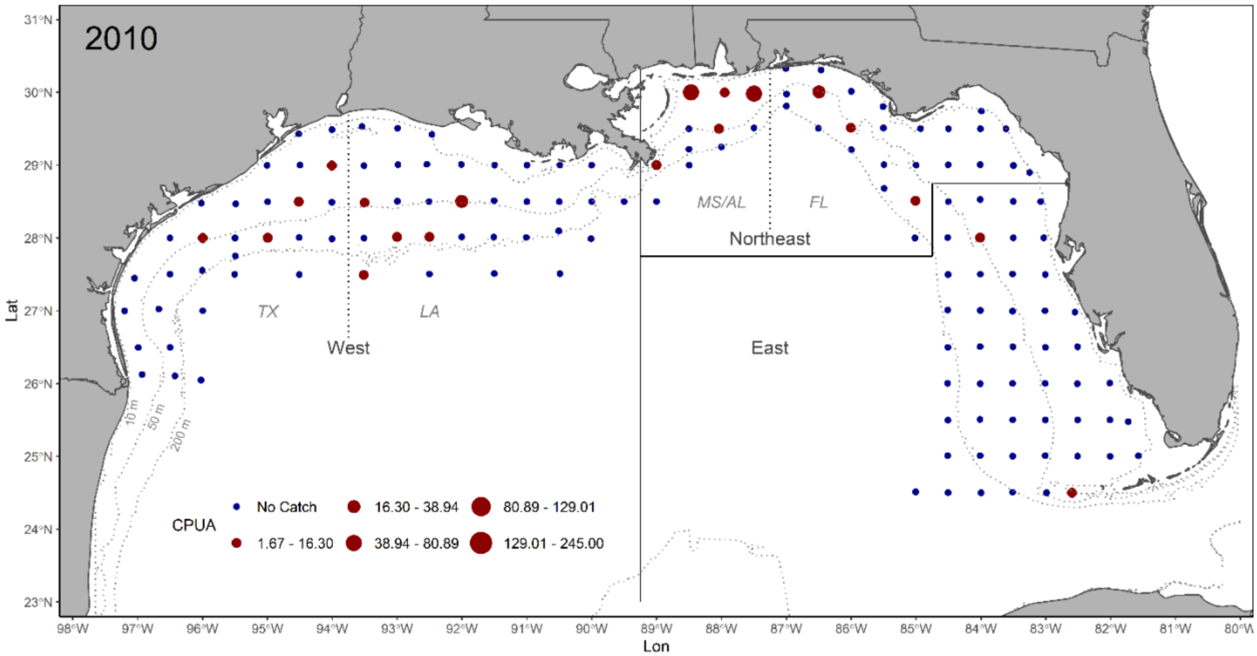

2010
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MS/AL
FL
10 m
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200 m
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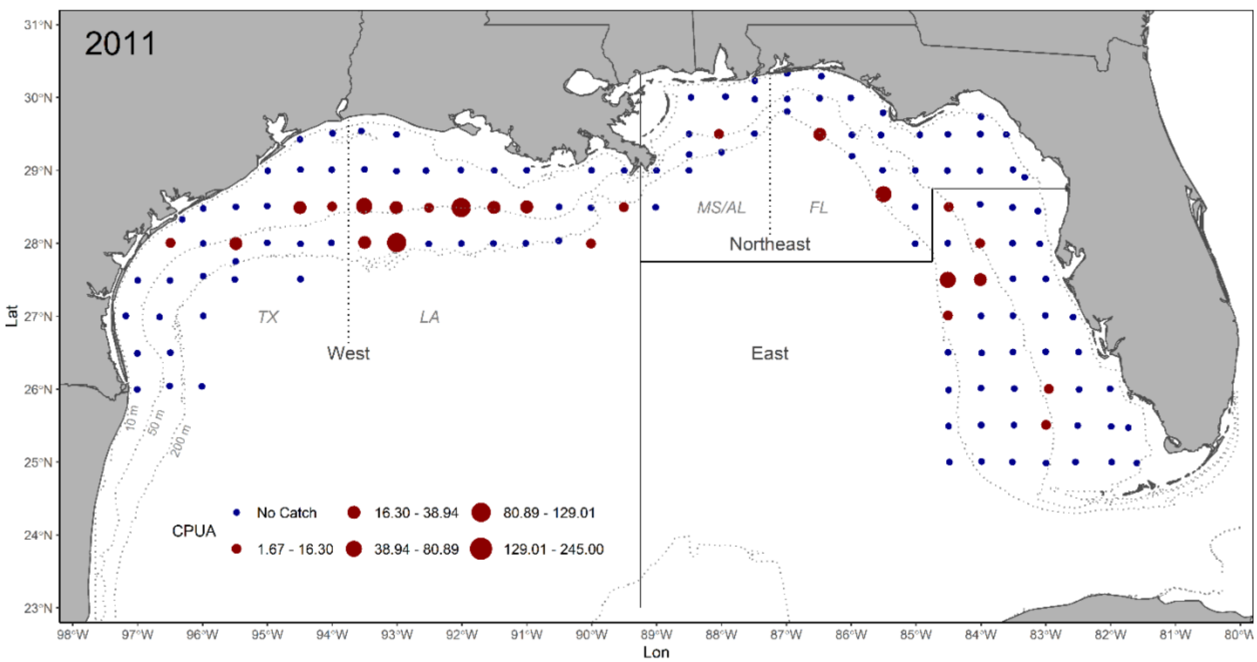

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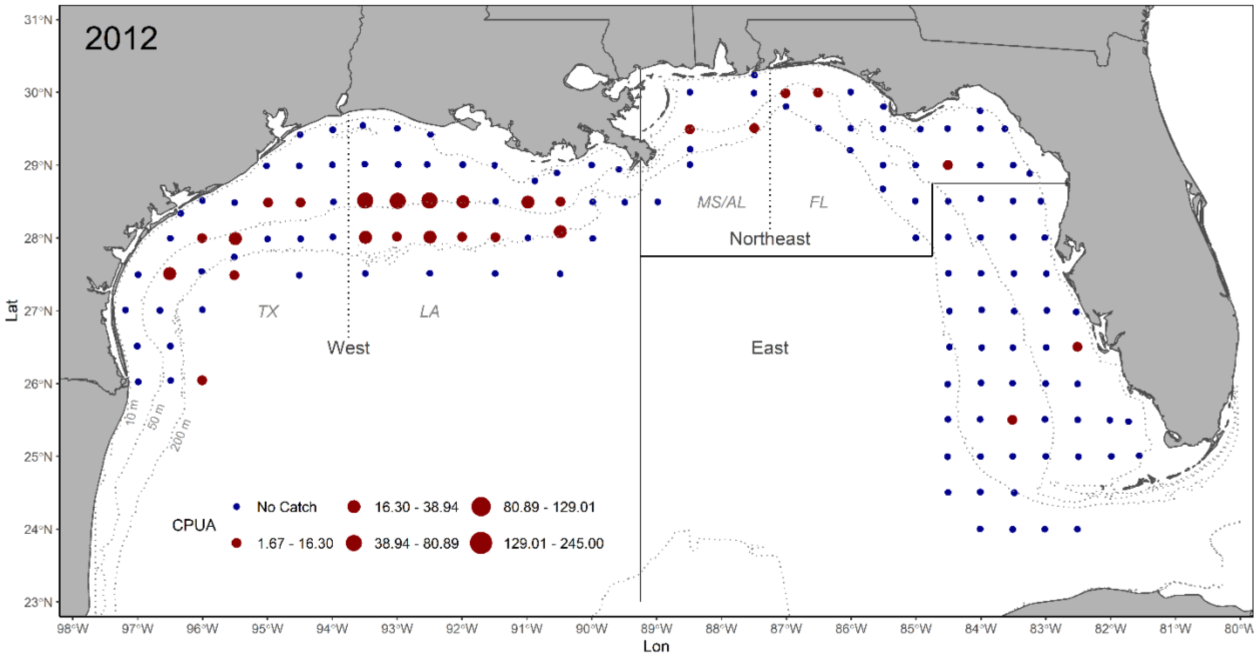
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MS/AL
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East
CPUA
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Lat
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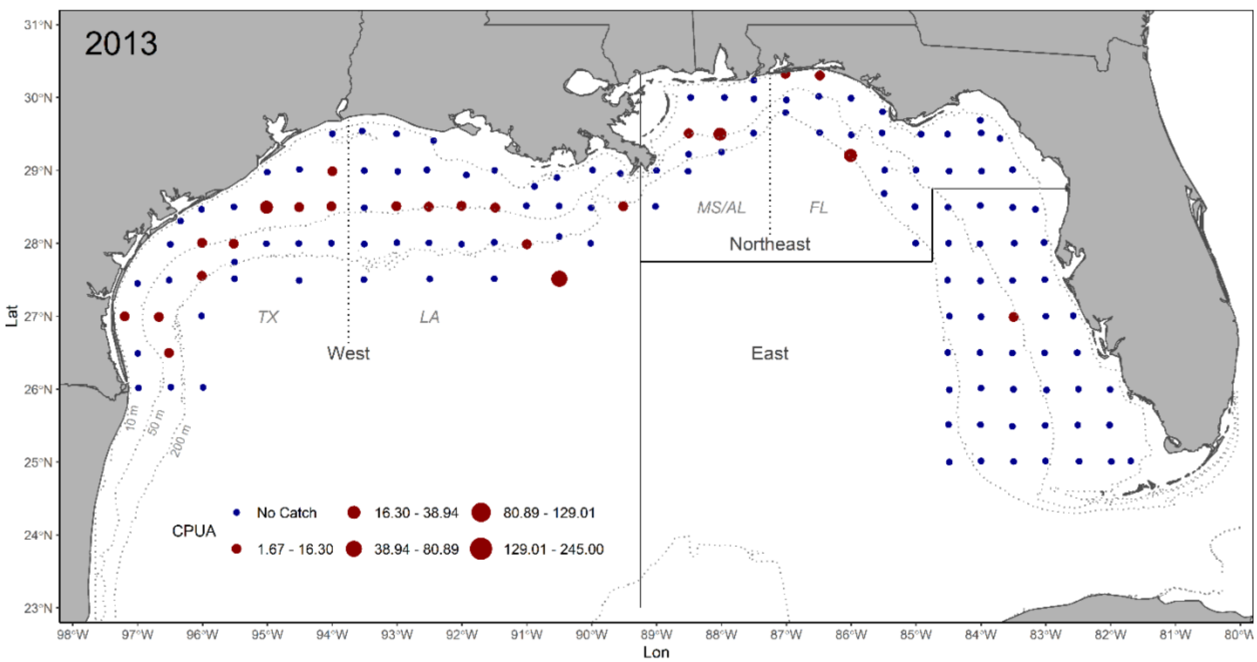
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MS/AL
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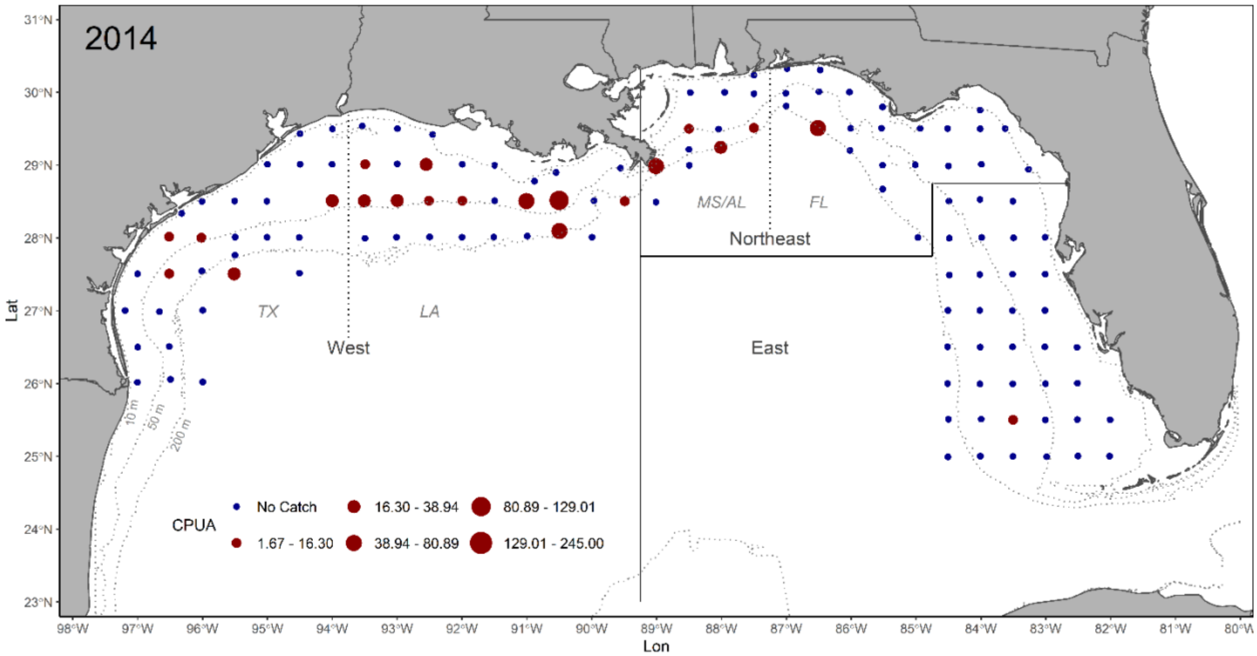

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East
CPUA
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80.89 - 129.01
129.01 - 245.00
10 m
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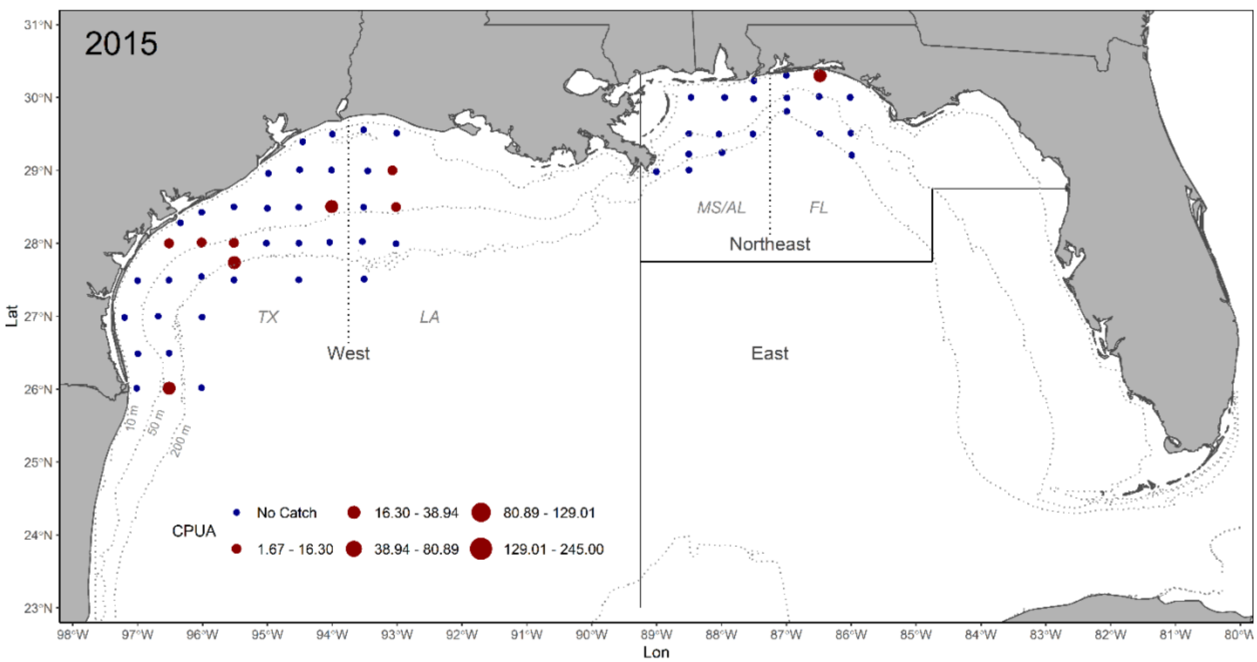

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CPUA
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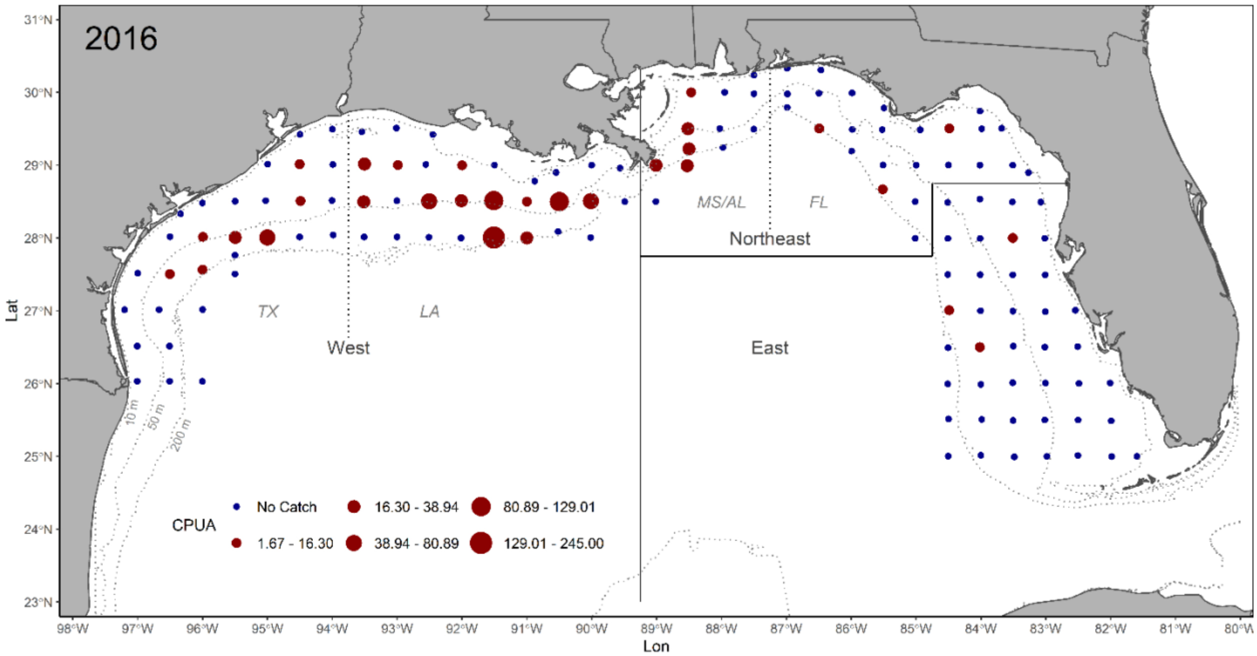
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MS/AL
FL
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50 m
200 m
CPUA
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16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
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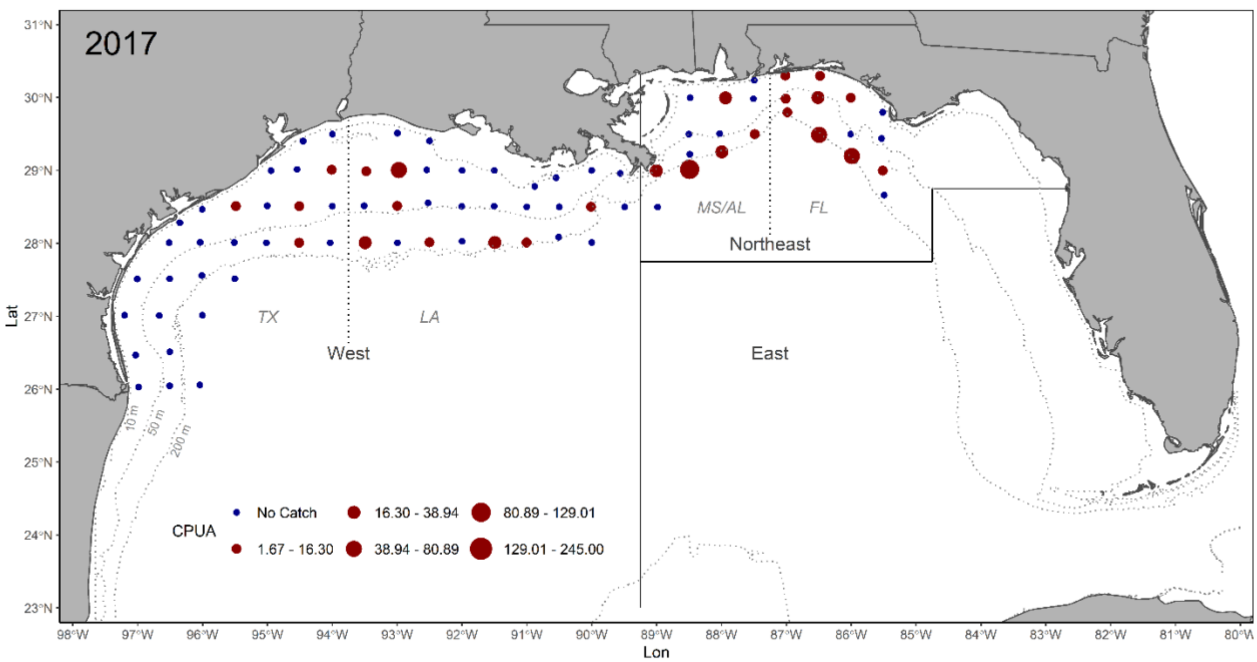
2017
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CPUA
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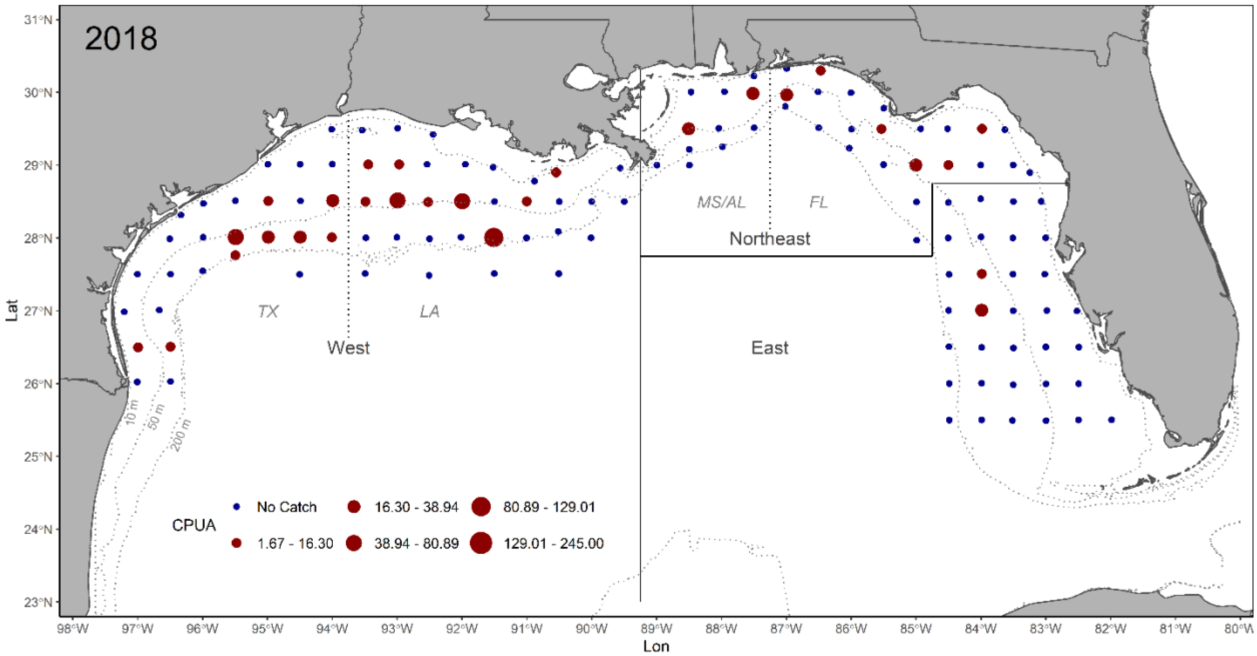

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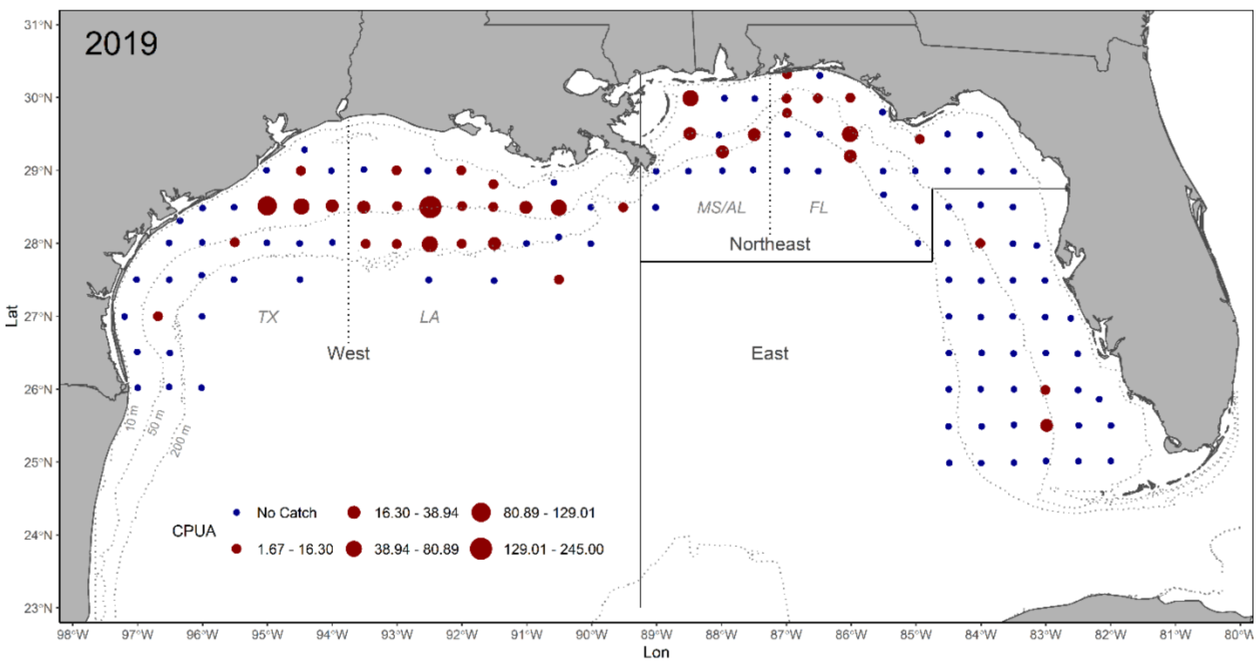
Lon



2019
MS/AL
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Northeast
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CPUA
No Catch
1.67 - 16.30
16.30 - 38.94
38.94 - 80.89
80.89 - 129.01
129.01 - 245.00
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Addendum to SEDAR74-DW-31

An initial delta-lognormal index that incorporated the effects of year, time of day and subregion on Red Snapper (*Lutjanus campechanus*) larval abundance in the northeastern (NEGOM) was reviewed by the SEDAR 74 Indices Working Group (IWG) May 2-6, 2022 (Figure 4 and Table 6). The initial NEGOM index excluded data from the 1998, 2002, 2005, 2015 and 2017 SEAMAP Fall Plankton surveys that were determined to have incomplete spatial coverage in the region (Appendix Figure 1). During the data workshop, the IWG requested a re-analysis of the NEGOM index to include the 1998, 2002, 2015 and 2017 surveys with partial spatial coverage in the MS/AL and FL subregions. The additional four survey years limited core grid locations in the NEGOM region to those sampled during at least 22 of the 33 years of the time series for the updated index (Addendum Figure 1). The 1998 and 2002 surveys had zero catch of red snapper larvae and could not be included in the time series due to the limitations of the delta-lognormal model. An updated NEGOM index with the addition of the 2015 and 2017 surveys was generated utilizing the methodology outlined in the main section of this working paper. The updated NEGOM index was presented to the IWG at the Data Workshop, discussed and was subsequently recommended by the IWG to replace the initial NEGOM index for exploration as a tuning index in the assessment model.

The updated NEGOM index is presented in Addendum Table 1 and Addendum Figure 2. The backward selection procedure retained year, time of day and subregion in the binomial submodel, and year, subregion and depth in the lognormal submodel (Addendum Table 2). The AIC for the binomial and lognormal submodels were 526.61 and 221.72, respectively. The diagnostic plots for the lognormal submodel are show in Addendum Figure 3, and indicated the distribution of the residuals is approximately normal.

The updated NEGOM delta-lognormal index indicates a similar trend to the initial index with abundance slowly increasing from 1986 to 2009, a marked increase in the population after 2010 and an even sharper increase after 2016. CPUA in 2017 and 2019 were roughly two to three time greater that than the period between 2010 and 2016. However, due to low sample sizes and low catch rates there is little precision to the trend. CVs are typically greater than 50% for all but the most recent years of the time series.

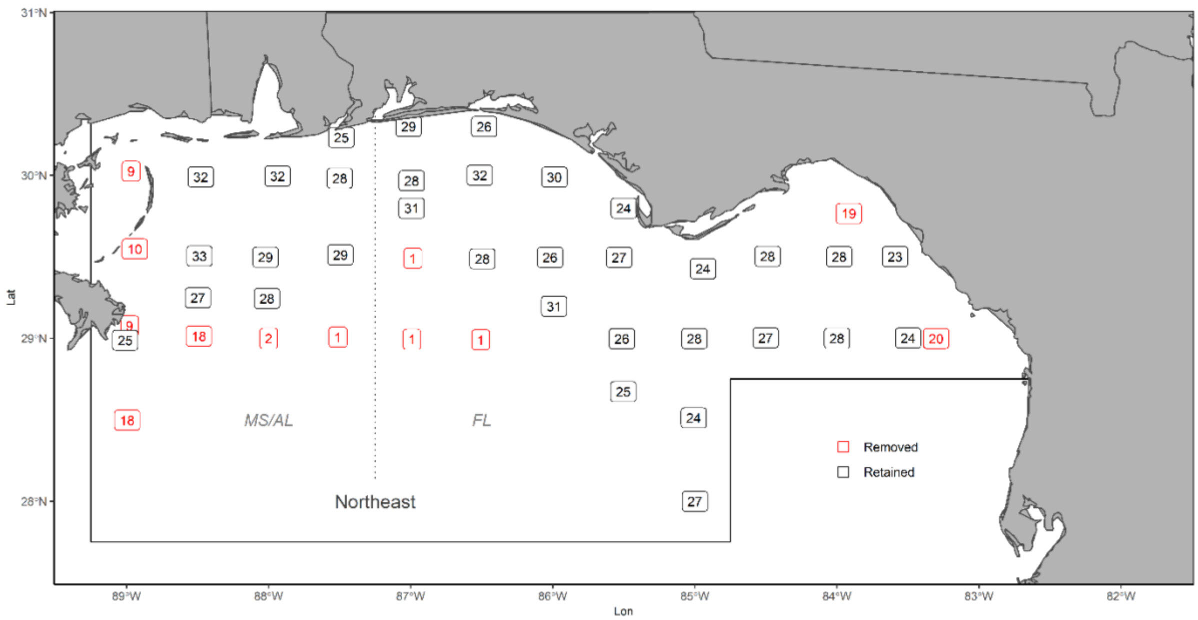
Addendum Table 1. SEAMAP Fall Plankton Survey updated index of northeastern Gulf of Mexico (NEGOM) larval Red Snapper age corrected abundance developed using the delta-lognormal (DL) model. The number of samples (N), proportion of positive occurrence (PPos), observed catch per unit effort (CPUA), the DL index (Index), the DL index scaled to a mean of one (StdIndex) for the time series, the lower and upper confidence limits (StdLCL and StdUCL) for the scaled index and the coefficient of variation of the mean (CV) are listed. Years with zero PPos represent true zero abundance for years with spatial coverage within the region. These years are not included in the delta-lognormal model

Year	N	PPos	CPUA	Index	StdIndex	StdLCL	StdUCL	CV
1986	26	0.0000	0.0000					
1987	28	0.0000	0.0000					
1988	13	0.0000	0.0000					
1989	15	0.0000	0.0000					
1990	18	0.0000	0.0000					
1991	17	0.0588	0.3648	0.3352	0.1200	0.0179	0.8029	1.2117
1992	33	0.0000	0.0000					
1993	30	0.0000	0.0000					
1994	33	0.0303	0.1115	0.0877	0.0314	0.0046	0.2128	1.2239
1995	30	0.0333	0.1665	0.1685	0.0603	0.0089	0.4085	1.2234
1996	33	0.0000	0.0000					
1997	32	0.0313	0.2535	0.2469	0.0884	0.0131	0.5962	1.2196
1998	14	0.0000	0.0000					
1999	33	0.0909	0.9764	1.0309	0.3690	0.1011	1.3461	0.7212
2000	33	0.1212	1.5907	2.2473	0.8043	0.2540	2.5470	0.6277
2001	31	0.0968	0.2962	0.4275	0.1530	0.0424	0.5514	0.7130
2002	12	0.0000	0.0000					
2003	32	0.1250	1.2729	1.1104	0.3974	0.1266	1.2472	0.6220
2004	33	0.0303	0.2959	0.4432	0.1586	0.0234	1.0751	1.2240
2005								
2006	33	0.0909	3.0701	1.6980	0.6077	0.1677	2.2024	0.7167
2007	33	0.1818	2.8415	2.4902	0.8912	0.3460	2.2953	0.5008
2008	25	0.0400	0.1348	0.2531	0.0906	0.0135	0.6082	1.2148
2009	33	0.0909	1.0575	1.4135	0.5059	0.1399	1.8287	0.7150
2010	32	0.2500	6.0103	7.6140	2.7249	1.2294	6.0394	0.4142
2011	33	0.0909	2.8409	2.5308	0.9057	0.2479	3.3093	0.7222
2012	27	0.1852	1.4382	2.2021	0.7881	0.2858	2.1730	0.5416
2013	33	0.1515	2.3859	2.3878	0.8545	0.3088	2.3648	0.5438
2014	31	0.1613	5.5663	4.1472	1.4842	0.5314	4.1455	0.5494
2015	19	0.0526	0.8814	1.3097	0.4687	0.0693	3.1689	1.2215
2016	33	0.2121	2.7535	2.8821	1.0315	0.4381	2.4283	0.4485
2017	23	0.5652	12.4208	11.8900	4.2551	2.3917	7.5703	0.2941
2018	32	0.2500	3.3120	5.0432	1.8049	0.8040	4.0514	0.4214
2019	29	0.4138	10.1764	12.3086	4.4050	2.3645	8.2063	0.3188

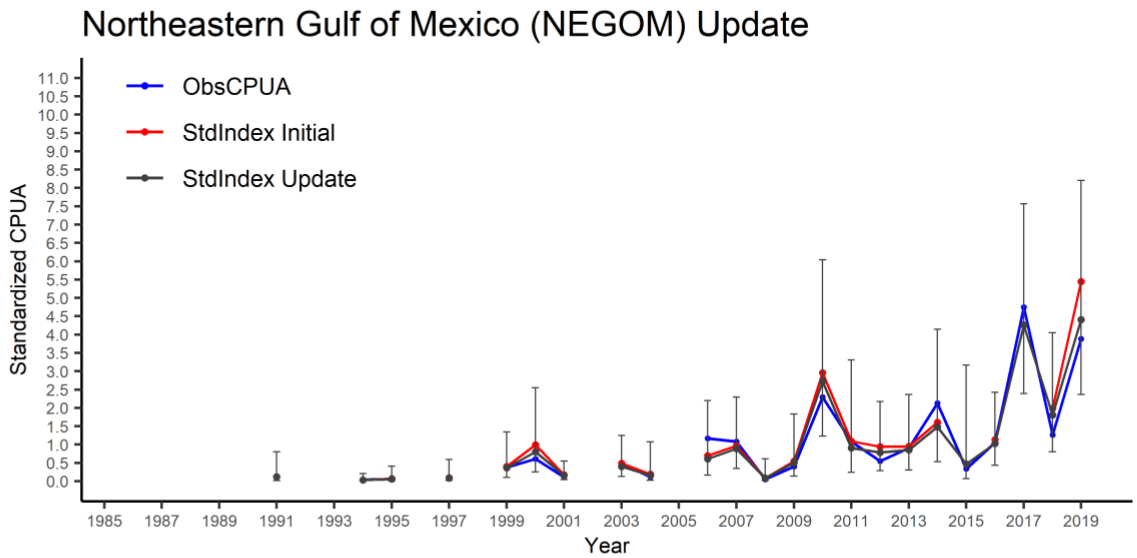
Addendum Table 2. Summary of the final delta-lognormal models from the backward selection procedure for the updated northeastern Gulf of Mexico (NEGOM) index of abundance.

Northeastern Gulf of Mexico (NEGOM) Update

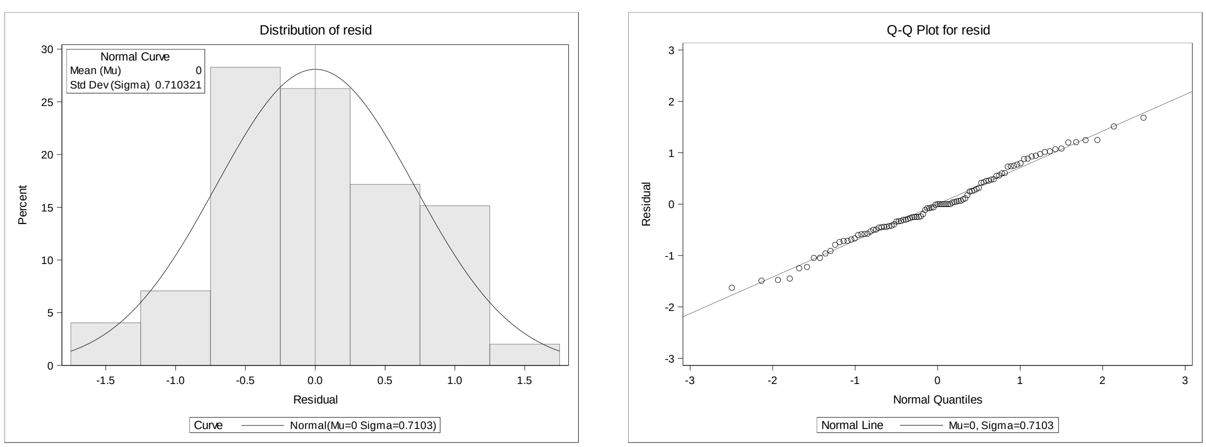
	Binomial Submodel Type 3 Tests(AIC=526.61)						Lognormal Submodel Type 3 Tests (AIC=221.72)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	22	655	58.79	2.67	<.0001	<.0001	22	74	1.35	0.1697
TOD	1	655	3.87	3.87	<.0001	<.0001			Dropped	
SUBREGION	1	655	18.74	18.74	0.0492	0.0497	1	74	9.47	0.0029
DEPTH				Dropped			1	74	9.34	0.0031



Addendum Figure 1. Number of primary bongo net samples taken at each SEAMAP B-Number location during SEAMAP Fall Plankton Surveys 1986 to 2019 with included spatial coverage in the northeastern (NEGOM) Gulf of Mexico. Only locations with primary samples equal to or exceeding 22 were included in the updated NEGOM index. Solid lines indicate the spatial extent of the northeastern Gulf of Mexico. Vertical dotted line indicates the spatial separation of the Mississippi/Alabama (MS/AL) and Florida (FL) subregions.



Addendum Figure 2. Nominal and delta-lognormal indices of larval Red Snapper age corrected catch per unit area (CPUA) from SEAMAP Fall Plankton Surveys from 1986 to 2019 for northeastern (NEGOM) Gulf of Mexico. Nominal CPUA (ObsCPUA) in blue, the initial NEGOM index (StdIndex Initial) in red and the updated NEGOM index (StdIndex Update) in black with upper and lower confidence intervals. Annual values are scaled to a mean of one respective to each time series.



Addendum Figure 3. Diagnostic plots for the lognormal submodel of the updated northeastern (NEGOM) index of abundance: Left column shows the frequency distribution of log (CPUA) on positive stations and the right column the cumulative normalized residuals (QQ plot).