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Red Snapper (*Lutjanus campechanus*) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2022

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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), SEDAR52 (2017) and SEDAR74 (2022) assessments. Nominal indices of proportion of positive occurrence (PPOS) and age corrected catch per unit area (CPUA) are provided for the west, northeast and east GOM as defined by the SEDAR98 terms of reference. Delta-lognormal standardized indices of age corrected CPUA were generated for the west and northeast GOM, and a standardized index of proportion of positive occurrence (PPOS) was generated for the east 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 and Lyczkowski-Shults, 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), SEDAR52 (2017) and SEDAR74 (2022) 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 and Lyczkowski-Shults, 2004 (2004), Hanisko *et al.* (2007), Pollack *et al.* (2012), Hanisko *et al.* (2017), Hanisko *et al.* (2022), the SEDAR 31 – Gulf of Mexico Red Snapper Stock Assessment Report (SEDAR, 2013), the SEDAR 31 Update Assessment Report (Cass-Calay *et al.,* 2015), the SEDAR 52 Assessment Report (SEDAR, 2018) and the SEDAR 74 Assessment Report (SEDAR, 2024)

This document outlines the development of Red Snapper larval indices for the west (WGOM), northeast (NEGOM) and east (EGOM) GOM continental shelf based on similar methodology utilized for the SEDAR 74 research track assessment. The development of indices for these three spatial areas follows the SEDAR 98 terms of reference for the development of a three-area model for the current assessment. Currently, the Fall Plankton Survey data available for analysis extends from 1986 to 2022. Larval lutjanid specimens from the 2023 survey are being cataloged, and have yet to to be processed through identification protocols. The process is expected to be completed by March of 2025.

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 NOAA Fisheries. Fish eggs and larvae were removed from bongo net samples. Fish eggs were not identified further, whereas, larvae were identified to the lower taxonomic levels, which in most cases was the family level. Body length (BL) was measured to the closest 0.1 mm 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 life 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 west GOM during the survey. Most stations are located at 30-nautical mile or 0.5º (~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 times 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, 2015 and 2023 surveys, and sampling effort was reduced across 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, 2017 and 2021 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 southeast (Tampa, FL to Key West, FL) portion of the survey area.

Year to year variability in spatial coverage from Fall Plankton Survey data is addressed by limiting observations to samples taken at SEAMAP stations that were sampled during at least 66% of years for which there was consistent spatial coverage respectively for the WGOM, NEGOM and EGOM through 2022. Based on this method, the core data of the WGOM includes all samples taken during at least 21 of the 32 years of available data, the core data of the NEGOM includes all samples taken during at least 20 of the 30 years of available data, and the core data of the EGOM includes all samples taken during at least 19 of 28 years of available data. Indices for the WGOM and EGOM in this working paper are based on the core data outline above (Figure 1). However, the core data included in the NEGOM follows the SEDAR 74 Indices Working Group requested re-analysis and adoption of a NEGOM index that includes data from the 1998, 2002, 2005, 2015 and 2017 surveys with partial spatial coverage (Hanisko *et al.,* 2022). The additional five survey years limited NEGOM core data to SEAMAP stations sampled during at least 23 of the 35 years of available data (Figure 1). Core data used to examine larval catch on a gulfwide basis, among regions and subregions is based on samples taken during at least 17 of 25 years of data with consistent spatial coverage, and do not include data from 1988, 1989, 1992, 1998, 2002, 2005, 2005, 2008, 2015, 2017 and 2021.

Aging of Larvae, Mortality Estimates and Age Corrected Abundance

A catch curve was developed for larval Red Snapper by summing the catch per unit area (CPUA) of each size class under 10 m^2 of sea surface. Size classes of 1.0 mm bins were utilized, with the midpoint (4.25 to 9.25 mm by .5 mm) 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 2022 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) $$l = 1.9302e^{0.0705t}$$

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=-0.1739) 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 for each sample and standardized to the total number of larvae per 10 m^2 of sea surface.

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) $I_y = c_y p_y$,

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 (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, 1996, 1998 and 2002) 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 10% for the 28 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 a 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 (PPOS) 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, mean age corrected larval CPUA and the percentage of total CPUA from all years with consistent gulfwide spatial coverage provide an overview of the difference among the WGOM, NEGOM and EGOM regions and within the subregions of the WGOM and NEGOM (Tables 1 and 2). Red Snapper larvae were captured throughout the gulfwide survey area but occurred 2.2 and 4.8 times more often and at 2.8 and 11.6 times greater CPUA in the WGOM than in the NEGOM and EGOM respectively. The WGOM accounted for 78.7 percent of the total gulfwide CPUA, the NEGOM accounted for 17.7 percent and the EGOM accounted for 4.0 percent. In the WGOM, the Louisiana subregion accounted for 68.7 percent of the total abundance in the region with larvae occurring 1.2 time more often and at 2.1 times greater CPUA than the Texas subregion. In the NEGOM, the Mississippi/Alabama subregion accounted for 57.5 percent of the total abundance in the region with larvae occurring 2.6 times more often and at 3.5 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 2009/2010 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, TOD and depth in the binomial submodel, and year, TOD and subregion in the lognormal submodel (Table 5). The AICs for the binomial and lognormal submodels were 1645.76 and 979.70, respectively. The diagnostic plots for the lognormal submodel is 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 submodels were 603.54 and 323.99, respectively. The diagnostic plots for the lognormal submodel are show in Figure 5, and indicated the distribution of the residuals is approximately normal.

The WGOM index exhibits a variable but steadily increasing trend over the entire time series. The trend is relatively gradual until 2019, but shows a sharp increase in CPUA in 2021 and 2022. 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 indices for three area SEDAR 98 assessment required the splitting of SEAMAP Fall Plankton survey east GOM (> -89.25 Degrees of Longitude) sampling effort between the NEGOM and EGOM regions, 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 2017 and 2019 posting the highest abundance recorded during the time series. Annual CPUA in 2021 and 2021 are more inline with estimates from 2010 to 1016. 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 (0.05) in the EGOM was less than half of the mean PPOS (.11) in the NEGOM. Our EGOM binomial model successfully converged with an AIC of 290.35. 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%. During the SEDAR 74 Data Workshop the Indices Working Group (IWG) raised concerns with the timing of the SEAMAP Fall Plankton Survey (late August and September) which is conducted towards the end of the Red Snapper spawning season and outside of peak spawning. Thus, raising the question as whether the SEAMAP Fall Plankton Survey indices were adequately capturing population trends. Particularly, in the EGOM where larvae were rarely taken. The IWG also held discussions with the life history group in regards to the timing of the survey and the capturing of trend. Based on the discussions and the extremely rare catch of larvae, the EGOM index was not recommended by the IWG as suitable to move forward for the SEDAR 74 assessment phase. It is included here as a means to monitor the potential expansion of Red Snapper spawning in the region.

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

West Gulf of Mexico (WGOM)

Factors	Levels	Description
Year	*31*	*1986-1987, 1989-1997,1999-2004,2006-2007,2009-2014, 2016-2019 and 2021-2022*
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*

Northeast Gulf of Mexico (NEGOM)

Factors	Levels	Description
Year	*25*	*1991, 1994-1995, 1997, 1999-2001, 2003-2004, 2006-2019, 2016 and 2021-2022*
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), positive occurrence (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. Percentage of total CPUA is based on gulfwide total CPUA for regions and on regional total CPUA for subregions.

Region SubRegion	N	NPOS	PPOS	PPOS SE	CPUA	CPUE SE	Total CPUA	Percent Total CPUA
GOM	2831	431	0.15	0.01	3.20	0.30	9067.65	
West	1287	305	0.24	0.01	5.55	0.62	7142.26	78.77
TX	634	133	0.21	0.02	3.53	0.46	2236.17	31.31
LA	653	172	0.26	0.02	7.51	1.13	4906.09	68.69
Northeast	795	90	0.11	0.01	1.97	0.28	1565.97	17.27
MS/AL	222	46	0.21	0.03	4.06	0.77	900.44	57.50
FL	573	44	0.08	0.01	1.16	0.25	665.53	42.50
East	749	36	0.05	0.01	0.48	0.13	359.42	3.96

Table 3. Sampling effort, nominal proportion of positive occurrence (PPOS) and nominal catch per unit effort (CPUA) for the west (WGOM), northeast (NEGOM) and east (EGOM) Gulf of Mexico.

	West			Northeast			East		
YEAR	**N**	**PPOS**	**CPUA**	**N**	**PPOS**	**CPUA**	**N**	**PPOS**	**CPUA**
1986	49	0.0816	0.9524	26	0.0000	0.0000	32	0.0313	0.1632
1987	55	0.0727	1.8346	28	0.0000	0.0000	33	0.0606	0.2539
1988	28	0.0000	0.0000	13	0.0000	0.0000	25	0.0400	0.2264
1989	28	0.1429	1.7077	15	0.0000	0.0000	25	0.0000	0.0000
1990	31	0.1935	1.6169	18	0.0000	0.0000	20	0.0000	0.0000
1991	31	0.0968	1.3383	17	0.0588	0.3538	25	0.0400	0.1643
1992	55	0.1273	0.8962	33	0.0000	0.0000			
1993	55	0.1273	1.3226	30	0.0000	0.0000	20	0.0000	0.0000
1994	55	0.0727	1.0796	33	0.0303	0.1115	32	0.0000	0.0000
1995	55	0.2364	2.9499	30	0.0333	0.1615	32	0.0313	0.0934
1996	55	0.1636	1.8224	33	0.0000	0.0000	27	0.0000	0.0000
1997	54	0.2593	3.0389	32	0.0313	0.2397	31	0.0323	0.0601
1998				14	0.0000	0.0000			
1999	55	0.1455	1.1385	33	0.0909	0.9480	27	0.0000	0.0000
2000	55	0.2727	5.2158	33	0.1212	1.5365	24	0.0000	0.0000
2001	47	0.1489	3.2398	31	0.0968	0.2962	32	0.0000	0.0000
2002	54	0.2222	2.4438	12	0.0000	0.0000	27	0.0741	0.4024
2003	54	0.2963	5.8882	32	0.1250	1.2381	33	0.0000	0.0000
2004	54	0.2222	2.3556	33	0.0303	0.2798			
2005									
2006	52	0.2308	4.8426	33	0.0909	2.8988	25	0.0000	0.0000
2007	55	0.2909	3.2722	33	0.1818	2.7138	33	0.0000	0.0000
2008				25	0.0400	0.1348			
2009	55	0.3091	3.9934	33	0.0909	1.0168	32	0.0938	0.9883
2010	53	0.1509	1.5096	32	0.2500	5.7434	33	0.0303	0.1940
2011	53	0.2453	7.7506	33	0.0909	2.6596	33	0.2121	3.1840
2012	55	0.3091	7.3858	27	0.1852	1.3827	33	0.0606	0.3273
2013	54	0.2963	3.0656	33	0.1515	2.3128	33	0.0303	0.0590
2014	52	0.2692	6.7908	31	0.1613	5.3476	31	0.0323	0.2314
2015				19	0.0526	0.8008			
2016	55	0.3455	14.4794	33	0.2121	2.7286	33	0.0909	0.6621
2017	53	0.2264	3.2001	23	0.5652	11.8119			
2018	53	0.3396	6.9277	32	0.2500	3.1656	33	0.0606	0.7983
2019	47	0.4681	12.7257	29	0.4138	9.7314	32	0.0938	1.0686
2020	No	Survey							
2021	49	0.3469	11.5566	31	0.3548	6.1019			
2022	52	0.4423	32.6139	32	0.2188	5.3019	30	0.2333	3.0483

Table 4. SEAMAP Fall Plankton Survey index of west 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	0.9524	1.0150	0.2174	0.0685	0.6899	0.6290
1987	55	0.0727	1.8346	1.6160	0.3462	0.1088	1.1013	0.6307
1988	28	0.0000	0.0000					
1989	28	0.1429	1.7077	2.0827	0.4461	0.1434	1.3884	0.6166
1990	31	0.1936	1.6169	1.7165	0.3677	0.1427	0.9472	0.5009
1991	31	0.0968	1.3383	0.8055	0.1726	0.0475	0.6266	0.7180
1992	55	0.1273	0.8962	0.9281	0.1988	0.0806	0.4906	0.4757
1993	55	0.1273	1.3226	1.0189	0.2183	0.0887	0.5371	0.4740
1994	55	0.0727	1.0796	0.7403	0.1586	0.0498	0.5046	0.6308
1995	55	0.2364	2.9499	2.8283	0.6058	0.3144	1.1674	0.3370
1996	55	0.1636	1.8224	1.9775	0.4236	0.1916	0.9365	0.4128
1997	54	0.2593	3.0389	3.2880	0.7043	0.3760	1.3192	0.3217
1998								
1999	55	0.1455	1.1385	1.3672	0.2929	0.1259	0.6813	0.4416
2000	55	0.2727	5.2158	4.4698	0.9575	0.5172	1.7726	0.3154
2001	47	0.1489	3.2398	3.0694	0.6575	0.2690	1.6071	0.4702
2002	54	0.2222	2.4438	2.3729	0.5083	0.2575	1.0034	0.3501
2003	54	0.2963	5.8882	4.3098	0.9232	0.5143	1.6572	0.2989
2004	54	0.2222	2.3556	2.4901	0.5334	0.2665	1.0676	0.3577
2005								
2006	52	0.2308	4.8426	4.3532	0.9325	0.4701	1.8498	0.3528
2007	55	0.2909	3.2722	3.7333	0.7997	0.4470	1.4307	0.2971
2008								
2009	55	0.3091	3.9934	4.6249	0.9907	0.5623	1.7456	0.2890
2010	53	0.1509	1.5096	1.8853	0.4038	0.1741	0.9368	0.4400
2011	53	0.2453	7.7506	7.3082	1.5655	0.8148	3.0076	0.3354
2012	55	0.3091	7.3858	7.0501	1.5102	0.8563	2.6635	0.2895
2013	54	0.2963	3.0656	3.7974	0.8134	0.4538	1.4581	0.2981
2014	52	0.2692	6.7908	5.5034	1.1789	0.6295	2.2078	0.3216
2015								
2016	55	0.3455	14.4794	11.3398	2.4291	1.4359	4.1091	0.2675
2017	53	0.2264	3.2001	2.9743	0.6371	0.3214	1.2630	0.3524
2018	53	0.3396	6.9277	5.6988	1.2207	0.7080	2.1048	0.2775
2019	47	0.4681	12.7257	10.0637	2.1557	1.3447	3.4559	0.2393
2020	No	Survey						
2021	49	0.3469	11.5566	13.9615	2.9907	1.7163	5.2113	0.2831
2022	52	0.4423	32.6139	26.3293	5.6399	3.5404	8.9846	0.2360

Table 5. Summary of the final delta-lognormal models from the backward selection procedure for the west Gulf of Mexico (WGOM) and northeast Gulf of Mexico (NEGOM) indices of abundance.

West Gulf of Mexico (WGOM)

	Binomial Submodel Type 3 Tests (AIC=1645.76)						*Lognormal Submodel Type 3 Tests (AIC=979.70)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	30	1547	79.22	2.64	<.0001	<.0001	30	336	4.23	<.0001
TOD	1	1547	38.85	38.85	<.0001	<.0001	1	336	33.82	<.0001
SUBREGION							1	336	16.09	<.0001
DEPTH	1	1547	5.60	5.60	0.0180	0.0180			Dropped	

Northeast Gulf of Mexico (NEGOM)

	Binomial Submodel Type 3 Tests (AIC=603.54)						*Lognormal Submodel Type 3 Tests (AIC=323.99)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	24	727	64.99	2.71	<.0001	<.0001	24	90	1.24	0.2301
TOD				Dropped					Dropped	
SUBREGION	1	727	19.81	19.81	<.0001	<.0001	1	90	16.55	0.0001
DEPTH				Dropped			1	90	10.13	0.0020

Table 6. SEAMAP Fall Plankton Survey index of northeast 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	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	0.3538	0.2944	0.1015	0.0151	0.6804	1.2137
1992	33	0.0000	0.0000					
1993	30	0.0000	0.0000					
1994	33	0.0303	0.1115	0.0864	0.0298	0.0044	0.2016	1.2224
1995	30	0.0333	0.1615	0.1577	0.0543	0.0080	0.3670	1.2206
1996	33	0.0000	0.0000					
1997	32	0.0313	0.2397	0.2127	0.0733	0.0108	0.4956	1.2215
1998	14	0.0000	0.0000					
1999	33	0.0909	0.9480	0.9367	0.3228	0.0884	1.1785	0.7218
2000	33	0.1212	1.5365	2.4241	0.8353	0.2654	2.6288	0.6238
2001	31	0.0968	0.2962	0.4201	0.1448	0.0401	0.5228	0.7143
2002	12	0.0000	0.0000					
2003	32	0.1250	1.2381	1.0919	0.3762	0.1202	1.1779	0.6204
2004	33	0.0303	0.2798	0.4693	0.1617	0.0239	1.0943	1.2224
2005								
2006	33	0.0909	2.8988	1.6180	0.5575	0.1537	2.0223	0.7173
2007	33	0.1818	2.7138	2.2890	0.7887	0.3059	2.0338	0.5015
2008	25	0.0400	0.1348	0.2380	0.0820	0.0121	0.5545	1.2215
2009	33	0.0909	1.0168	1.3696	0.4719	0.1299	1.7143	0.7182
2010	32	0.2500	5.7434	6.8843	2.3721	1.0597	5.3102	0.4198
2011	33	0.0909	2.6596	2.5060	0.8635	0.2365	3.1532	0.7218
2012	27	0.1852	1.3827	2.2631	0.7798	0.2854	2.1308	0.5361
2013	33	0.1515	2.3128	2.2797	0.7855	0.2816	2.1912	0.5486
2014	31	0.1613	5.3476	3.5430	1.2208	0.4325	3.4464	0.5559
2015	19	0.0526	0.8008	1.2267	0.4227	0.0624	2.8640	1.2237
2016	33	0.2121	2.7286	2.6749	0.9217	0.3864	2.1984	0.4560
2017	23	0.5652	11.8119	11.6988	4.0310	2.2582	7.1957	0.2959
2018	32	0.2500	3.1656	4.7999	1.6539	0.7321	3.7361	0.4250
2019	29	0.4138	9.7314	12.1009	4.1696	2.2368	7.7724	0.3191
2020	No	Survey						
2021	31	0.3548	6.1019	6.4130	2.2097	1.1348	4.3029	0.3427
2022	32	0.2188	5.3019	4.5564	1.5700	0.6610	3.7290	0.4536

Table 8. SEAMAP Fall Plankton Survey index of east 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	PPOS	Index	StdIndex	StdLCL	StdUCL	CV
1986	32	0.0313	0.0313	0.4259	0.0576	2.6852	1.0005
1987	33	0.0606	0.0606	0.8260	0.2018	2.9559	0.6967
1988	25	0.0400	0.0400	0.5451	0.0736	3.3029	0.9960
1989	25	0.0000					
1990	20	0.0000					
1991	25	0.0400	0.0400	0.5451	0.0736	3.3029	0.9960
1992							
1993	20	0.0000					
1994	32	0.0000					
1995	32	0.0313	0.0313	0.4259	0.0576	2.6852	1.0005
1996	27	0.0000					
1997	31	0.0323	0.0323	0.4396	0.0594	2.7589	1.0000
1998							
1999	27	0.0000					
2000	24	0.0000					
2001	32	0.0000					
2002	27	0.0741	0.0741	1.0095	0.2468	3.5114	0.6916
2003	33	0.0000					
2004							
2005							
2006	25	0.0000					
2007	33	0.0000					
2008							
2009	32	0.0938	0.0938	1.2777	0.4074	3.5132	0.5587
2010	33	0.0303	0.0303	0.4130	0.0558	2.6153	1.0010
2011	33	0.2121	0.2121	2.8909	1.4060	5.2682	0.3410
2012	33	0.0606	0.0606	0.8260	0.2018	2.9559	0.6967
2013	33	0.0303	0.0303	0.4130	0.0558	2.6153	1.0010
2014	31	0.0323	0.0323	0.4396	0.0594	2.7589	1.0000
2015	.	.	.	.	.	.	.
2016	33	0.0909	0.0909	1.2390	0.3949	3.4207	0.5596
2017							
2018	33	0.0606	0.0606	0.8260	0.2018	2.9559	0.6967
2019	32	0.0938	0.0938	1.2777	0.4074	3.5132	0.5587
2020	No	Survey					
2021							
2022	30	0.2333	0.2333	3.1800	1.5521	5.7082	0.3364

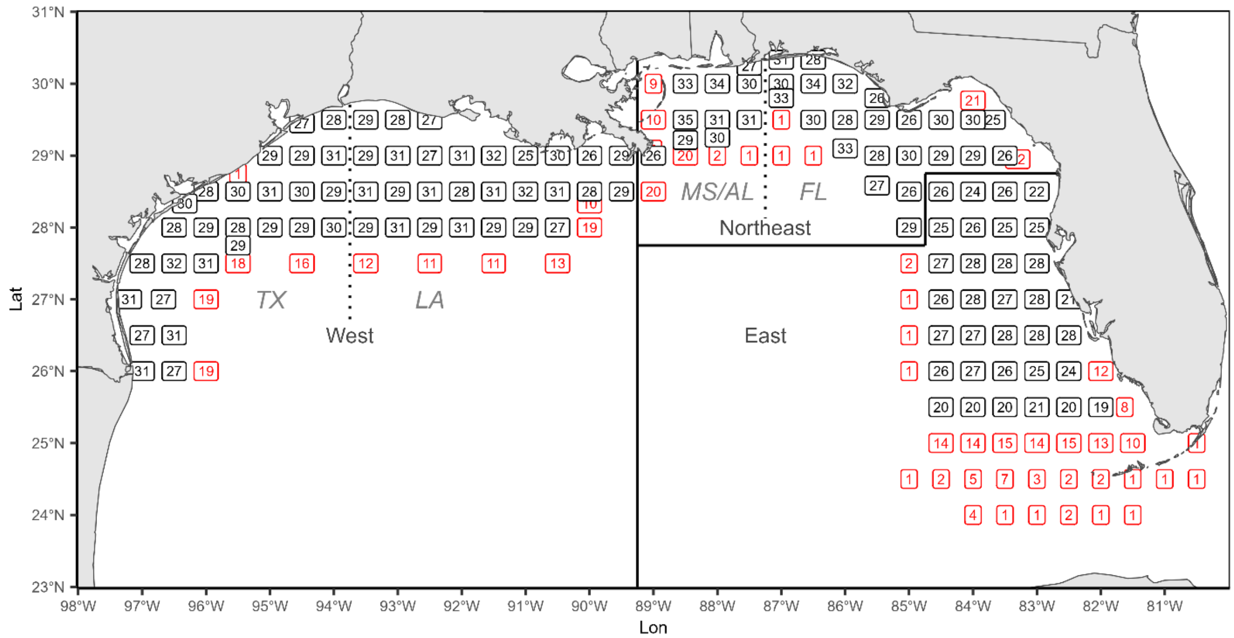


Figure 1. Number of primary bongo net samples taken at each SEAMAP B-Number location during SEAMAP Fall Plankton Surveys 1986 to 2022 respective to the west (WGOM), northeast (NEGOM) and east (EGOM) Gulf of Mexico. Only locations with primary samples equal to or exceeding 21 were included in the WGOM, only locations with primary samples equal to or exceeding 23 were included in the NEGOM, and only locations with primary samples equal to or exceeding 19 were included in the EGOM. Solid lines indicate spatial breaks of the west, northeast and east 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.

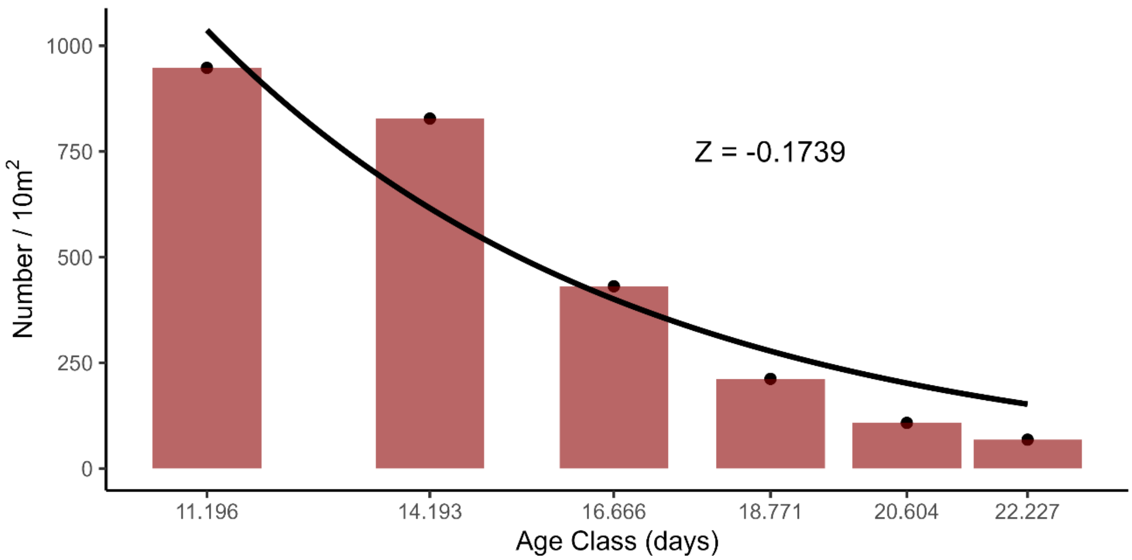


Figure 2. Red Snapper total duration corrected larval catch per unit area (CPUA) by age class and the resulting daily loss rate curve (Z = -0.1739).

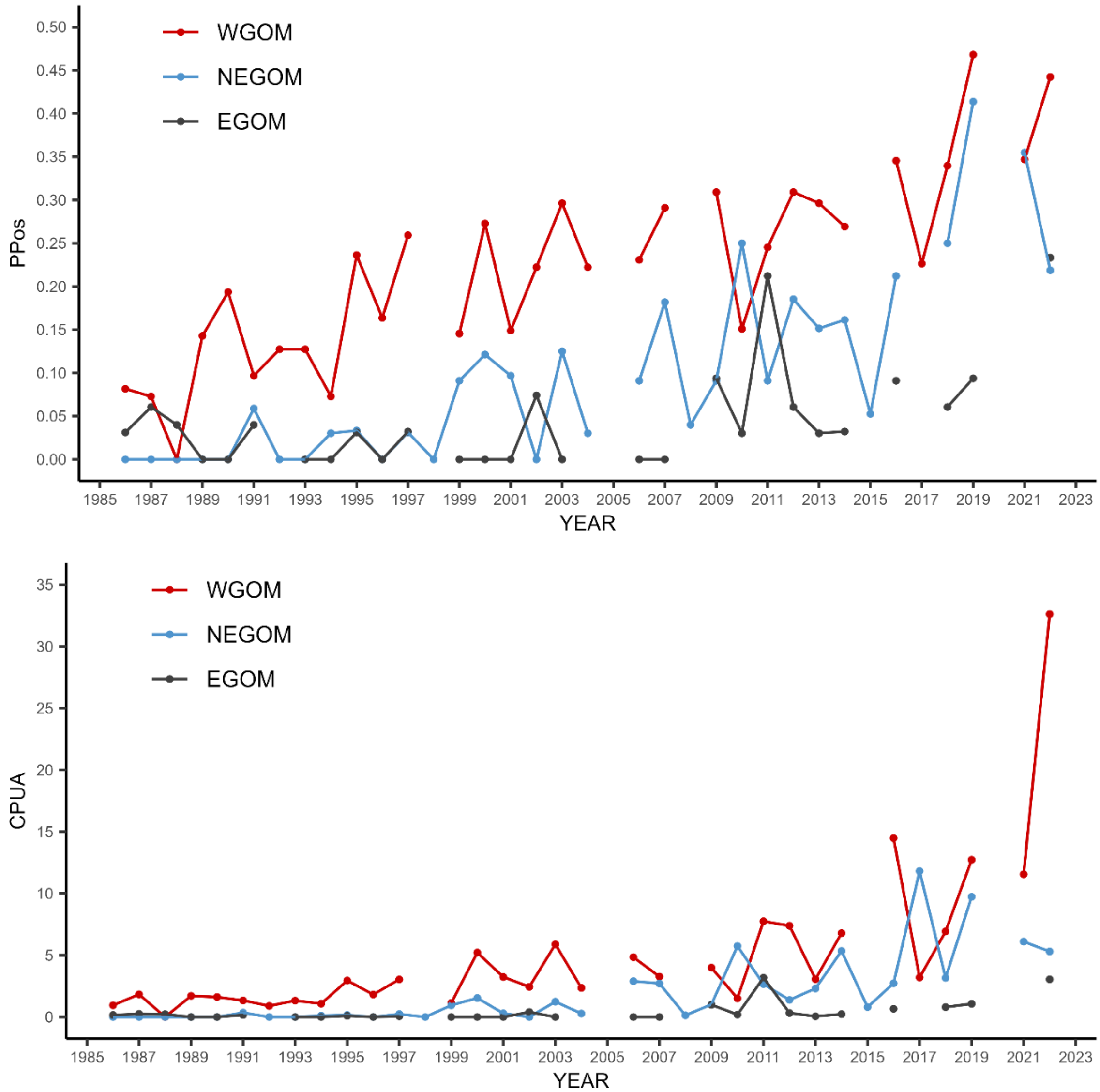


Figure 3. Nominal proportion of positive occurrence (PPos, top) and age corrected catch per unit area (CPUA, bottom) for the west (WGOM), northeast (NEGOM) and east (EGOM) Gulf of Mexico.

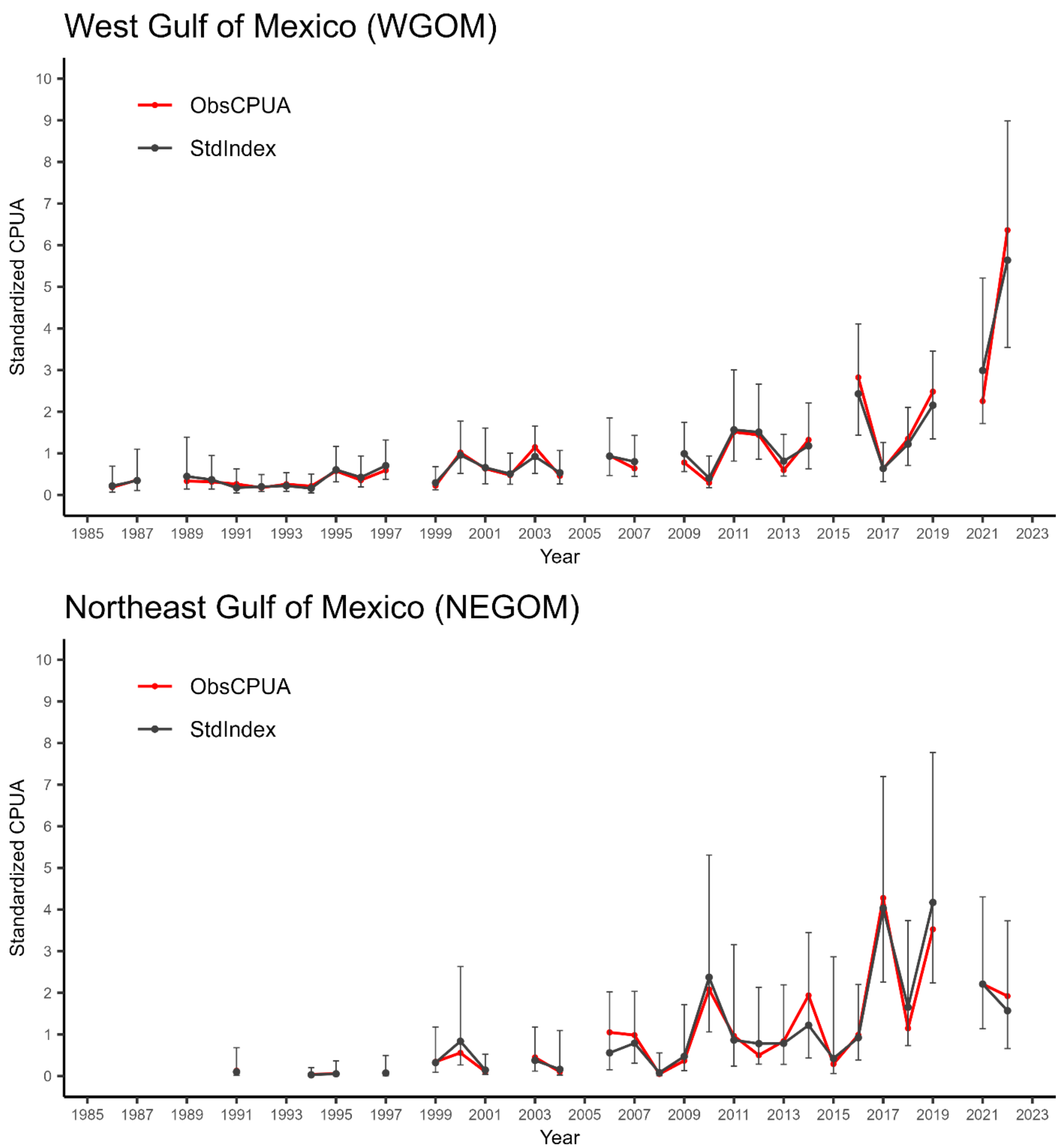
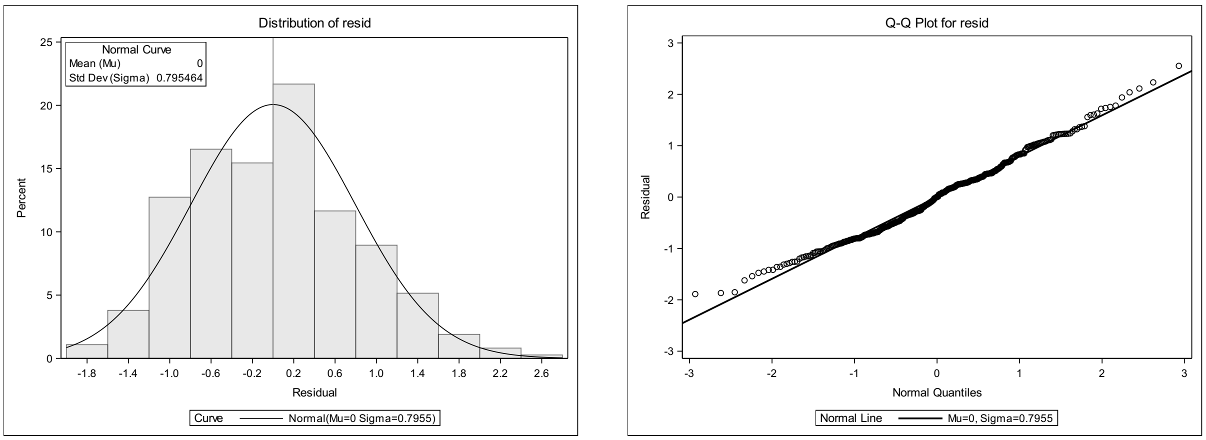


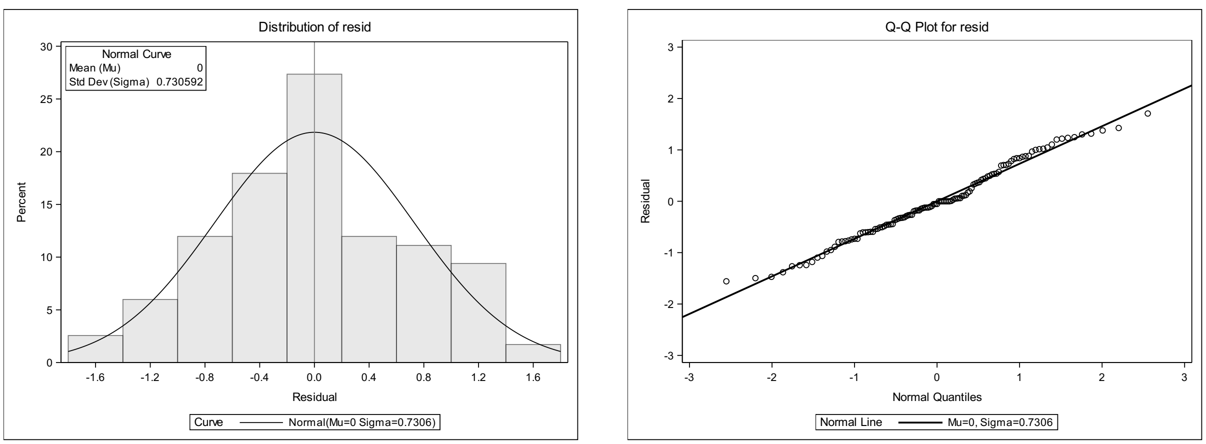
Figure 4. Annual index of larval Red Snapper age corrected abundance from SEAMAP Fall Plankton Surveys from 1986 to 2019 for the west (WGOM) and northeast (NEGOM) Gulf of Mexico.

Figure 5. Diagnostic plots for the lognormal submodels of the west (WGOM, top) and northeast (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).

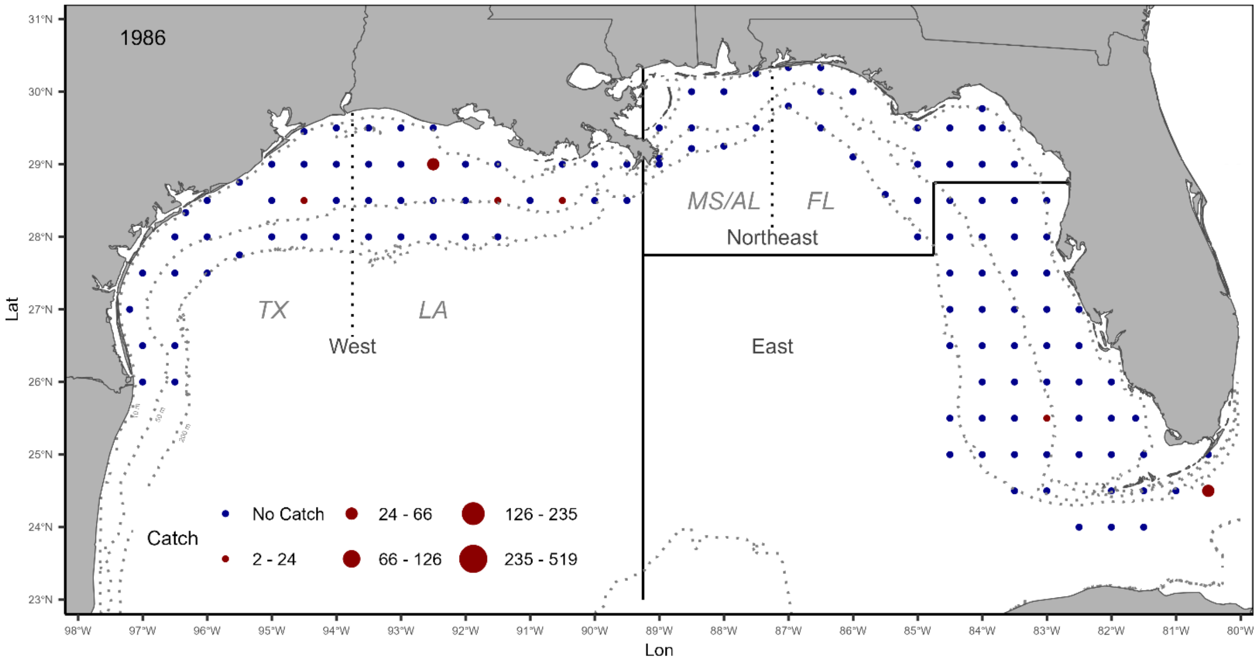
West Gulf of Mexico (WGOM)

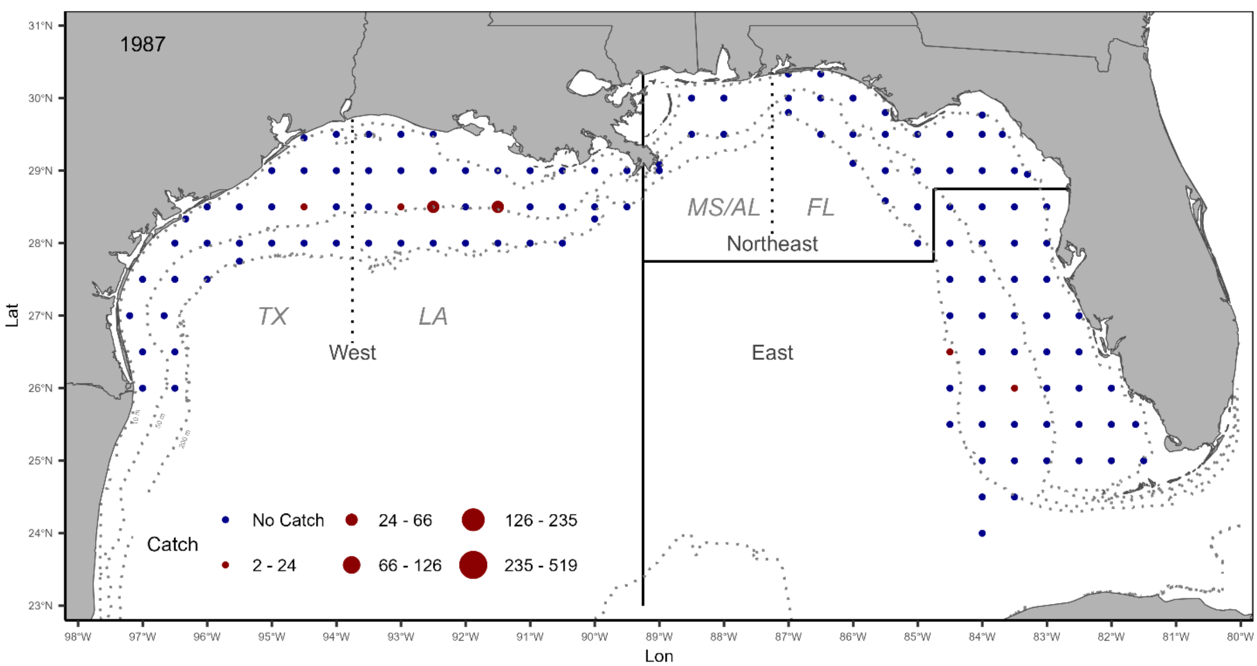


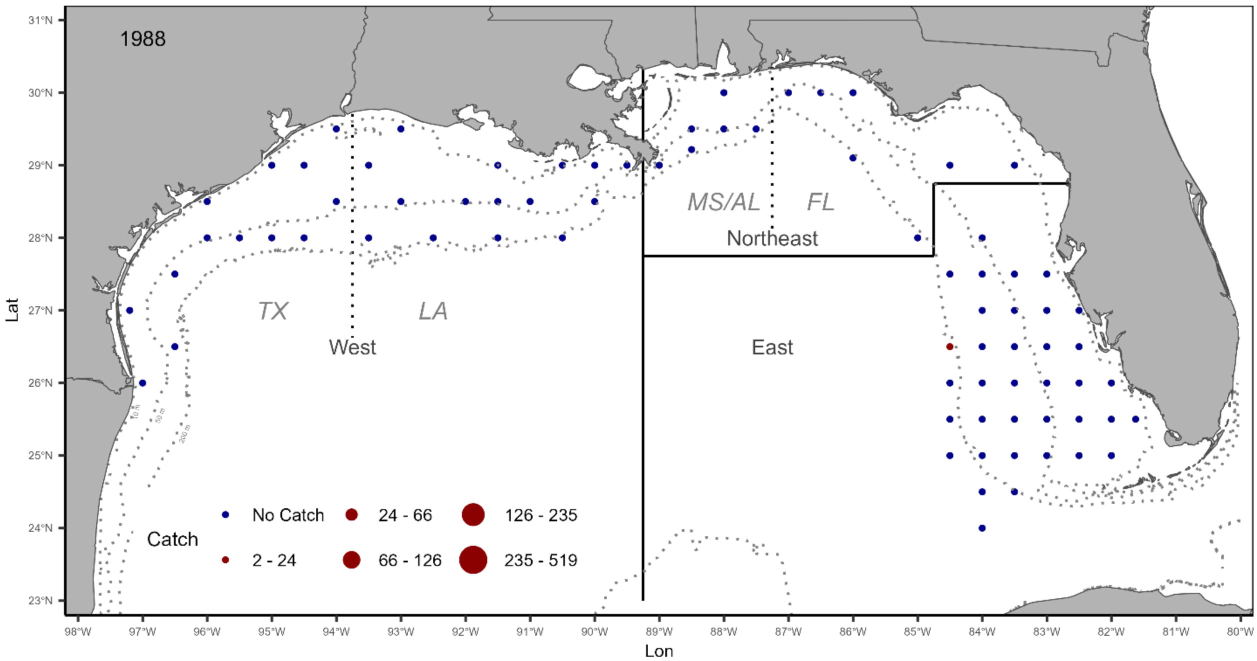
Northeast Gulf of Mexico (NEGOM)



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 west, northeast and east Gulf of Mexico. Vertical dotted lines indicate spatial breaks of the Texas (TX) and Louisiana (LA) subregions within the west Gulf of Mexico and the Mississippi/Alabama (MS/AL) and Florida (FL) subregions of the northeast Gulf of Mexico. The 10m, 50m and 200m depth contours are included for reference.






1988
TX
LA
West
MS/AL
FL
Northeast
East
Catch
No Catch
2 - 24
24 - 66
66 - 126
126 - 235
235 - 519
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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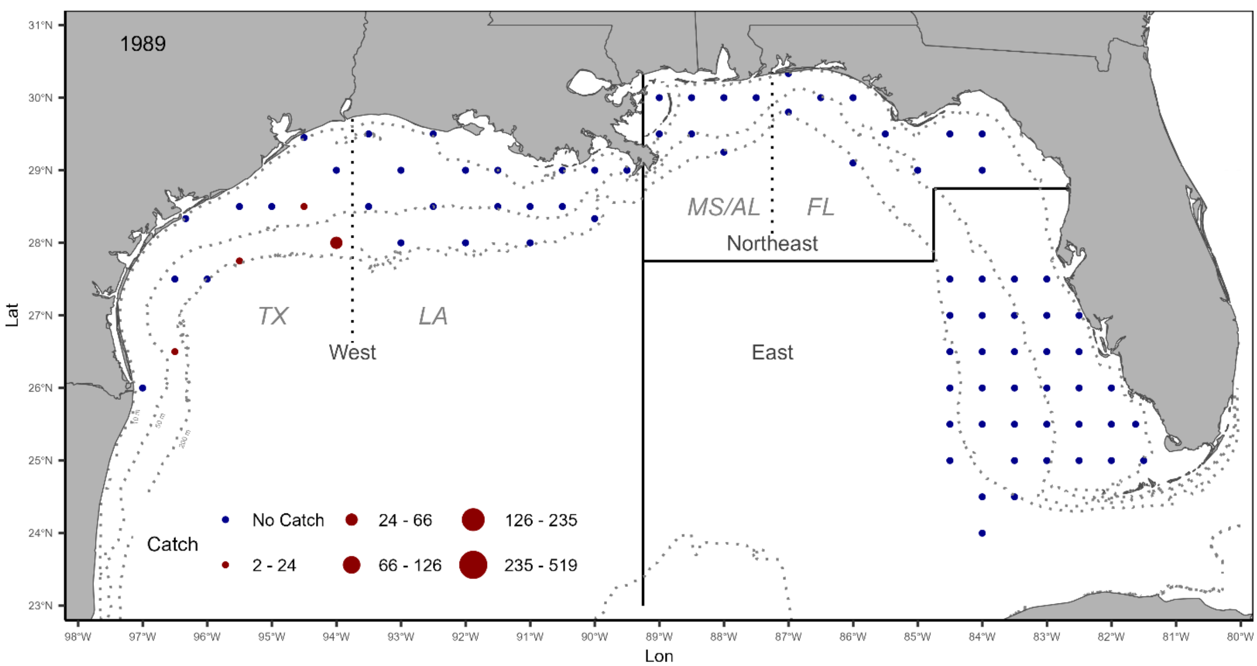
82°W
81°W
80°W


1989
TX
LA
West
MS/AL
FL
Northeast
East
Catch
No Catch
2 - 24
24 - 66
66 - 126
126 - 235
235 - 519
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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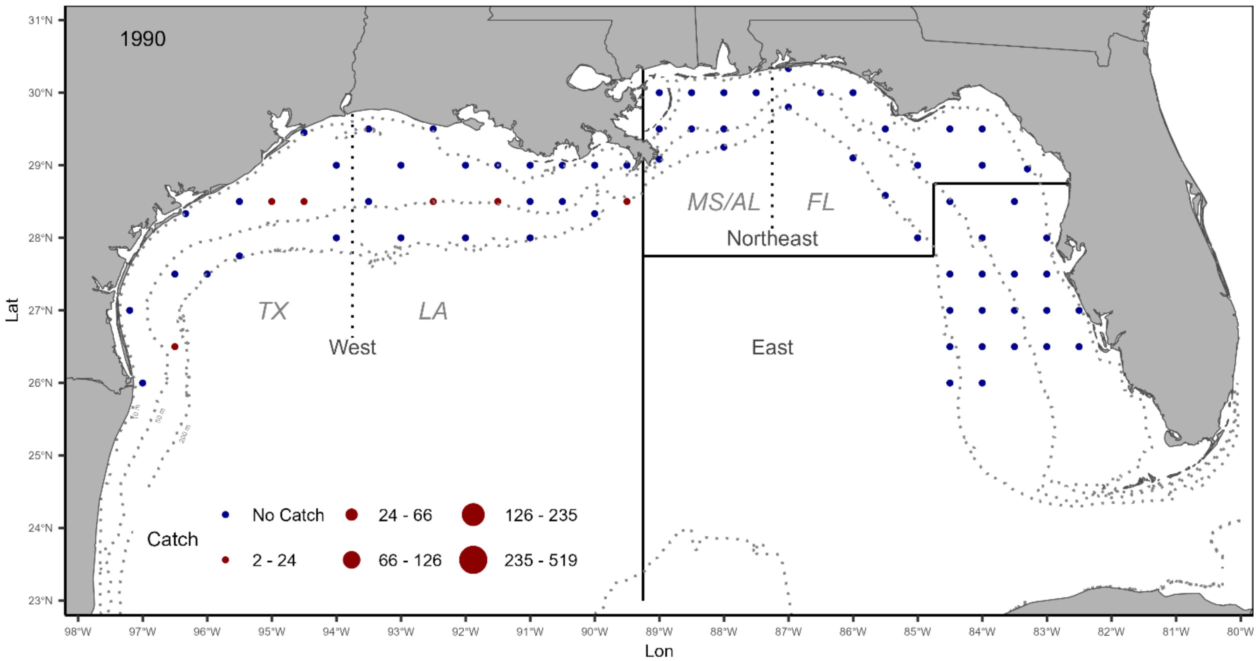
82°W
81°W
80°W


1990
TX
LA
West
MS/AL
FL
Northeast
East
Catch
No Catch
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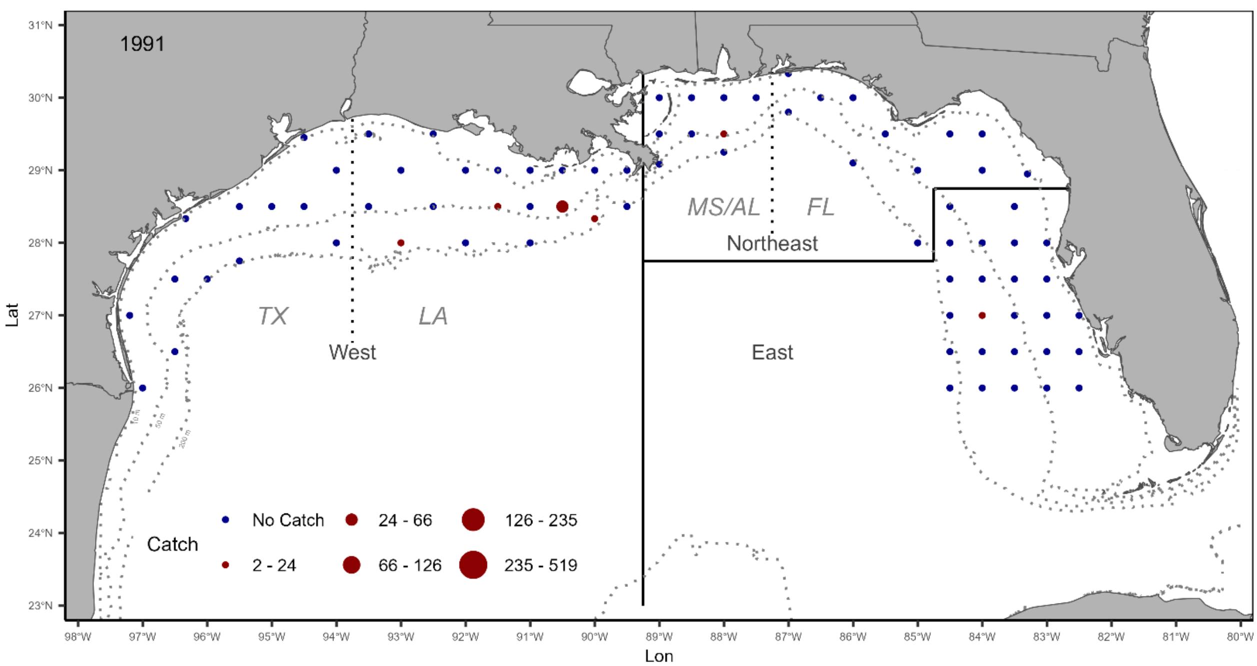
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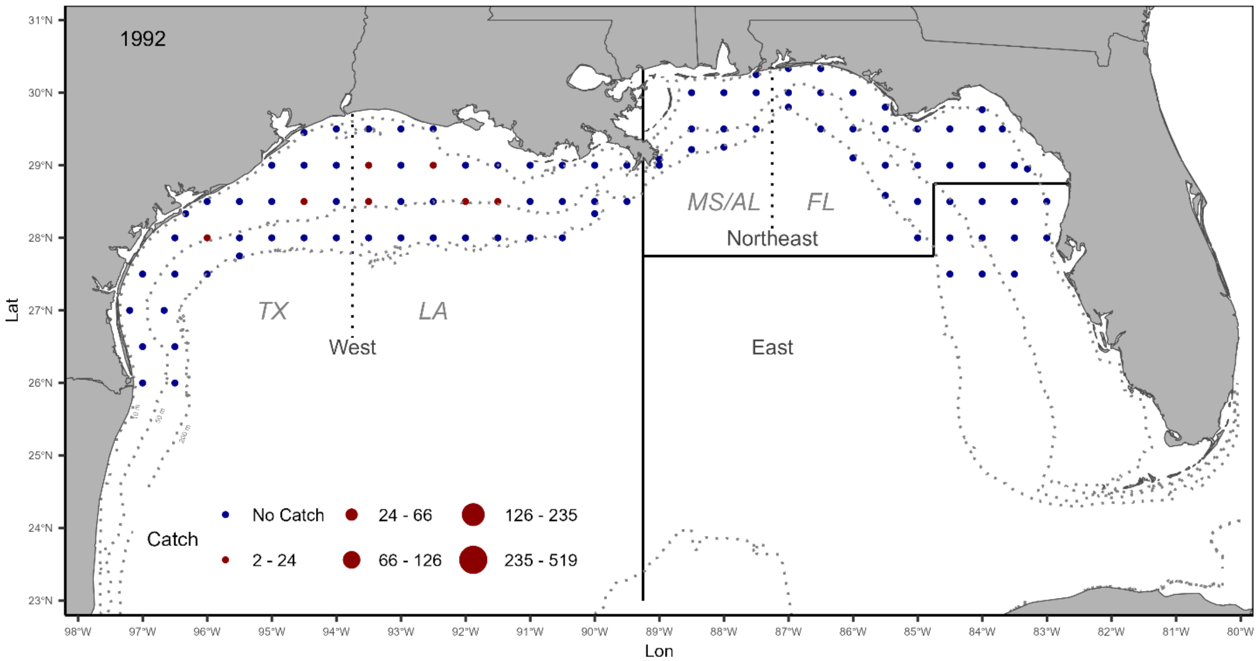

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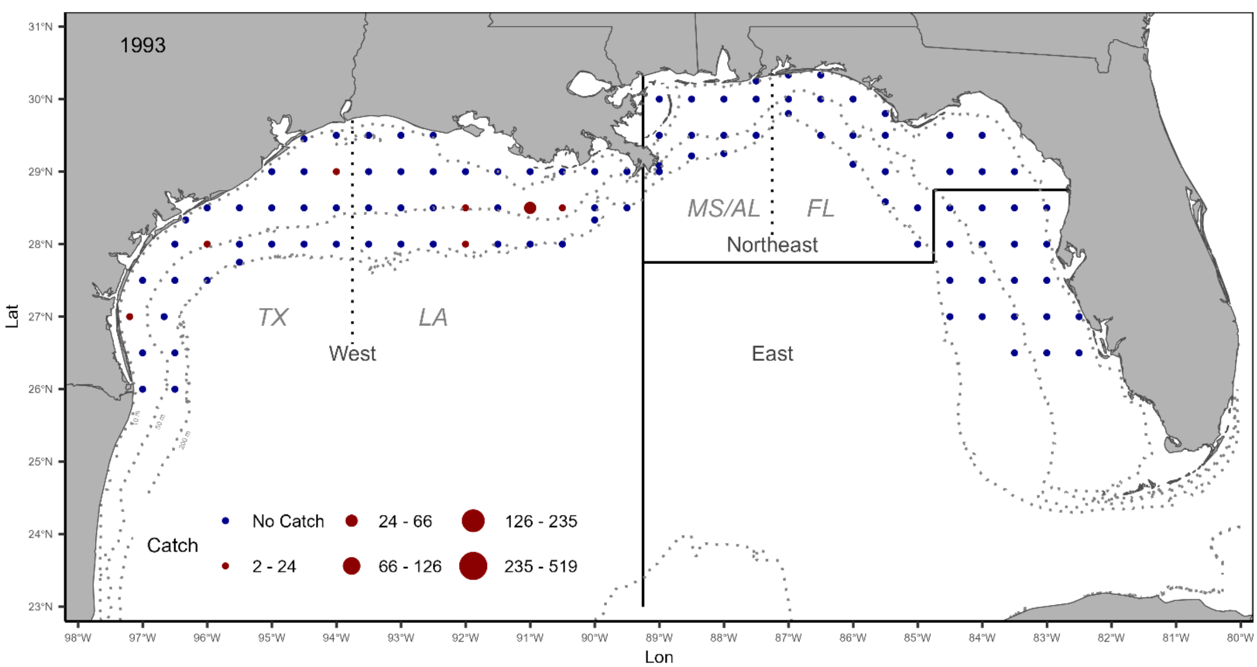

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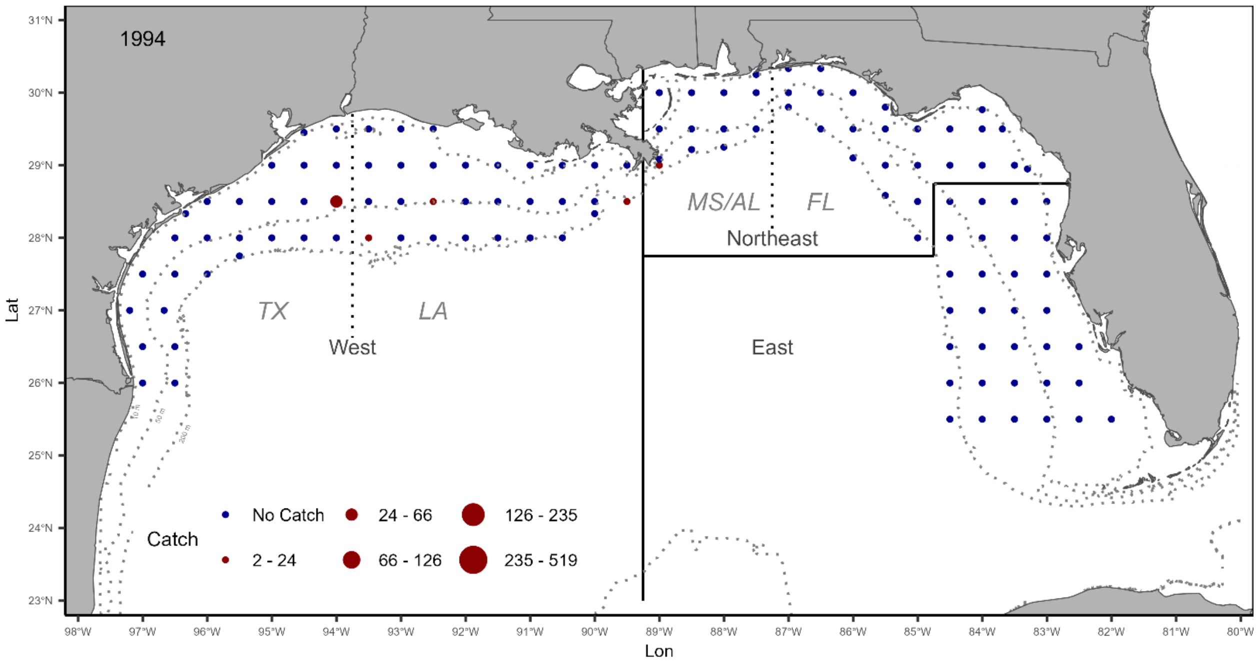
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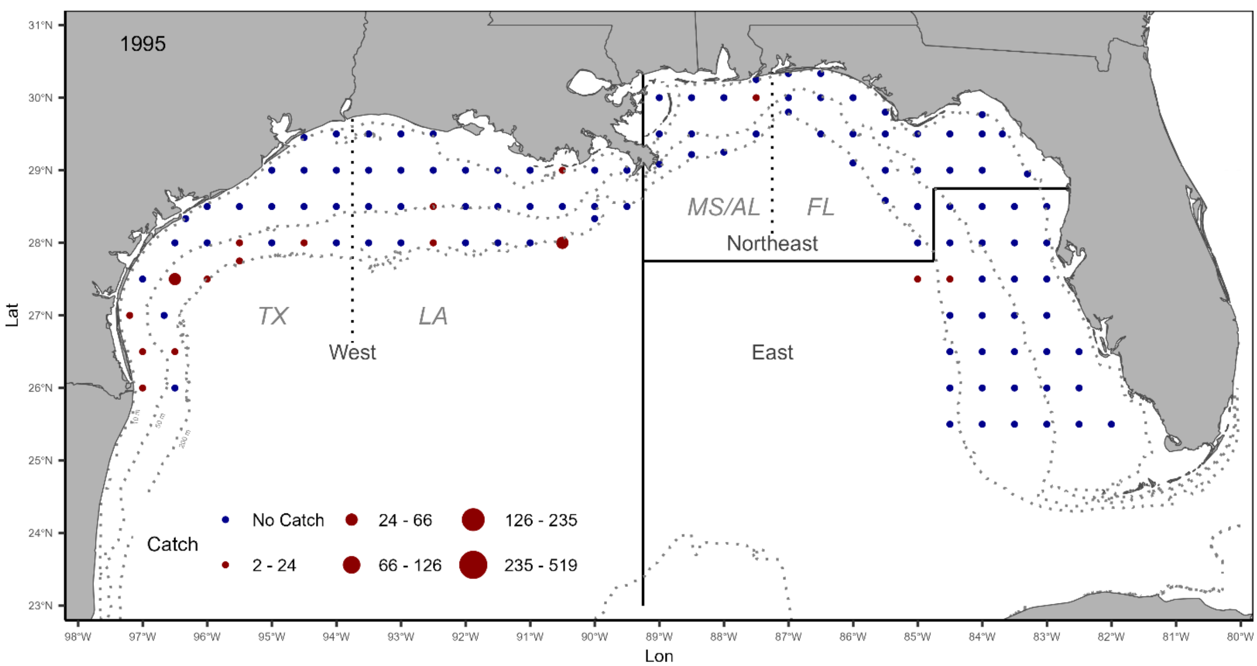
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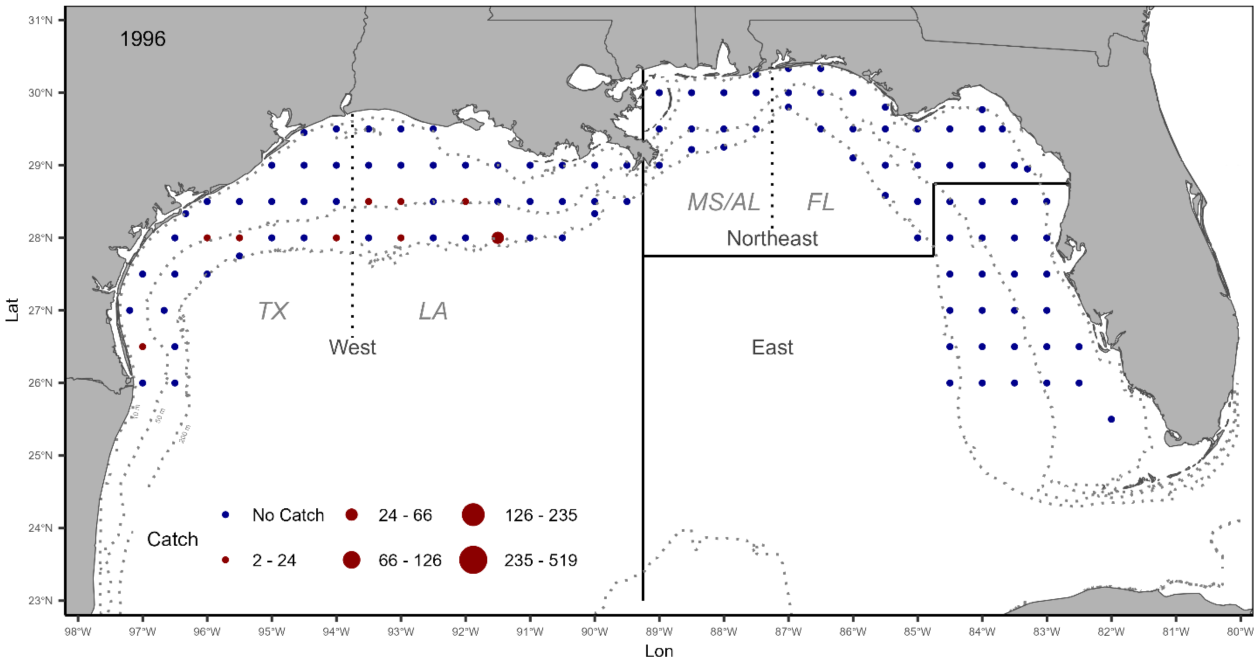
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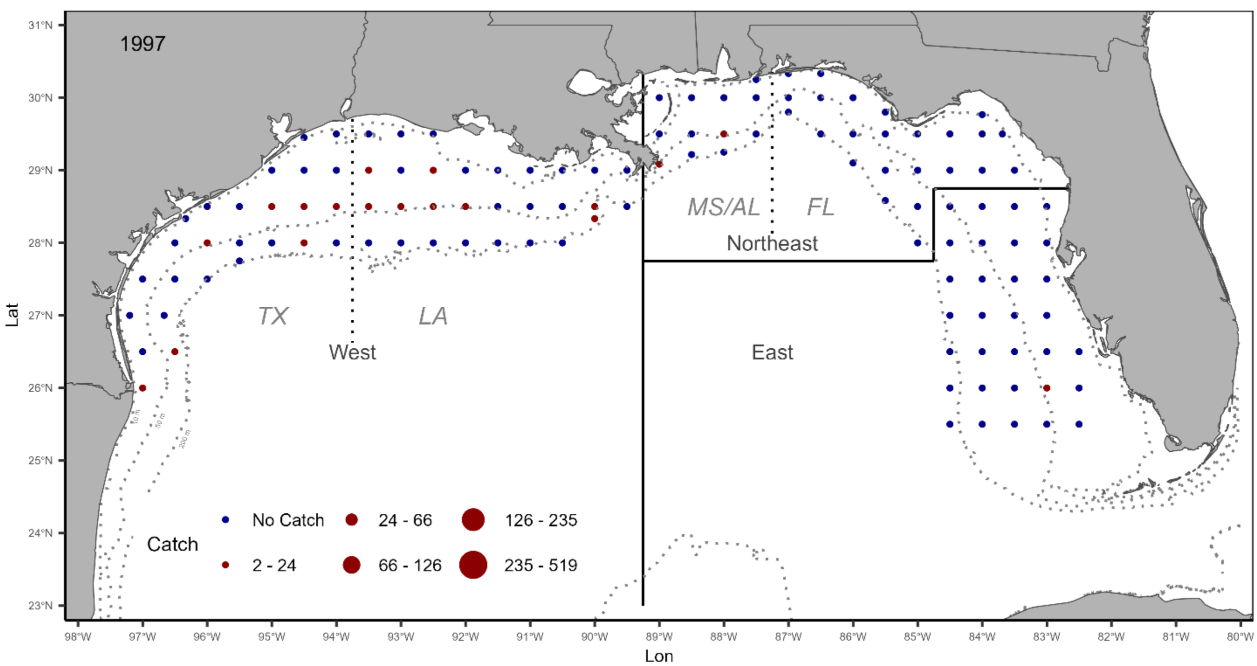
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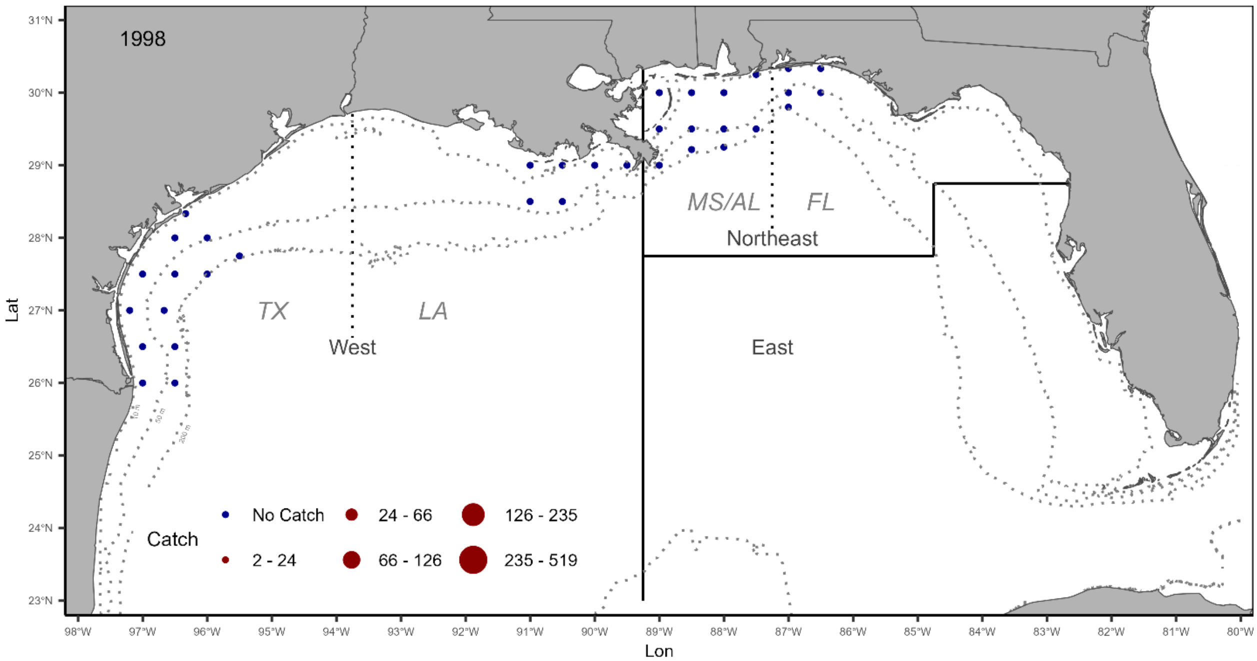
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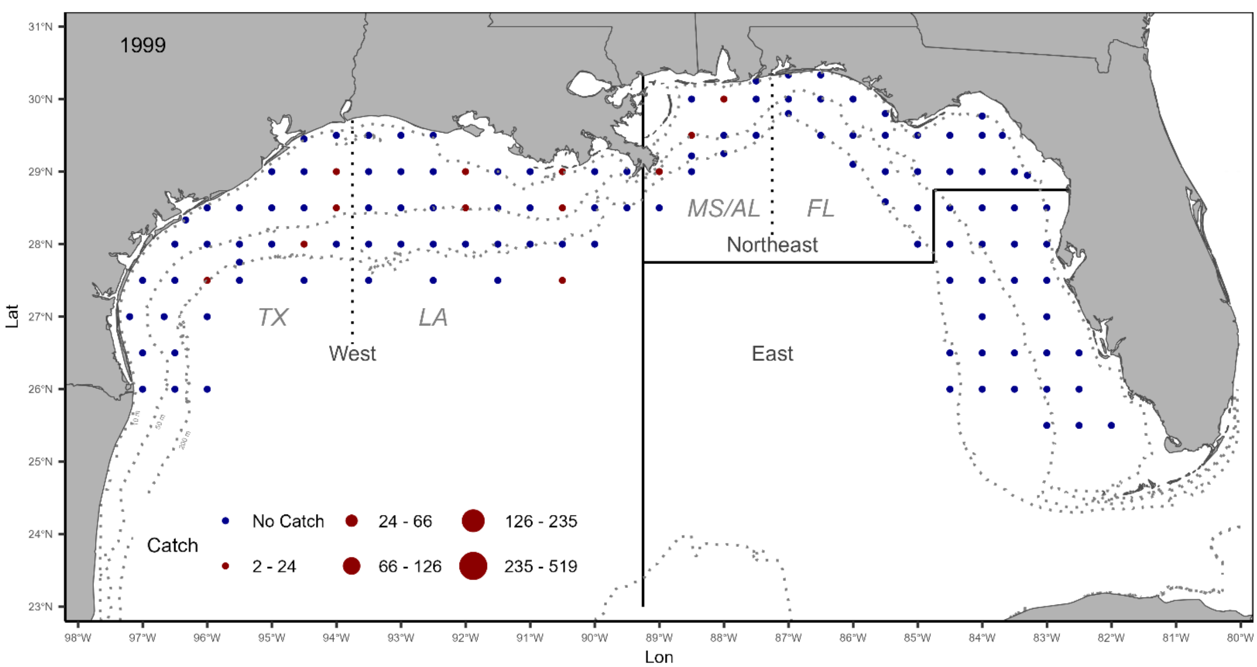
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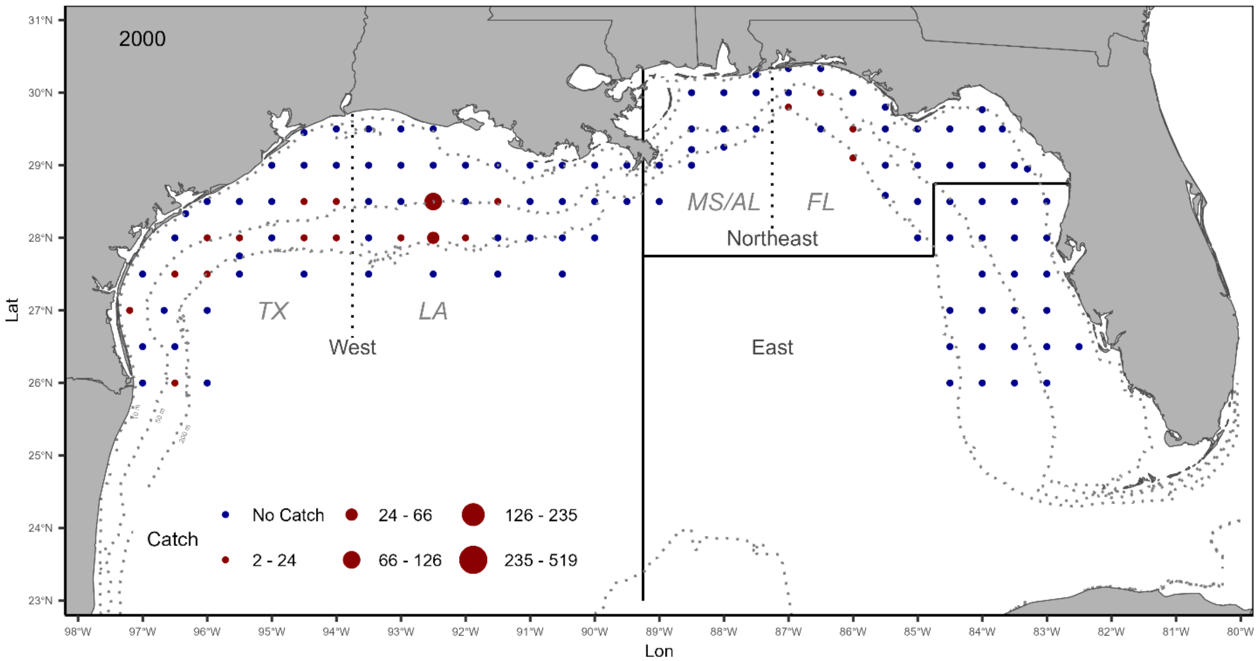
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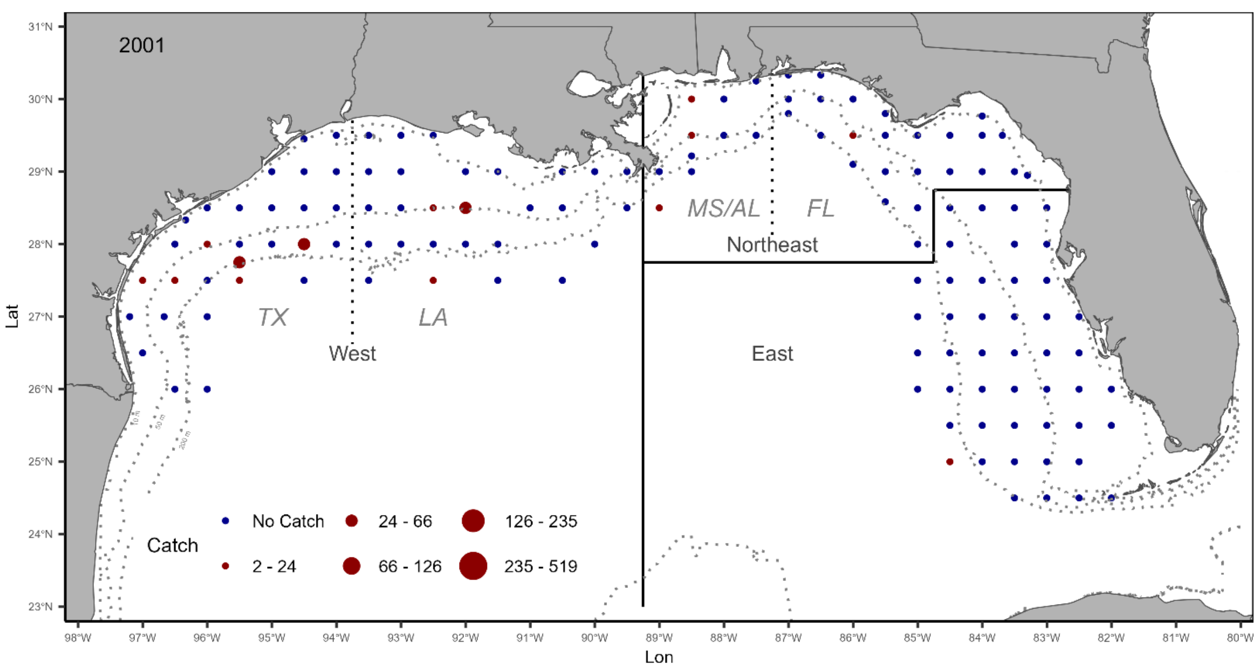
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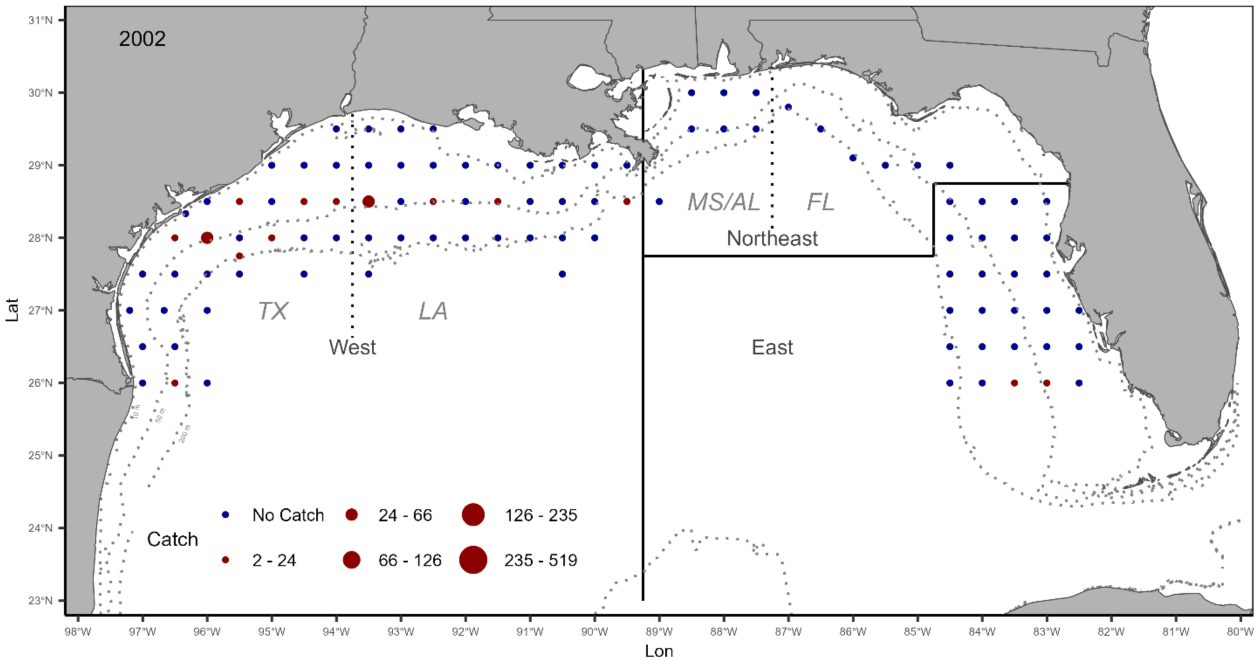

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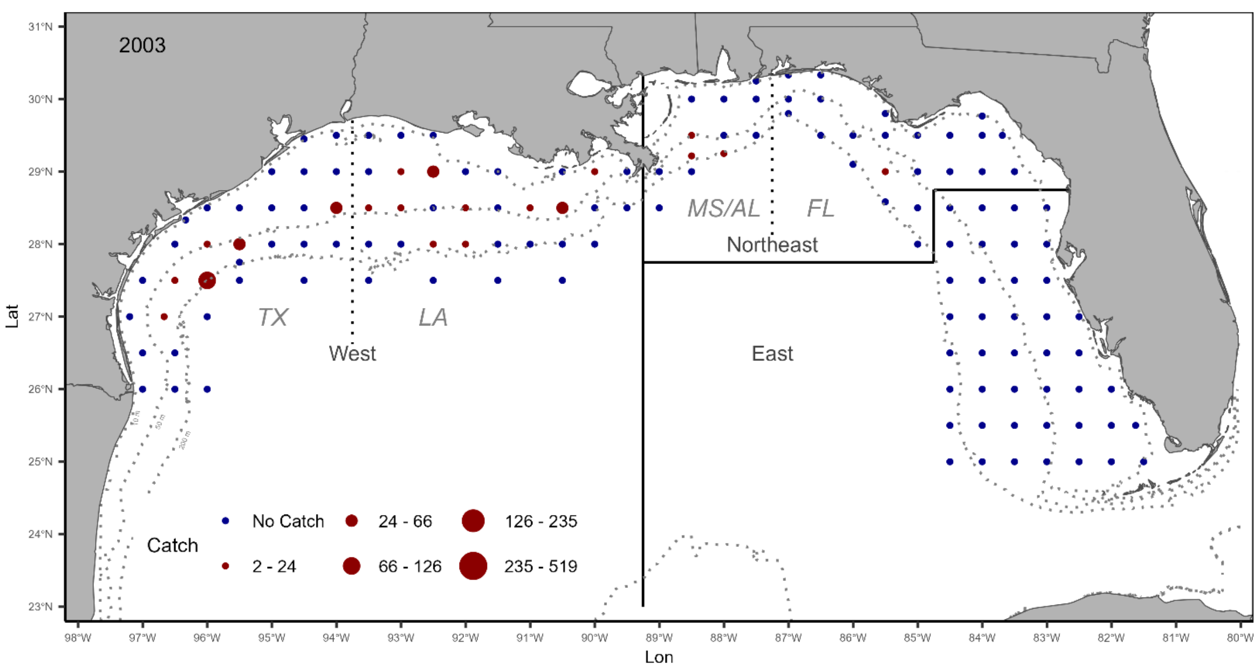

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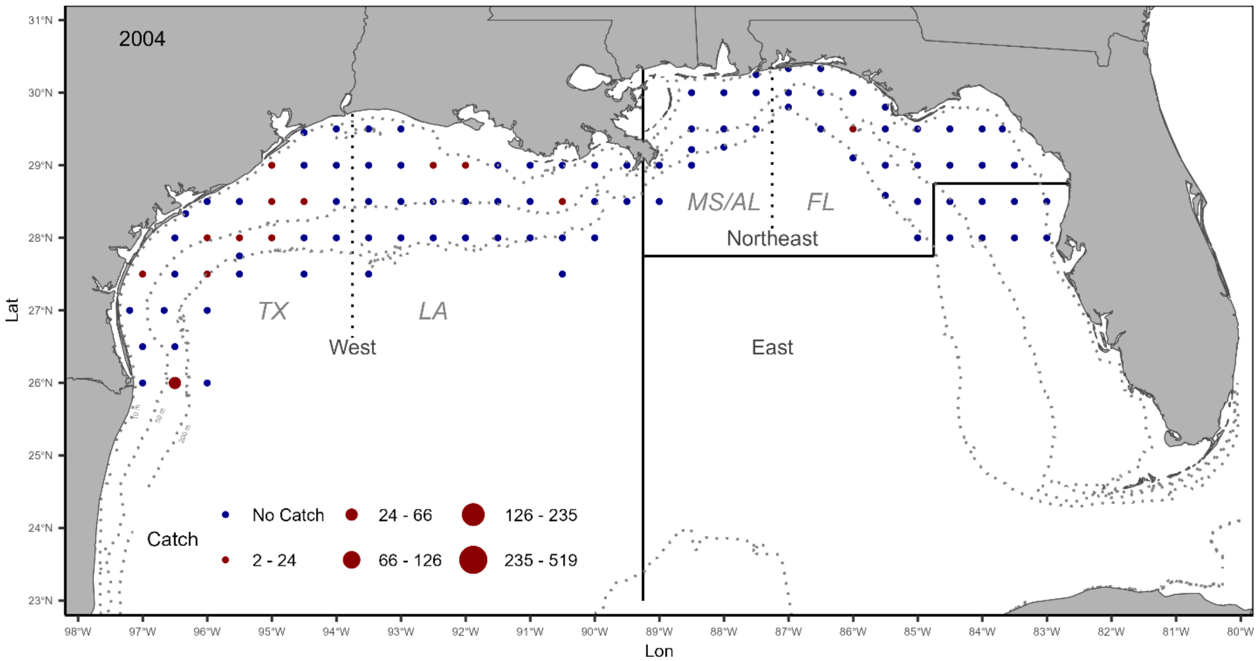
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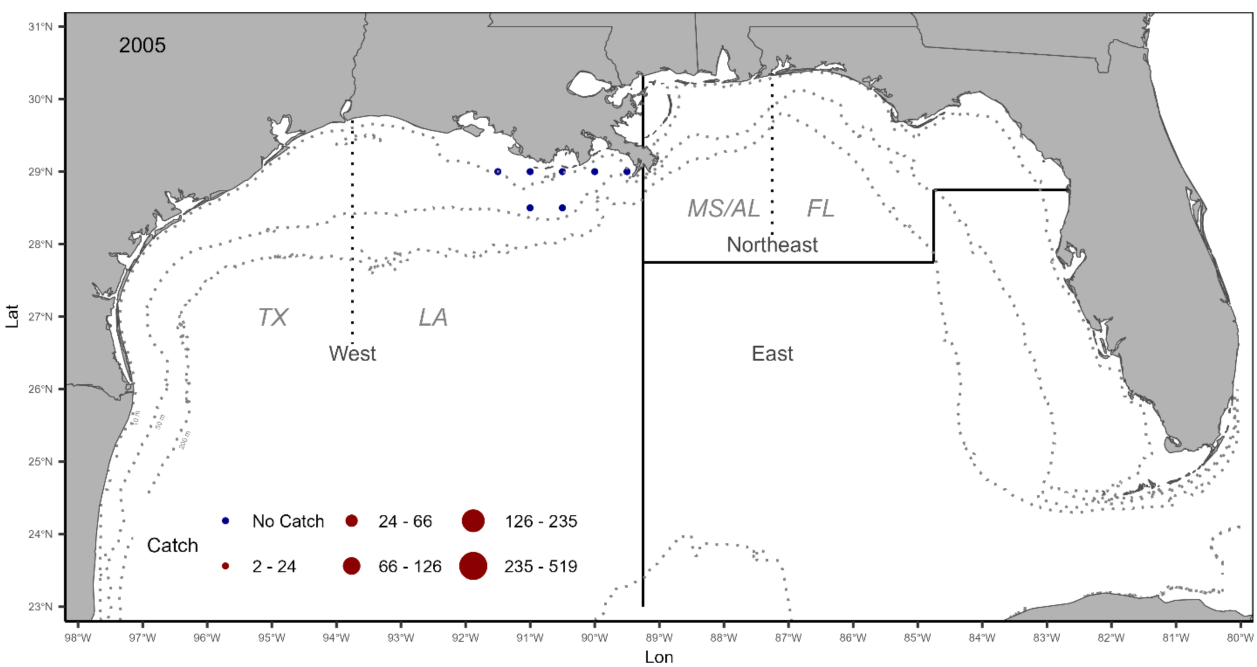
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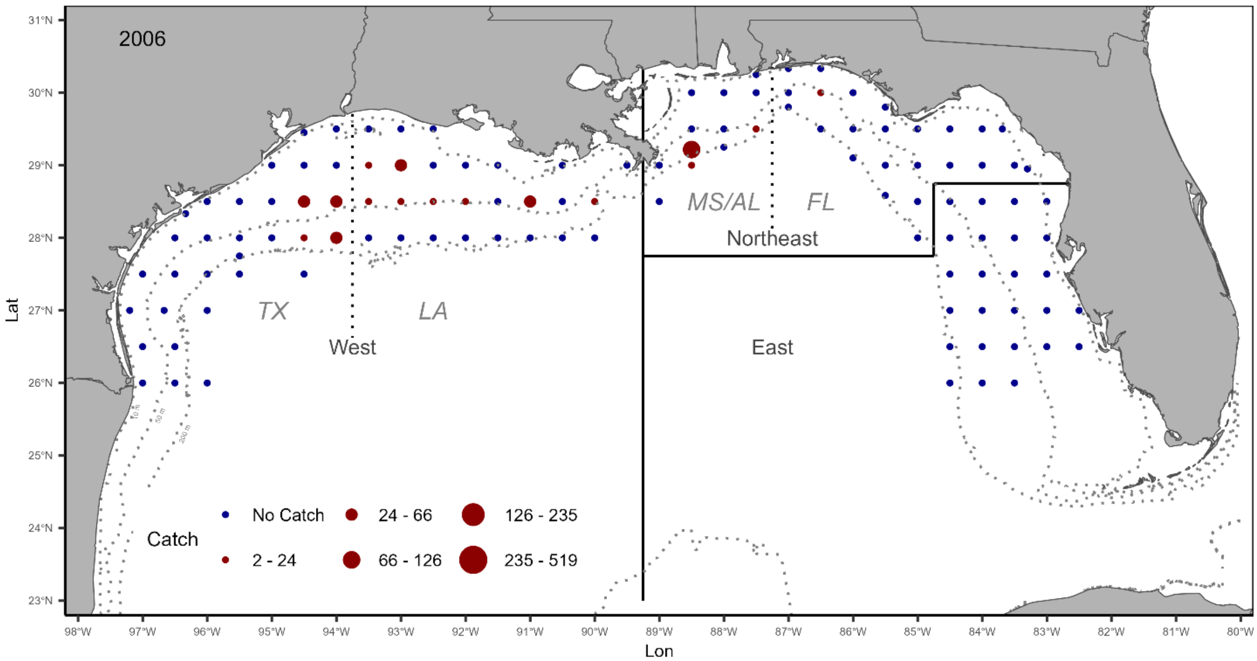
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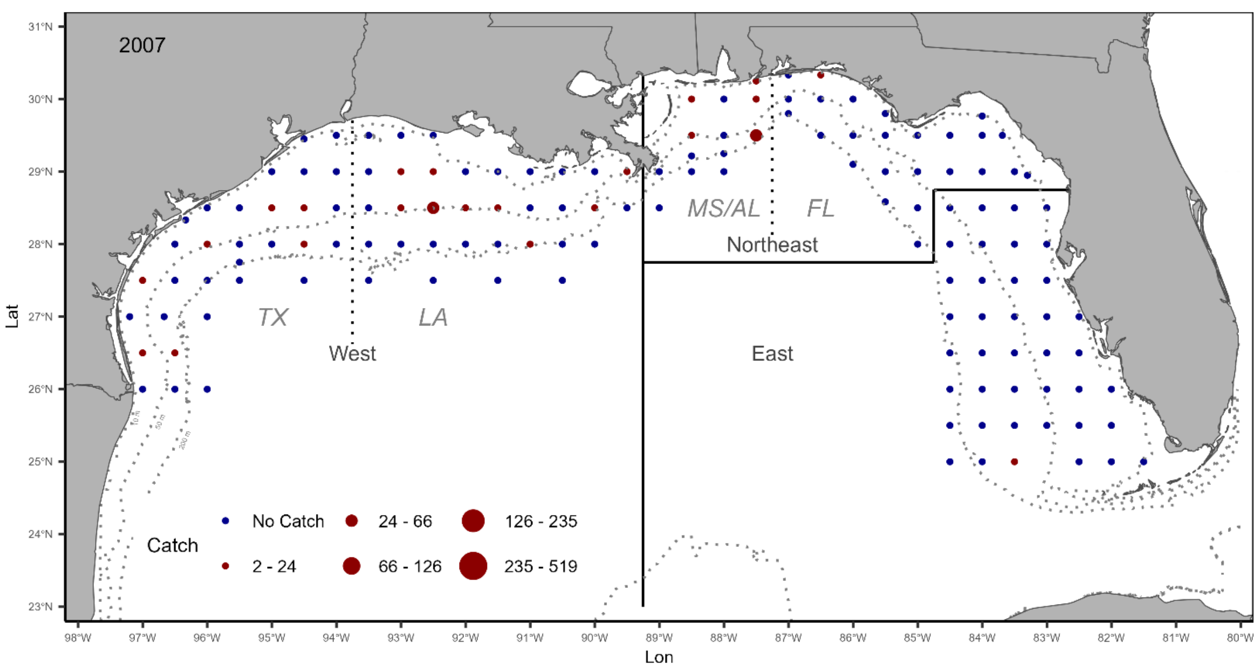
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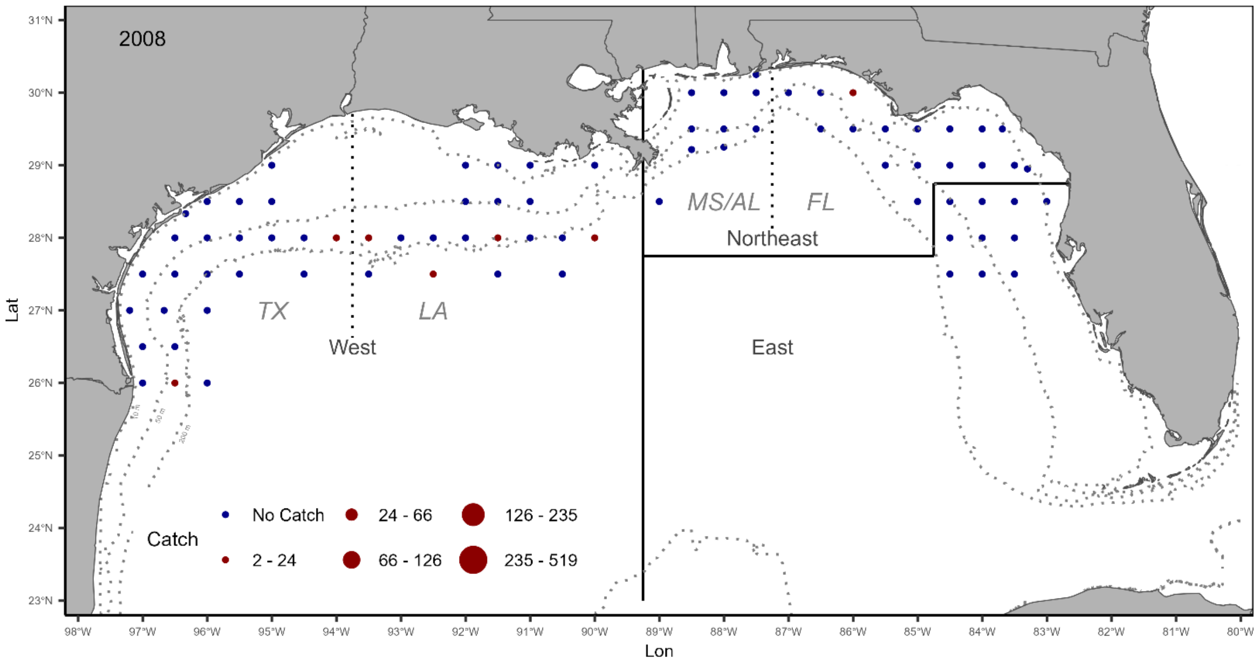
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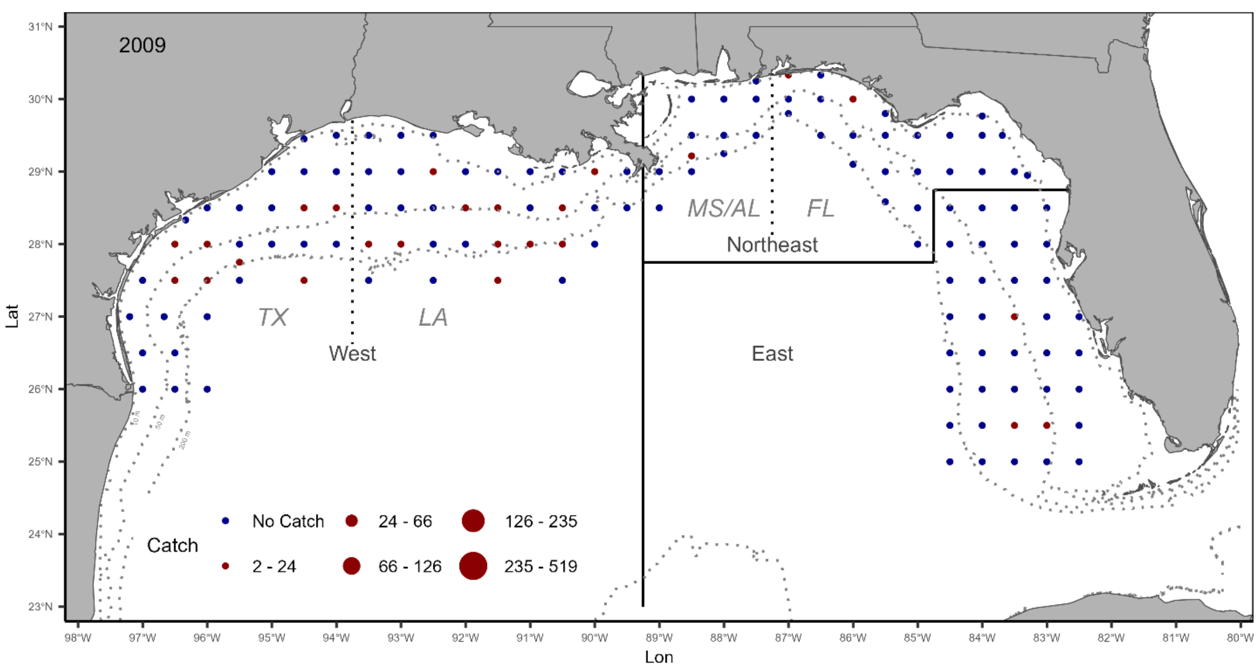
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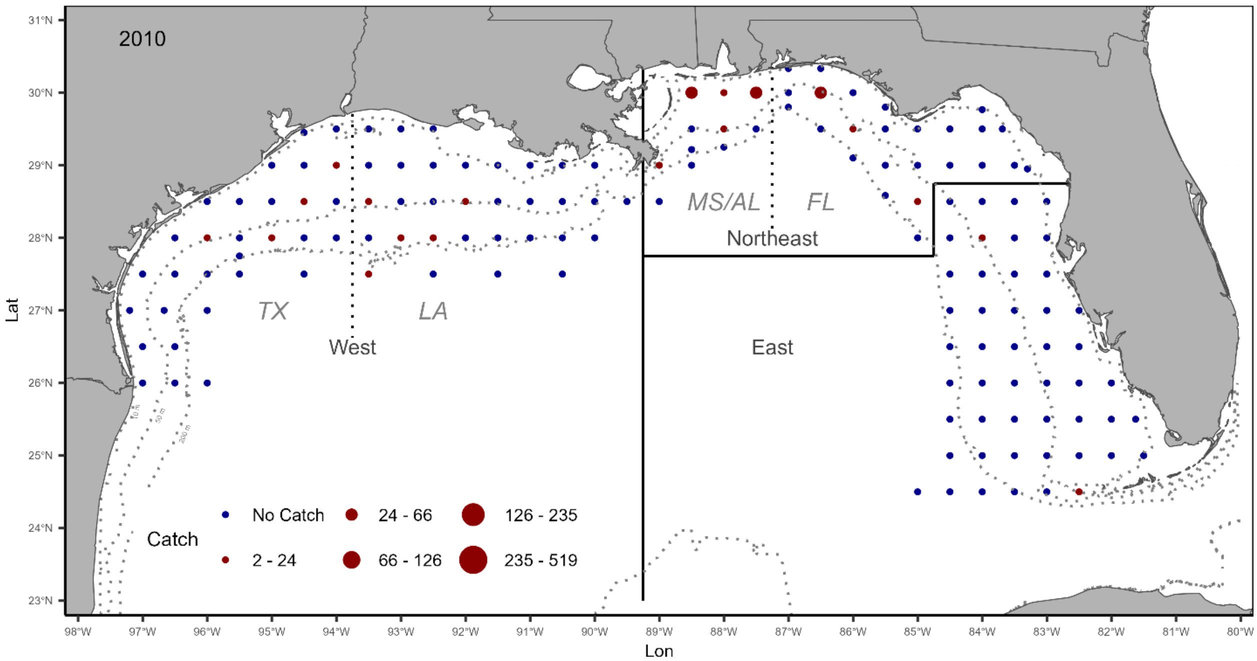
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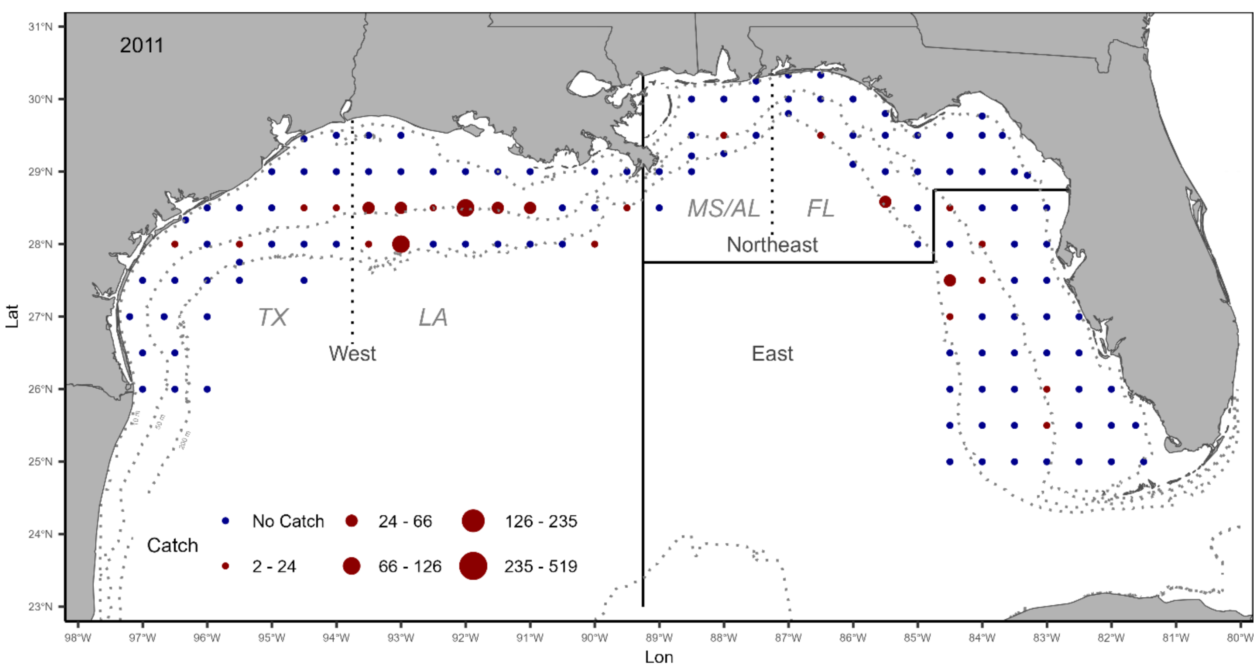
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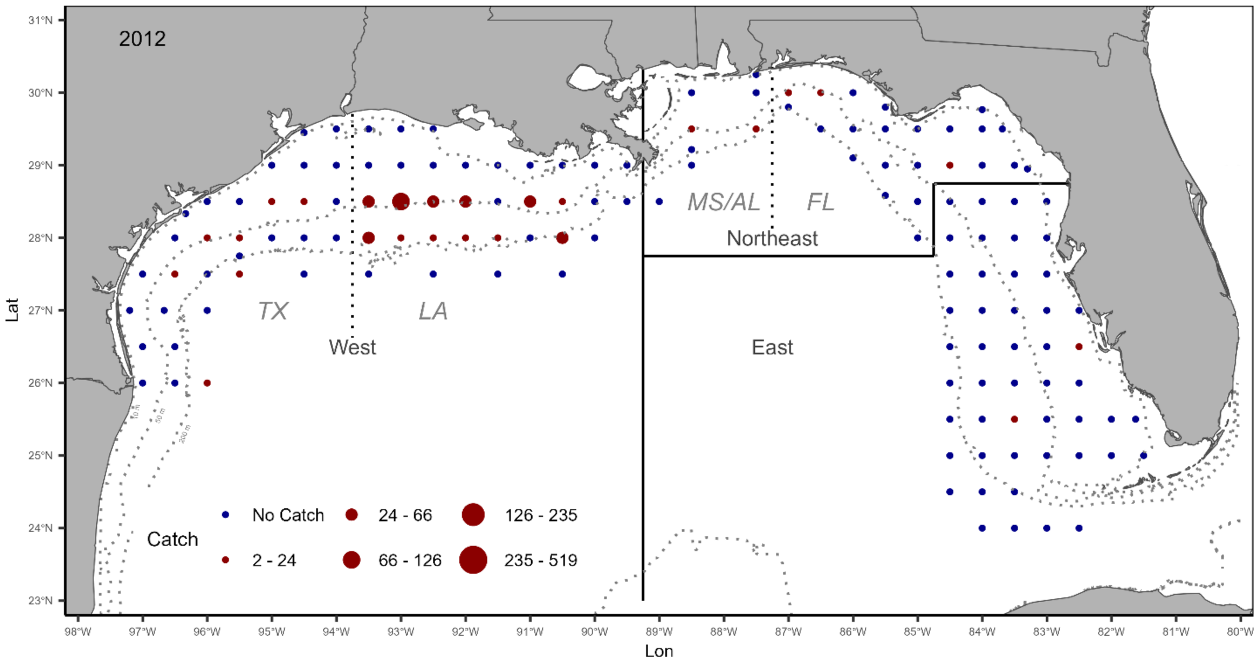
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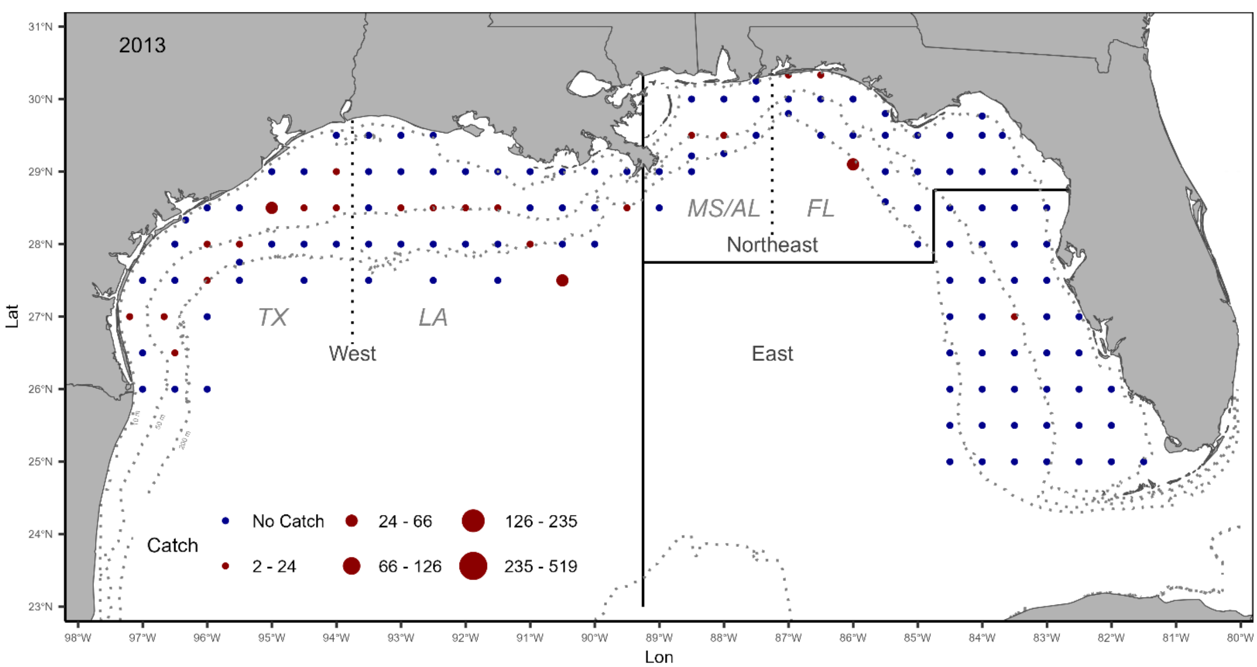
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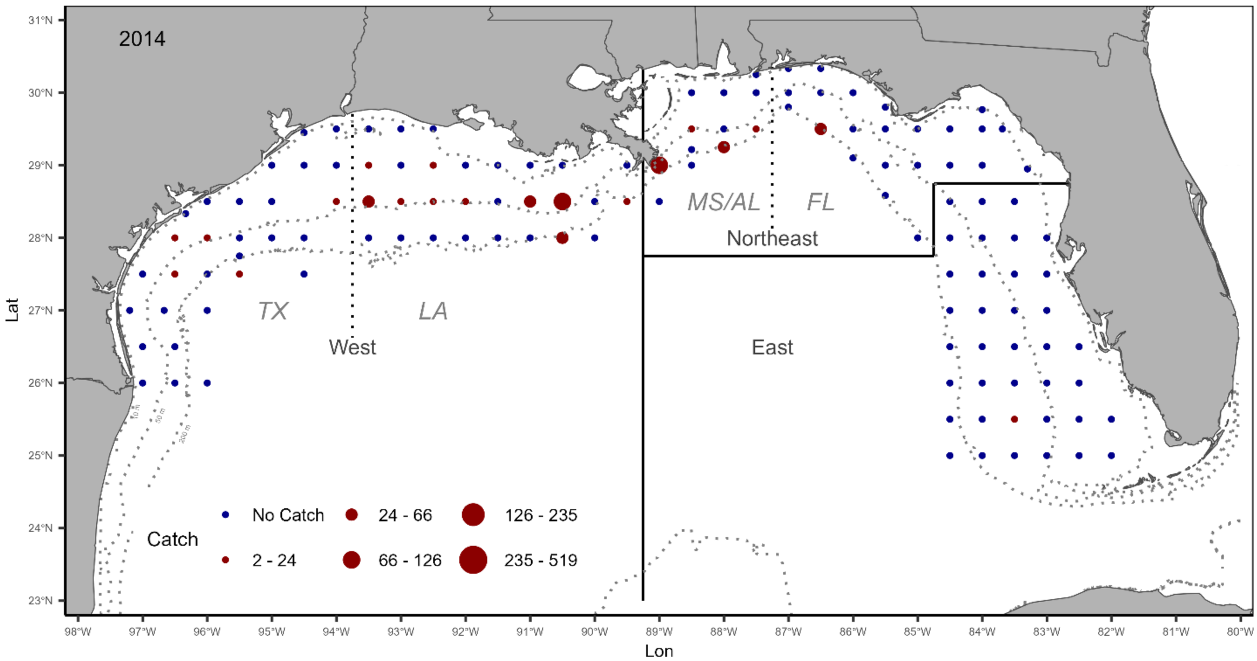
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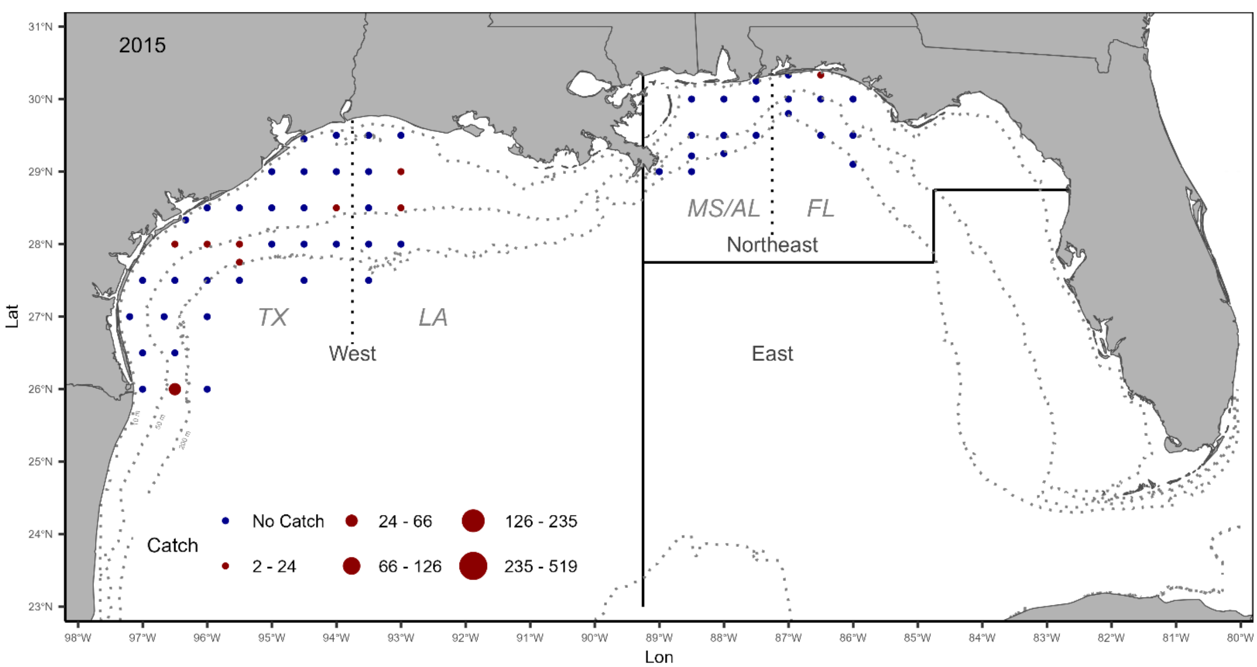
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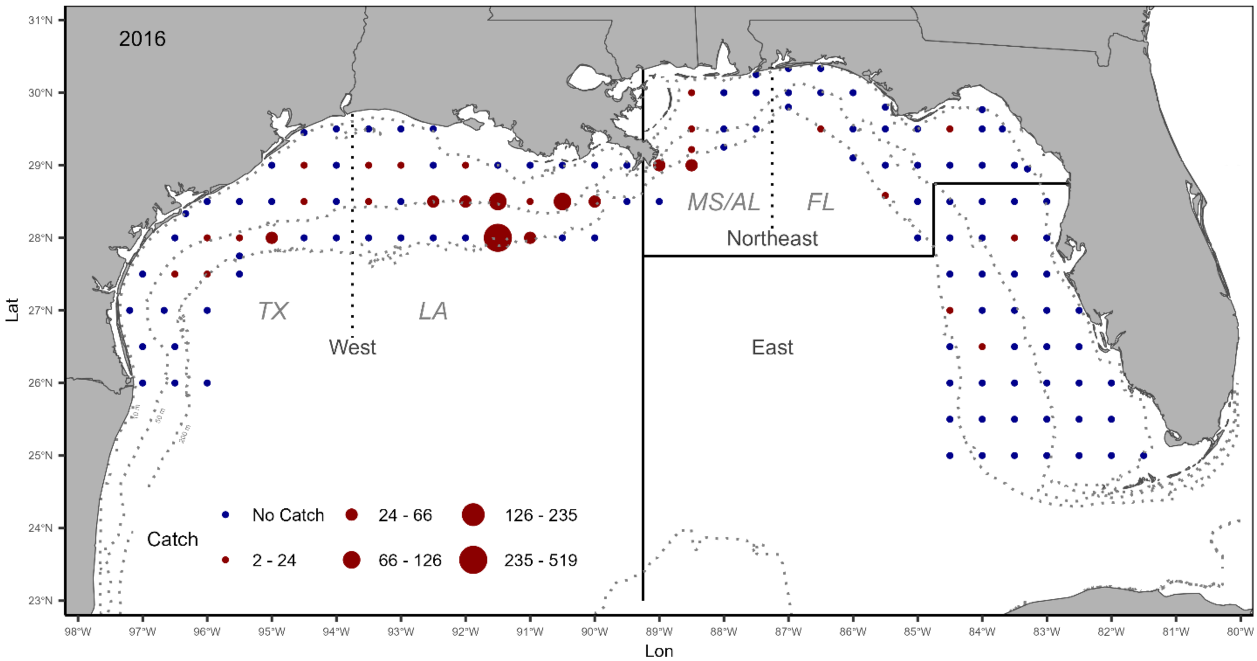
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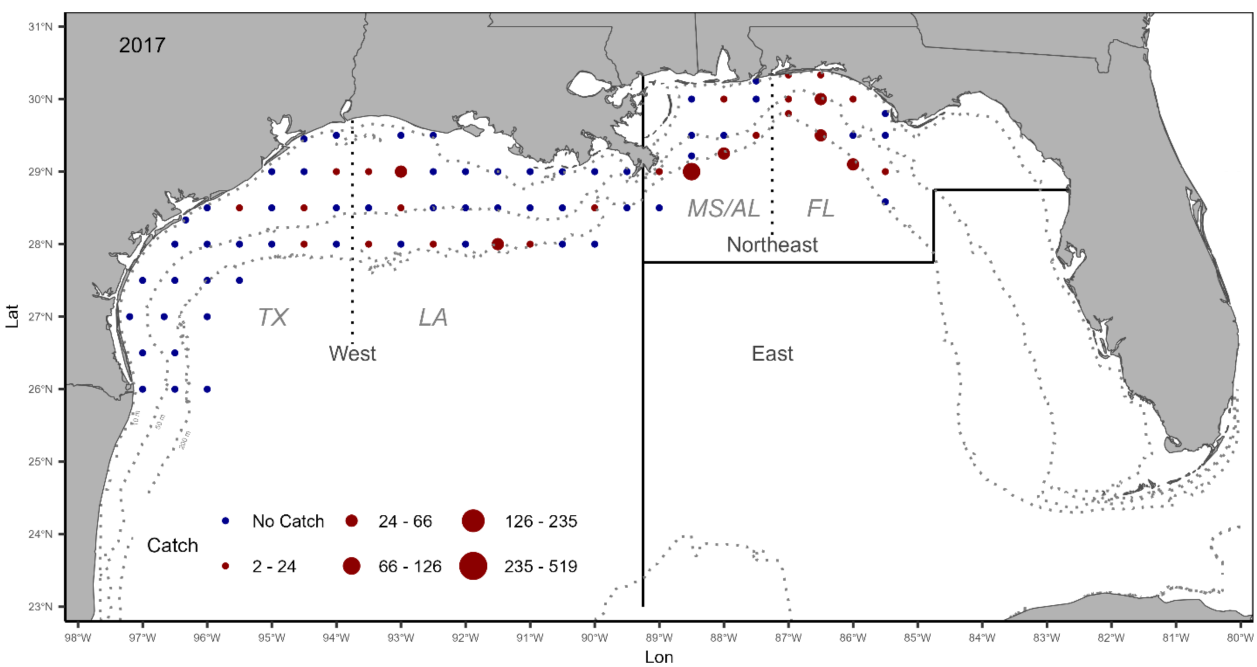
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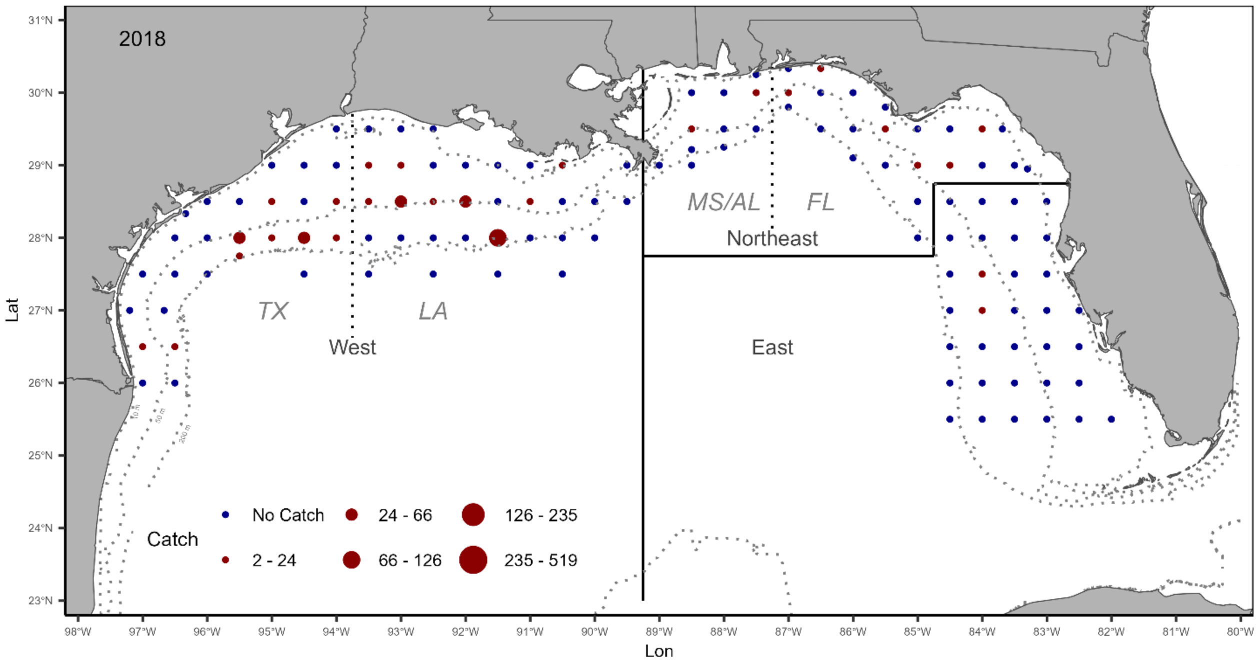
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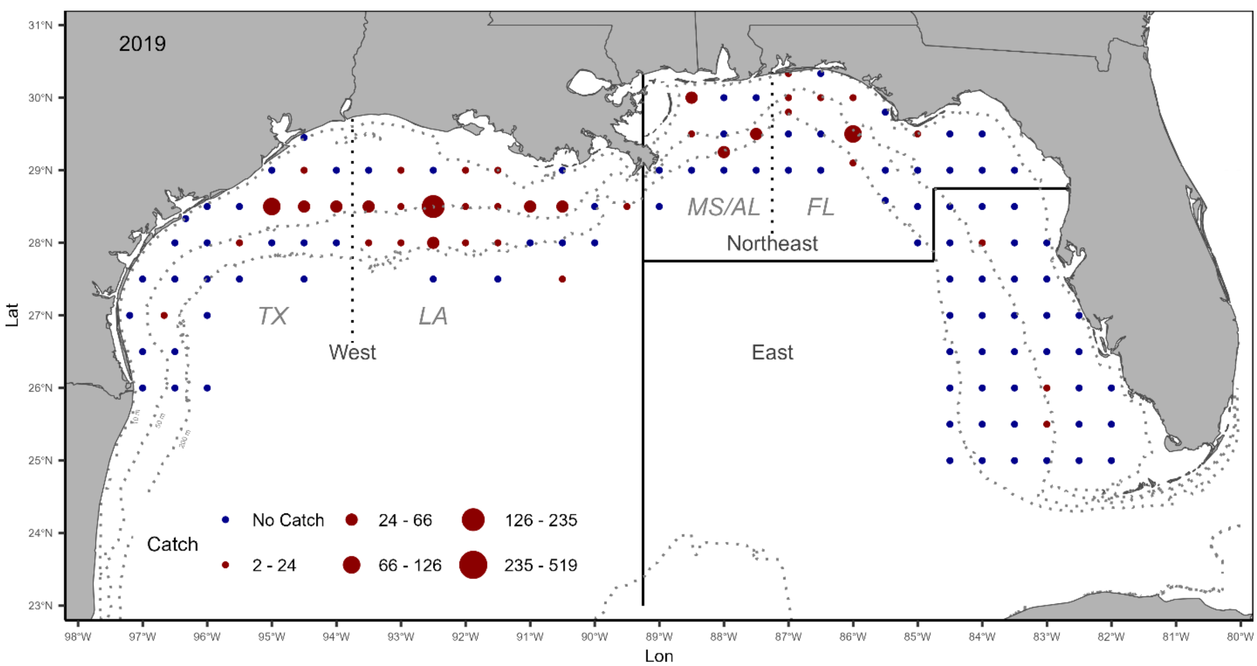
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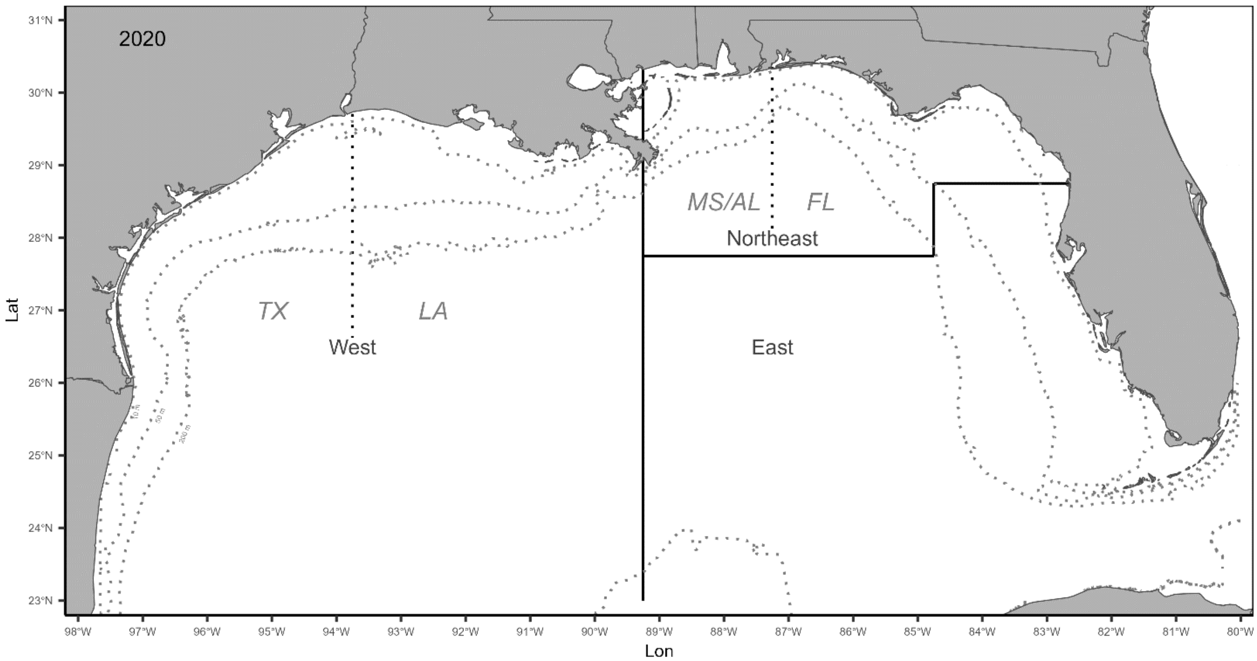
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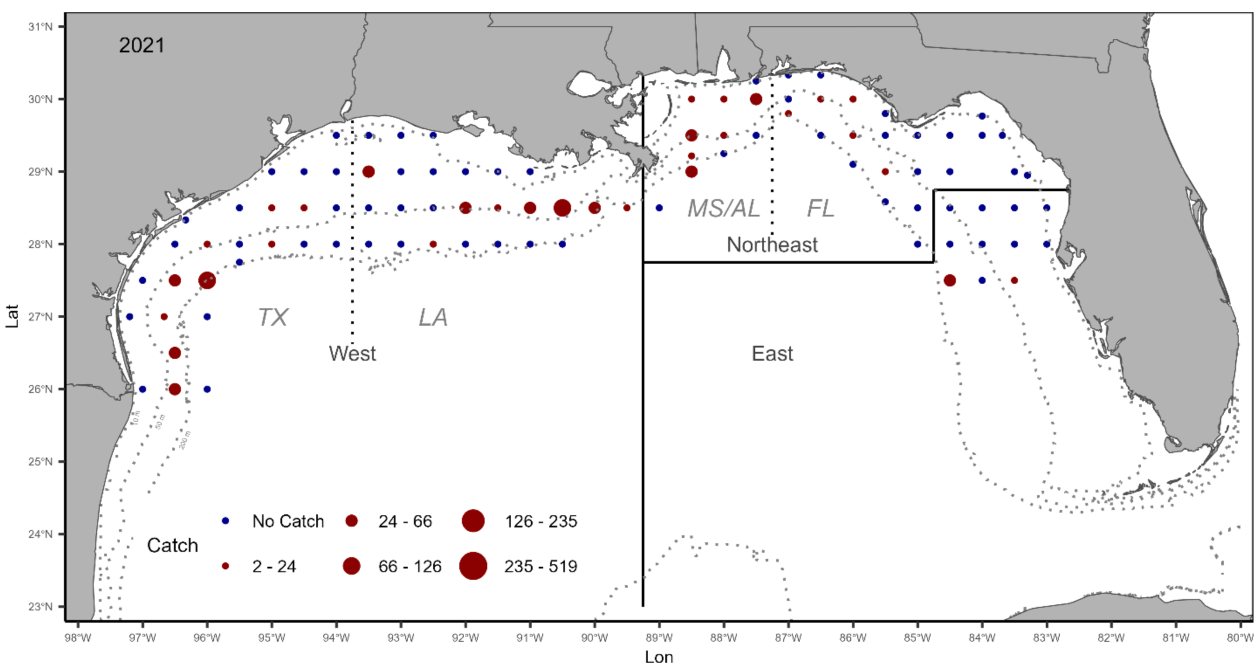
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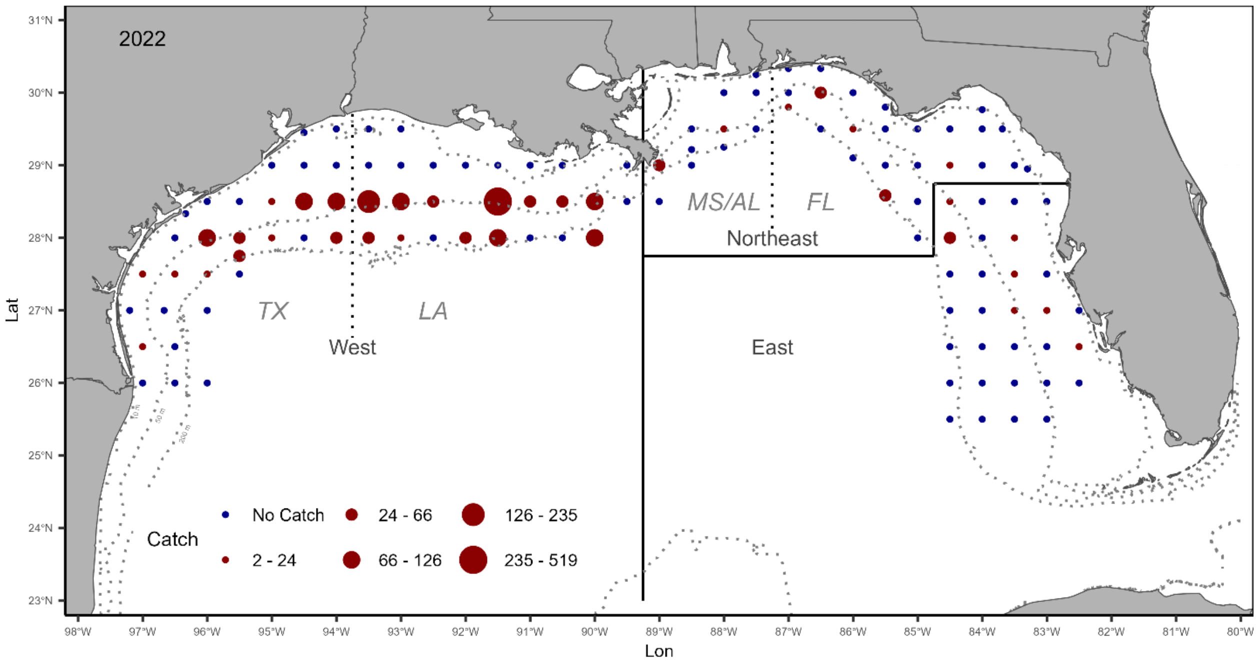
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Addendum to SEDAR98-DW-19

Initial delta-lognormal indices of larval Red Snapper based on age corrected CPUA generated for the west (WGOM) and northeast (NEGOM) Gulf of Mexico were reviewed by the Indices and Bycatch Working Group (IBWG) during the December 2025 Data Workshop. The WGOM index of larval of abundance indicated an extremely sharp increase in the terminal year (2022) of the index. Age corrected catch per unit area (CPUA) in the terminal year was roughly two times greater than the previous years, and the highest value estimated over the time series. The raw data indicated that the number of individual stations with very high CPUAs in 2022 was much greater than in previous years. However, these high abundance values were similar to previously recorded high CPUA catches throughout the later part of the time series.

The age corrected CPUA of 11.2 days old larvae are back calculated based of age at length and estimated daily mortality. During the Data Workshop delta-lognormal indices of larval abundance without age correction were generated on the same base data to determine if the sharp increase in the terminal year CPUA of the WGOM index was a result of the age correction process. The WGOM and NEGOM indices of abundance with the age correction removed showed nearly identical trends and CVs as those based on age corrected CPUA (Figures 1 and 2). In essence, the age correction process simply scales up the annual estimates. Given the near identical results in trend between the age corrected and non-age corrected indices, the IBWG recommended the use of the WGOM and NEGOM larval indices of abundance without age correction for inclusion in the assessment process.

The delta-lognormal index of larval Red Snapper CPUA without age correction for the WGOM index is presented in Table 1 and Figure 1. The backward selection procedure retained year, TOD and depth in the binomial submodel, and year, TOD and subregion in the lognormal submodel (Table 2). The AICs for the binomial and lognormal submodels were 1645.76 and 875.14, respectively. The diagnostic plots for the lognormal submodel is show in Figure 3, and indicated the distribution of the residuals is approximately normal. The delta-lognormal index of larval Red Snapper CPUA without age correction for the NEGOM is presented in Table 3 and Figure 2. The backward selection procedure retained year and subregion in the binomial submodel, and year, subregion and depth in the lognormal submodel (Table 2). The AIC for the binomial and lognormal submodels were 603.54 and 287.11, respectively. The diagnostic plots for the lognormal submodel are show in Figure 3, and indicated the distribution of the residuals is approximately normal.

Table 1. SEAMAP Fall Plankton Survey index of west Gulf of Mexico (WGOM) larval Red Snapper abundance without age correction 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	0.3913	0.4692	0.1747	0.0580	0.5265	0.5963
1987	55	0.0727	1.1262	0.8847	0.3295	0.1090	0.9959	0.5982
1988	28	0.0000	0.0000					
1989	28	0.1429	0.9031	1.2661	0.4715	0.1599	1.3909	0.5829
1990	31	0.1936	1.1680	1.2787	0.4762	0.1942	1.1680	0.4721
1991	31	0.0968	0.5814	0.5486	0.2043	0.0594	0.7028	0.6817
1992	55	0.1273	0.5388	0.5441	0.2026	0.0860	0.4776	0.4492
1993	55	0.1273	0.7172	0.6372	0.2373	0.1010	0.5577	0.4474
1994	55	0.0727	0.9218	0.5683	0.2117	0.0700	0.6397	0.5981
1995	55	0.2364	2.0913	1.8212	0.6783	0.3663	1.2560	0.3155
1996	55	0.1636	1.2406	1.3212	0.4921	0.2324	1.0417	0.3886
1997	54	0.2593	1.7667	1.8728	0.6975	0.3871	1.2569	0.3009
1998								
1999	55	0.1455	0.5842	0.6845	0.2549	0.1146	0.5673	0.4165
2000	55	0.2727	2.5056	2.3259	0.8662	0.4857	1.5449	0.2954
2001	47	0.1489	1.5555	1.4345	0.5342	0.2290	1.2461	0.4432
2002	54	0.2222	1.5754	1.6527	0.6155	0.3248	1.1666	0.3281
2003	54	0.2963	2.9331	2.5239	0.9400	0.5434	1.6260	0.2792
2004	54	0.2222	1.2116	1.3916	0.5183	0.2695	0.9968	0.3359
2005								
2006	52	0.2308	3.0184	2.7085	1.0087	0.5293	1.9225	0.3310
2007	55	0.2909	1.7869	2.0979	0.7813	0.4534	1.3465	0.2772
2008								
2009	55	0.3091	2.6970	2.7976	1.0419	0.6132	1.7703	0.2698
2010	53	0.1509	1.0109	1.1112	0.4139	0.1866	0.9181	0.4147
2011	53	0.2453	3.5225	3.3155	1.2348	0.6687	2.2804	0.3141
2012	55	0.3091	3.6863	3.7230	1.3866	0.8154	2.3580	0.2702
2013	54	0.2963	1.7922	2.1577	0.8036	0.4654	1.3877	0.2783
2014	52	0.2692	4.2811	3.3516	1.2483	0.6929	2.2489	0.3008
2015								
2016	55	0.3455	8.3130	7.0066	2.6095	1.5989	4.2588	0.2486
2017	53	0.2264	1.7905	1.4808	0.5515	0.2896	1.0502	0.3306
2018	53	0.3396	3.7152	3.2970	1.2279	0.7383	2.0422	0.2585
2019	47	0.4681	8.8051	6.9648	2.5940	1.6773	4.0115	0.2206
2020								
2021	49	0.3469	6.8274	7.2502	2.7003	1.6086	4.5327	0.2634
2022	52	0.4423	16.8373	14.7483	5.4928	3.5688	8.4540	0.2181

Table 2. Summary of the final delta-lognormal models from the backward selection procedure for the west Gulf of Mexico (WGOM) and northeast Gulf of Mexico (NEGOM) indices of abundance.

West Gulf of Mexico (WGOM)

	Binomial Submodel Type 3 Tests (AIC=1645.76)						*Lognormal Submodel Type 3 Tests (AIC=875.14)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	30	1547	79.22	2.64	<.0001	<.0001	30	336	5.36	<.0001
TOD	1	1547	38.85	38.85	<.0001	<.0001	1	336	28.32	<.0001
SUBREGION			Dropped				1	336	6.75	<.0098
DEPTH	1	1547	5.60	5.60	0.0180	0.0180			Dropped	

Northeast Gulf of Mexico (NEGOM)

	Binomial Submodel Type 3 Tests (AIC=603.54)						*Lognormal Submodel Type 3 Tests (AIC=287.11)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	24	727	64.99	2.71	<.0001	<.0001	24	90	1.06	0.3994
TOD				Dropped					Dropped	
SUBREGION	1	727	19.81	19.81	<.0001	<.0001	1	90	24.49	0.0001
DEPTH				Dropped			1	90	13.43	0.0004

Table 3. SEAMAP Fall Plankton Survey index of northeast Gulf of Mexico (NEGOM) larval Red Snapper abundance without age correction 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	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	0.2101	0.1740	0.1127	0.0178	0.7127	1.1576
1992	33	0.0000	0.0000					
1993	30	0.0000	0.0000					
1994	33	0.0303	0.1115	0.0866	0.0561	0.0088	0.3584	1.1668
1995	30	0.0333	0.0959	0.0928	0.0601	0.0094	0.3831	1.1649
1996	33	0.0000	0.0000					
1997	32	0.0313	0.0926	0.0818	0.0530	0.0083	0.3381	1.1659
1998	14	0.0000	0.0000					
1999	33	0.0909	0.6221	0.5070	0.3285	0.0965	1.1185	0.6748
2000	33	0.1212	0.8924	1.2678	0.8214	0.2796	2.4127	0.5803
2001	31	0.0968	0.2962	0.3863	0.2503	0.0743	0.8433	0.6679
2002	12	0.0000	0.0000					
2003	32	0.1250	0.7822	0.6850	0.4438	0.1517	1.2981	0.5777
2004	33	0.0303	0.1081	0.1800	0.1166	0.0183	0.7447	1.1669
2005								
2006	33	0.0909	1.3263	1.0844	0.7026	0.2074	2.3798	0.6714
2007	33	0.1818	1.4209	1.3542	0.8774	0.3633	2.1191	0.4632
2008	25	0.0400	0.1348	0.2349	0.1522	0.0239	0.9706	1.1658
2009	33	0.0909	0.6459	0.9434	0.6112	0.1803	2.0725	0.6721
2010	32	0.2500	3.0984	3.1994	2.0729	0.9850	4.3624	0.3853
2011	33	0.0909	1.1379	1.1534	0.7473	0.2195	2.5446	0.6749
2012	27	0.1852	0.8742	1.3332	0.8638	0.3383	2.2060	0.4958
2013	33	0.1515	1.4698	1.4931	0.9674	0.3702	2.5282	0.5094
2014	31	0.1613	2.8923	1.5955	1.0338	0.3921	2.7255	0.5146
2015	19	0.0526	0.1560	0.2356	0.1526	0.0239	0.9758	1.1680
2016	33	0.2121	2.2891	2.0470	1.3263	0.5918	2.9723	0.4205
2017	23	0.5652	5.7738	5.7860	3.7488	2.2345	6.2894	0.2631
2018	32	0.2500	1.5817	2.3277	1.5081	0.7108	3.1998	0.3898
2019	29	0.4138	5.2474	5.7098	3.6994	2.1068	6.4959	0.2872
2020								
2021	31	0.3548	4.2540	4.1488	2.6880	1.4641	4.9351	0.3109
2022	32	0.2188	2.3066	2.4781	1.6056	0.7199	3.5810	0.4178

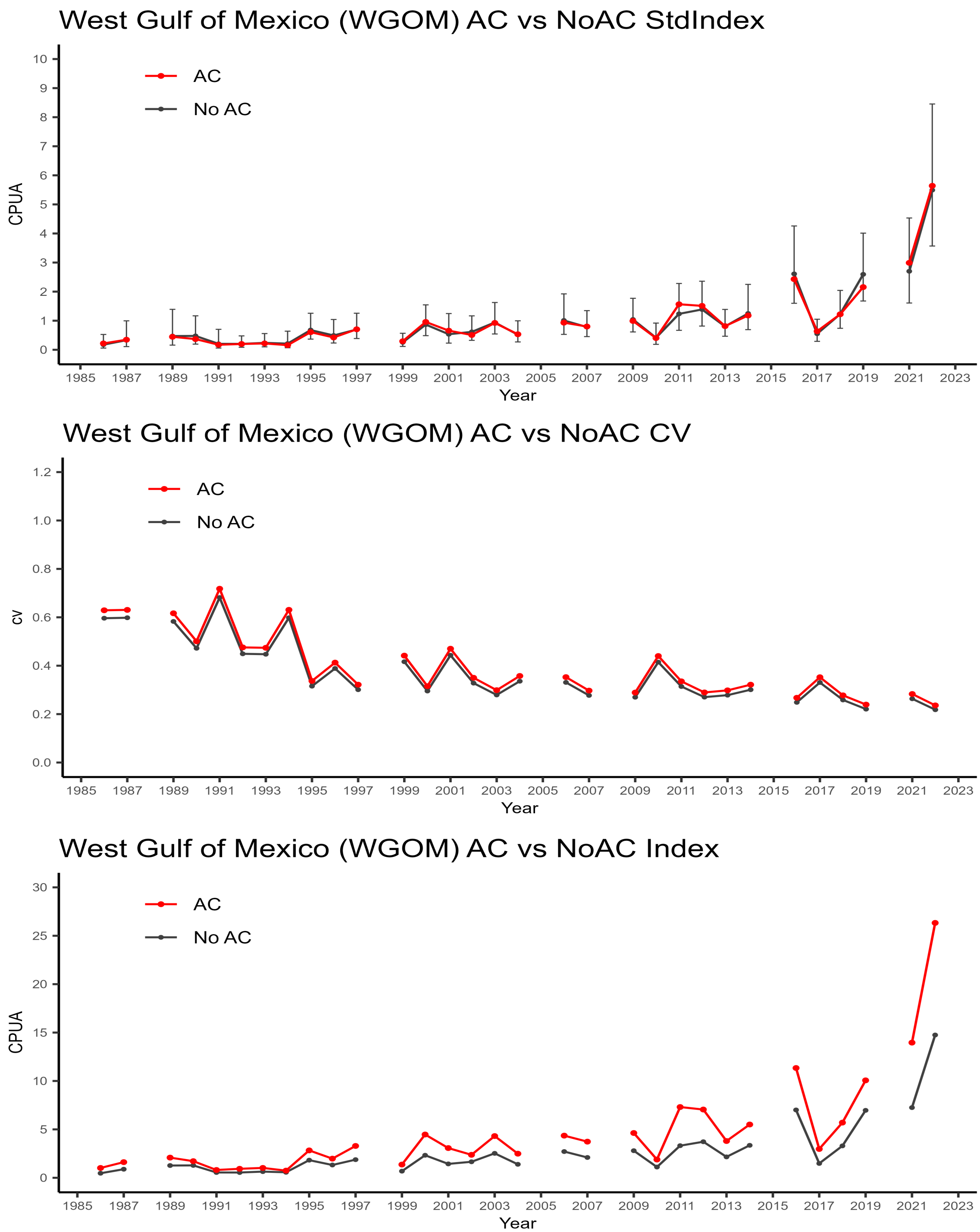


Figure 1. Age corrected (AC) vs non-age corrected (NoAC) scaled (top) annual index of larval Red Snapper catch per unit area (CPUA), coefficient of variation (standard error/mean) of CPUA and unscaled annual index of CPUA (bottom) from SEAMAP Fall Plankton Surveys from 1986 to 2022 for the west (WGOM) Gulf of Mexico.

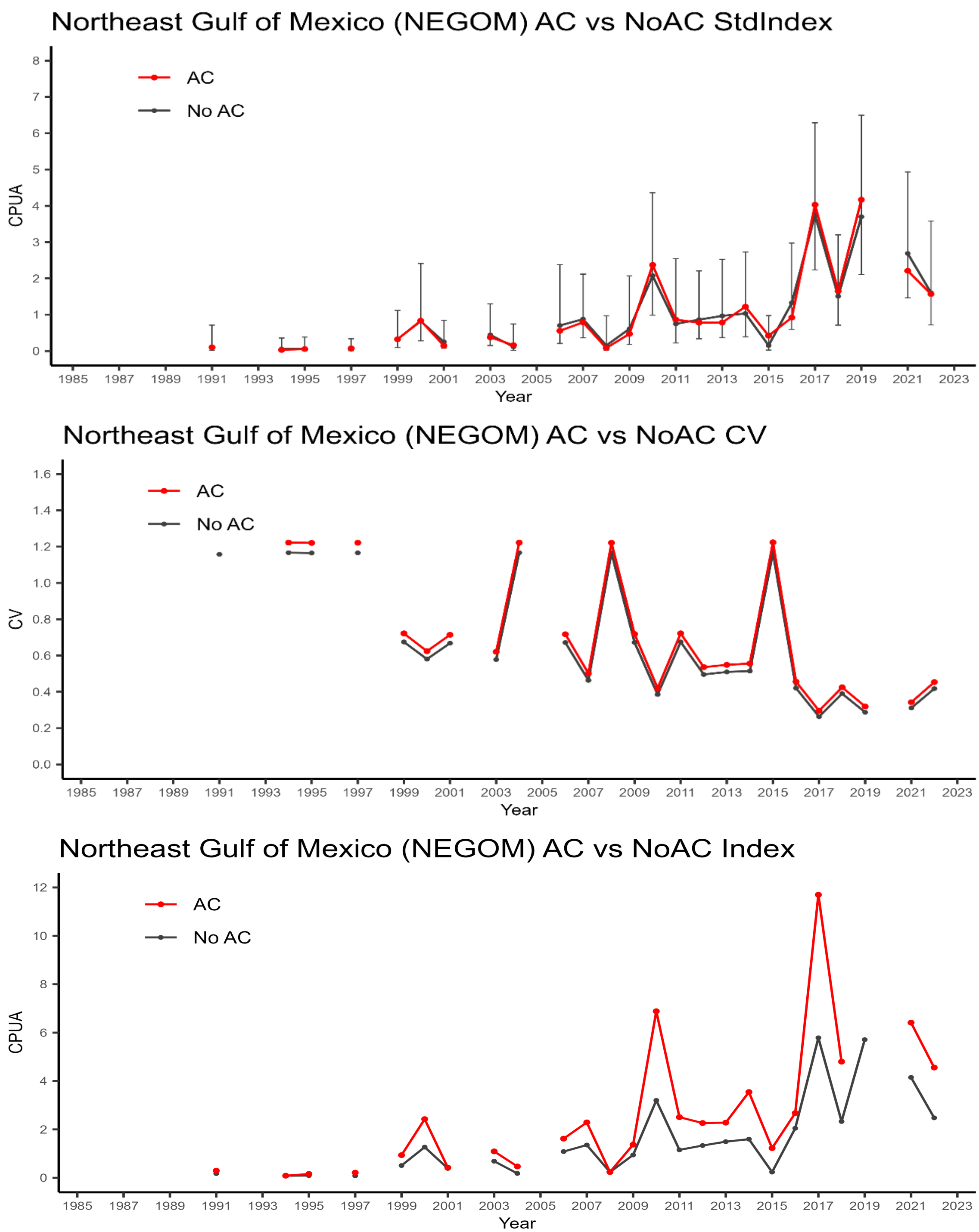
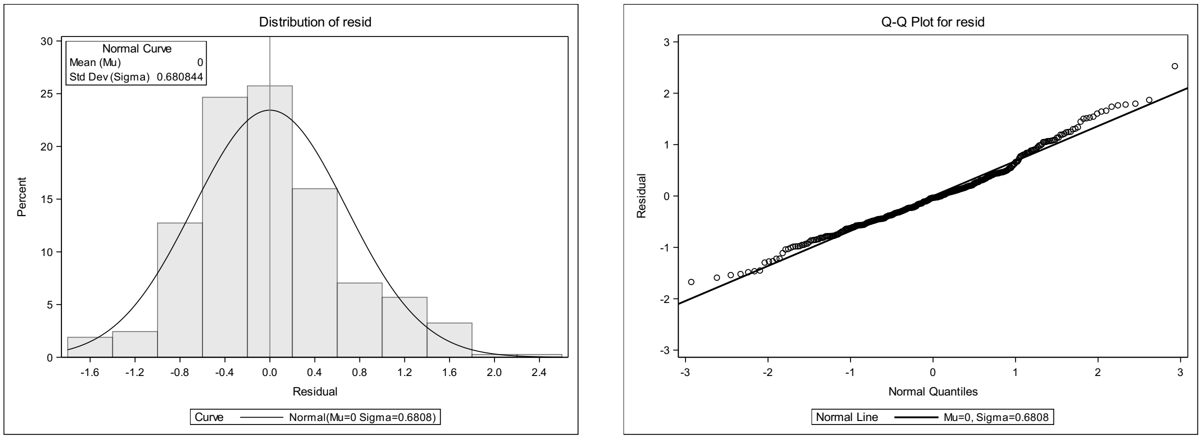


Figure 2. Figure 1. Age corrected (AC) vs non-age corrected (NoAC) scaled (top) annual index of larval Red Snapper catch per unit area (CPUA), coefficient of variation (standard error/mean) of CPUA and unscaled annual index of CPUA (bottom) from SEAMAP Fall Plankton Surveys from 1986 to 2022 for the west (WGOM) and northeast (NEGOM) Gulf of Mexico.

Western Gulf of Mexico (WGOM)



Northeastern Gulf of Mexico (NEGOM)

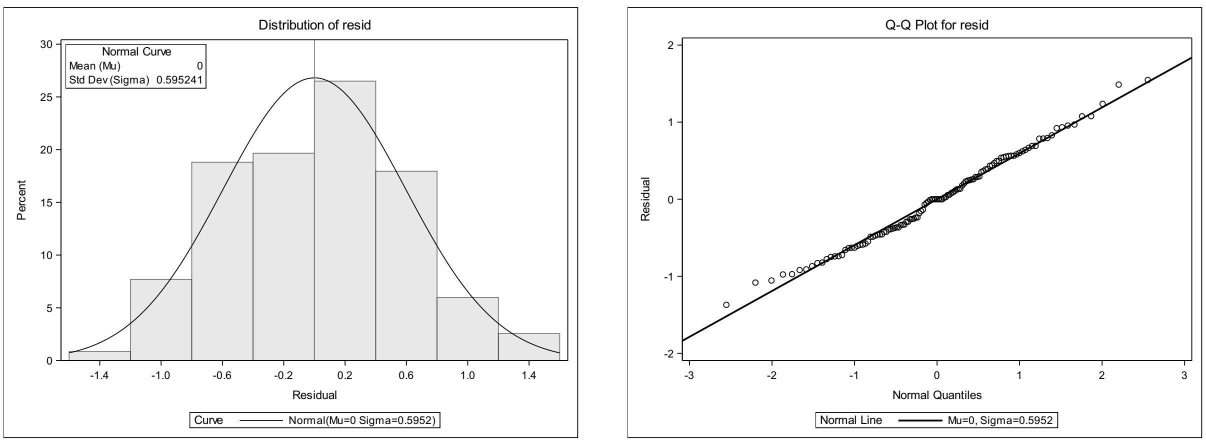


Figure 3. Diagnostic plots for the lognormal submodel of the non-age corrected west (WGOM, top) and northeast (NEGOM, bottom) indices of abundance: Left column shows the frequency distribution of log (CPUA) on positive stations and the right column the cumulative normalized residuals (QQ plot).