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Spanish Mackerel Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico

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Abstract

The NOAA Fisheries Southeast Fisheries Science Center (SEFSC), Population and Ecosystem Monitoring Division, Trawl and Plankton Branch and state partners have conducted groundfish surveys since 1972 in the northern Gulf of Mexico (GOM) during the summer and fall under several sampling programs. In 1987, both groundfish surveys (summer and fall) were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent data were used to develop abundance indices for Spanish mackerel (Scomberomorus maculatus). The recommendation from SEDAR 28 was for one abundance index for Spanish mackerel from the SEAMAP Summer and Fall Groundfish Surveys. However, following current best practices the time series was split when the survey design was changed in 2008 and two indices were produced for Spanish mackerel. The first index covers the time period from 1987 – 2008 covering the northwestern and central GOM and the second from 2008 – 2021 covering the entire northern GOM. Although the second index goes through 2021, it should be noted that zero Spanish mackerel were captured in 2021.

Introduction

The NOAA Fisheries Southeast Fisheries Science Center (SEFSC), Population and Ecosystem Monitoring Division, Trawl and Plankton Branch and state partners have conducted standardized fall groundfish surveys under the Southeast Area Monitoring and Assessment Program (SEAMAP) in the Gulf of Mexico (GOM) since 1987. Prior to 1987, the summer survey was conducted under SEAMAP protocols; however, the fall survey operated independent of SEAMAP and dates back to 1972. SEAMAP is a collaborative effort between federal, state and university programs, designed to collect, manage and distribute fishery independent data throughout the region. The primary objective of this trawl survey is to collect data on the abundance and distribution of demersal organisms in the northern GOM. This survey, which is conducted semi-annually (summer and fall), provides an important source of fisheries independent information on many commercially and recreationally important species throughout the GOM.

The recommendation of the SEDAR 28 Indices Workgroup (SEDAR 2013) was a single abundance index produced for Spanish mackerel (*Scomberomorus maculatus*) from 1987-2011 (Pollack and Ingram 2012). However, in keeping with current best practices, two abundance indices were produced, with the split in the time series occurring when the survey design was changed in 2008. The indices still utilized combined data from both the summer and fall surveys in the western and central GOM for the 1987-2008 index. For the 2009-2021 years, a full GOM index was produced due to the expanded sampling off Florida that occurred when the design was changed in 2008/2009. The purpose of this document is to provide abundance indices for Spanish mackerel from the SEAMAP Summer and Fall Groundfish Surveys.

Methodology

Survey Design

The survey methodologies and descriptions of the datasets used herein have been presented in detail by Nichols (2004) and Pollack and Ingram (2010). A change to the survey design was implemented between the summer and fall surveys of 2008. Prior to the fall survey of 2008, the basic structure of the groundfish surveys (i.e. 1987- summer of 2008) follows a stratified random station location assignment with strata derived from depth zones (5-6, 6-7, 7-8, 8-9, 9-10, 10-11, 11-12, 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-22, 22-25, 25-30, 30-35, 35-40, 40-45, 45-50 and 50-60 fm), shrimp statistical zones (SSZ) (between 88° and 97° W longitude, paired SSZ from west to east: 21-20, 19-18, 17-16, 15-13 and 12-10), and time of day (i.e. day or night). Survey methodology prior to 1987 was presented in detail by Nichols (2004).

Starting in the fall of 2008 and continuing until the present, station allocation is randomized within each SSZ with a weighting by area. Other notable changes included a standardized 30 min tow and dropping the day/night stratification. The main purpose of these changes was to increase the sample size of each survey and expand the survey into the waters off Florida.

Even though the survey design was changed in different years for the summer and fall surveys (2009 and 2008, respectively), for purposes of this analysis, the 2008 SEAMAP Fall Groundfish Survey was included with the early time series (1987-2008) in order to have a full year of coverage.

Data

A total of 17,368 stations were sampled from 1987- 2021 with 8,870 and 8,498 stations sampled during the summer and fall surveys, respectively (Tables 1 and 2). Trawl data from SEFSC was obtained from the SEFSC Oracle database and combined with data from the Gulf States Marine Fisheries Commission (GSMFC) database, which contains data collected by state agencies/partners from Alabama, Florida, Louisiana, Mississippi and Texas.

Data Exclusions

Data were limited by several factors:

(1) No problems with tow (i.e. net torn, doors crossed, etc.)
(2) Depths between 9 and 110 m
(3) Within SSZ 1 – 21
(4) Sampled with a 40 ft. shrimp trawl (Texas uses a 20 ft. shrimp trawl and data are not used)
(5) Sampled between 1987 and 2021

Data Caveats

The survey area has been expanded throughout the course of the fall time series. Prior to 1987, the areas of East Louisiana and Mississippi/Alabama were considered the primary sampling area, areas directly west and east of the primary area were designated the secondary sampling areas; East Florida and Texas were not sampled. During this time, triplicate 10 min tows were done at each station.

From 1987 – 2008 (summer), the area sampled was from Brownsville, TX to Mobile Bay, AL. Sampling rarely extended past Mobile Bay due to an increase in the number of hangs. During this time, tow length was dependent on how long it took to cover a full depth stratum (defined above). However, single tows never exceeded 55 min. Full details about this survey can be found in Nichols (2004).

Beginning in 2008, sampling was expanded to cover the eastern GOM, down to the Florida Keys. The other changes to the survey are outlined above in the survey design section and in Pollack and Ingram (2010).

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for Spanish mackerel (Bradu and Mundlak 1970, Pennington 1983). 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 III analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using Akaike Information Criterion (AIC), while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and quantile-quantile (QQ) plots in addition to AIC. Variables that could be included in the submodels were:

SEAMAP Summer and Fall Groundfish Surveys (1987-2008)

Year: 1987-2008
Paired Statistical Zones: 10-11, 13-15, 16-17, 18-19, 20-21
Depth Zone: 5-6, 6-7, 7-8, 8-9, 9-10, 10-11, 11-12, 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-22, 22-25, 25-30, 30-35, 35-40, 40-45, 45-50, 50-60 fm
Time of Day: Day, Night
Season: Summer, Fall

SEAMAP Summer and Fall Groundfish Surveys (1987-2008)

Year: 2009-2021
Area: Texas, Louisiana, Mississippi/Alabama, Florida
Depth: 5-110 m (continuous)
Time of Day: Day, Night
Season: Summer, Fall

Results and Discussion

Distribution and Size

The distribution and abundance of Spanish mackerel captured during the surveys are presented in Figures 1 and 2, with seasonal/annual abundance and distribution presented in the Appendix

Figures 1 and 2. The length frequency distribution of Spanish mackerel used in the relative abundance index is shown in Figure 3.

Index of Abundance

For the SEAMAP Summer and Fall Groundfish Surveys (1987-2008) abundance index of Spanish mackerel in the northwestern and central GOM, year, depth zone, time of day, paired statistical zone, and season were retained in the both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 3 summarizes the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 61547.8and 1774.0, respectively. The diagnostic plots for the lognormal submodel are shown in Figure 4, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 4 and Figure 5.

For the SEAMAP Summer and Fall Groundfish Surveys (2009-2021) abundance index of Spanish mackerel in the northern GOM, year, area, depth, time of day, and season were retained in the binomial submodel, while year and time of day were retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 2. Table 5 summarizes the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 59,553.7and 520.9, respectively. The diagnostic plots for the lognormal submodel are shown in Figure 6, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 6 and Figure 7.

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Table 1. Number of stations sampled by shrimp statistical zone during the SEAMAP Summer Groundfish Surveys from 1987-2021.

	Shrimp Statistical Zone																				
Year	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1987										29	59	6	20	19	25	20	16	25	28	19	266
1988										17	46	5	4	3	19	24	14	25	28	23	208
1989										21	30		3	18	25	7	15	20	29	24	192
1990											65	11	20	15	23	16	20	23	24	20	237
1991											44	12	24	13	23	22	24	18	23	26	229
1992										1	44	2	20	24	20	25	12	31	26	20	225
1993											44	10	19	17	24	19	14	29	24	22	222
1994											60	6	17	22	25	17	20	22	26	22	237
1995											42	10	16	18	22	23	13	27	26	21	218
1996											46	14	12	19	22	18	17	21	26	25	220
1997											42		12	16	22	23	10	28	26	26	205
1998											34	2	14	21	25	18	14	22	36	17	203
1999											43	7	20	19	20	23	13	25	32	20	222
2000											43	2	19	15	19	27	8	29	31	21	214
2001											34	7	18	18	13	3	10	9	17	21	150
2002											44	11	14	21	27	19	15	25	29	22	227
2003											42	9	10	8	2	17	20	22	26	23	179
2004											38	11	18	17	20	25	21	19	25	21	215
2005											31	10	9	11	16	21	5	28	22	27	180
2006											45	11	21	12	20	23	17	23	31	18	221
2007											40		6	15	22	23	7	29	32	21	195
2008				1	8	11	6	11	8	11	42	24	19	26	23	21	16	24	21	28	300
2009				36	21	29	14	16	18	24	66	25	20	36	39	46	50	33	29	23	525
2010			31	26	20	24	10	12	14	13	21	5	19	16	21	33	34	27	27	19	372
2011		11	24	22	20	29	2	15	11	8	16	7	14	17	23	29	29	18	21	13	329
2012		12	39	33	29	30	19	16	16	13	16	7	14	18	25	30	27	20	20	15	399
2013		9	27	28	23	19	8	11	8	7	14	5	12	14	22	21	22	16	17	12	295
2014		15	31	23	24	30	17	14	9	7	15	6	15	18	22	28	23	18	18	14	347
2015	1	9	32	29	22	27	21	17	10	8	16	7	15	18	21	28	27	19	20	13	360
2016		9	25	29	25	22	15	15	10	8	15	6	16	16	21	30	23	19	17	14	335
2017		10	28	19	28	14	15	14	6	10	17	7	13	13	23	26	24	19	21	14	321
2018		8	30	28	24	23	16	12	5	7	14	7	12	14	21	26	19	11	11	14	302
2019		11	31	23	21	15	5	15	8	9	14	3	12	13	20	27	22	16	20	12	297
2020																					
2021		9	24	21	19	3		9	7	6	6	4	9	8	17	22	20	14	14	11	223

Table 2. Number of stations sampled by shrimp statistical zone during the SEAMAP Fall Groundfish Surveys from 1987-2021.

	Shrimp Statistical Zone																				
Year	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1987										16	26	15	14	16	17	15	15	15	18	3	170
1988										8	27	7	22	17	18	26	19	21	31	20	216
1989											43	12	19	17	22	20	17	22	25	26	223
1990											52	14	12	23	22	19	18	22	19	27	228
1991											45	6	24	14	20	25	24	19	25	22	224
1992											32	7	23	14	25	18	17	27	30	18	211
1993											70	10	19	17	26	18	16	25	28	18	247
1994											49	9	16	21	25	20	21	23	24	20	228
1995											39	10	17	18	24	19	14	26	30	19	216
1996											43	9	18	19	17	28	13	25	29	24	225
1997											43	10	17	20	26	19	18	23	22	24	222
1998											43	10	22	14	34	11	15	24	29	22	224
1999											42	9	17	18	29	18	12	28	29	22	224
2000											42	10	14	22	20	26	12	30	25	21	222
2001											43	10	17	19	26	20	14	27	28	23	227
2002										1	49	10	13	22	22	23	14	26	30	21	231
2003										1	74	9	16	21	24	22	20	23	25	23	258
2004											43		11	18	17	27	14	24	30	21	205
2005											43	11	20	16	33	18	14	23	24	27	229
2006										1	45	7	22	14	18	28	13	23	32	19	222
2007											31	9	20	17	18	28	17	20	18	26	204
2008					15	14	4	4	3	4	34	16	28	34	42	46	44	19	36	20	363
2009				20	21	25	11	21	13	12	47	12	23	23	30	49	47	31	36	22	443
2010				9	25	27	17	16	11	14	15	7	15	18	26	30	29	18	19	14	310
2011								9	11	6	15	6	15	16	27	31	28	21	18	15	218
2012			2	3	6	6	17	10	7	5	12	5	11	13	19	23	22	13	15	11	200
2013		4	14	9	9	11	10	10	6	5	10	5	11	9	3	12	16	12	14	9	179
2014	1	8	31	25	22	23	13	12	7	7	16	5	13	14	21	27	22	15	17	12	311
2015	1	10	28	25	25	21	13	11	9	11	16	6	13	13	19	27	21	16	17	12	314
2016	1	5	4	8	11	9	6	13	5	4	8	4	12	10	18	22	17	13	13	8	191
2017		9	19	27	19	18	8	12	7	7	15	6	9	12	22	25	22	15	18	14	284
2018		9	29	21	14	10	7	13	8	7	13	5	12	15	21	25	22	13	15	14	273
2019		11	17	17	19	24	9	11	9	10	12	4	9	13	20	25	22	16	16	12	276
2020		9	15	17	20	8	4	8	7	9	12	4	9	10	18	22	18	15	14	11	230
2021		6	23	17	17	14	2	12	5	5	12	4	11	12	19	25	22	16	16	12	250

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for SEAMAP Summer and Fall Groundfish Surveys (1987-2008) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 61547.8)*						*Lognormal Submodel Type 3 Tests (AIC 1774.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	21	9649	61.41	2.92	<.0001	<.0001	21	546	1.28	0.1832
Depth Zone	22	9649	265.62	12.07	<.0001	<.0001	22	546	5.04	<.0001
Season	1	9649	78.59	78.59	<.0001	<.0001	1	546	8.76	0.0032
Time of Day	1	9649	79.91	79.91	<.0001	<.0001	1	546	20.68	<.0001
Paired Statistical Zone	4	9649	65.20	16.30	<.0001	<.0001	4	546	3.84	0.0044

Table 4. Index of Spanish mackerel abundance developed using the delta-lognormal (DL) model for SEAMAP Summer and Fall Groundfish Surveys (1987-2008). The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.02752	436	0.06530	0.26433	0.43071	0.11583	0.60320
1988	0.07311	424	0.30493	1.23439	0.27831	0.71484	2.13153
1989	0.06747	415	0.34713	1.40524	0.28980	0.79633	2.47977
1990	0.07742	465	0.34643	1.40242	0.25962	0.84147	2.33730
1991	0.05960	453	0.19295	0.78108	0.29546	0.43793	1.39309
1992	0.05734	436	0.17345	0.70215	0.30736	0.38500	1.28055
1993	0.08529	469	0.43367	1.75558	0.25046	1.07195	2.87518
1994	0.04516	465	0.14470	0.58578	0.33166	0.30700	1.11771
1995	0.07143	434	0.30821	1.24769	0.27926	0.72125	2.15837
1996	0.05169	445	0.21101	0.85419	0.31794	0.45921	1.58888
1997	0.04450	427	0.09952	0.40286	0.35217	0.20331	0.79826
1998	0.05621	427	0.17287	0.69980	0.31312	0.37960	1.29007
1999	0.05157	446	0.19722	0.79838	0.31827	0.42895	1.48599
2000	0.06881	436	0.20794	0.84176	0.28395	0.48230	1.46911
2001	0.05305	377	0.26567	1.07548	0.33946	0.55558	2.08187
2002	0.02402	458	0.09404	0.38070	0.44849	0.16171	0.89625
2003	0.06865	437	0.34201	1.38450	0.28414	0.79299	2.41724
2004	0.05714	420	0.16429	0.66508	0.31320	0.36072	1.22624
2005	0.11736	409	0.49890	2.01964	0.22972	1.28321	3.17870
2006	0.07223	443	0.21090	0.85375	0.27364	0.49880	1.46129
2007	0.09774	399	0.48788	1.97500	0.25250	1.20124	3.24715
2008	0.03806	578	0.16556	0.67022	0.32335	0.35670	1.25929

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for SEAMAP Summer and Fall Groundfish Surveys (2009-2021) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 59,553.7)*						*Lognormal Submodel Type 3 Tests (AIC 520.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	7093	73.39	6.67	<.0001	<.0001	11	189	2.56	0.0048
Season	1	7093	28.09	28.09	<.0001	<.0001	1	189	0.70	0.4046
Time of Day	1	7093	39.70	39.70	<.0001	<.0001	1	189	7.70	0.0061
Depth	1	7093	109.62	109.62	<.0001	<.0001	1	189	1.73	0.1904
Zone	3	7093	102.36	34.12	<.0001	<.0001	3	189	2.47	0.0629
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 59,553.7)*						*Lognormal Submodel Type 3 Tests (AIC 519.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	7093	73.39	6.67	<.0001	<.0001	11	190	2.57	0.0047
Season	1	7093	28.09	28.09	<.0001	<.0001		Dropped		
Time of Day	1	7093	39.70	39.70	<.0001	<.0001	1	190	7.79	0.0058
Depth	1	7093	109.62	109.62	<.0001	<.0001	1	190	1.64	0.2025
Zone	3	7093	102.36	34.12	<.0001	<.0001	3	190	2.38	0.0707
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 59,553.7)*						*Lognormal Submodel Type 3 Tests (AIC 513.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	7093	73.39	6.67	<.0001	<.0001	11	191	2.81	0.0020
Season	1	7093	28.09	28.09	<.0001	<.0001		Dropped		
Time of Day	1	7093	39.70	39.70	<.0001	<.0001	1	191	7.48	0.0068
Depth	1	7093	109.62	109.62	<.0001	<.0001		Dropped		
Zone	3	7093	102.36	34.12	<.0001	<.0001	3	191	2.42	0.0676
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 59,553.7)*						*Lognormal Submodel Type 3 Tests (AIC 520.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	7093	73.39	6.67	<.0001	<.0001	11	194	3.01	0.0010
Season	1	7093	28.09	28.09	<.0001	<.0001		Dropped		
Time of Day	1	7093	39.70	39.70	<.0001	<.0001	1	194	7.06	0.0086
Depth	1	7093	109.62	109.62	<.0001	<.0001		Dropped		
Zone	3	7093	102.36	34.12	<.0001	<.0001		Dropped		

Table 6. Index of Spanish mackerel abundance developed using the delta-lognormal (DL) model for SEAMAP Summer and Fall Groundfish Surveys (2008-2021). The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2009	0.061983	968	0.07405	1.70412	0.23902	1.06357	2.73045
2010	0.045455	682	0.08212	1.88996	0.29571	1.05917	3.37240
2011	0.021938	547	0.01908	0.43921	0.41646	0.19738	0.97732
2012	0.020033	599	0.01630	0.37516	0.42039	0.16743	0.84064
2013	0.048523	474	0.18961	4.36379	0.32481	2.31625	8.22133
2014	0.006079	658	0.00632	0.14539	0.66394	0.04341	0.48689
2015	0.041543	674	0.06076	1.39830	0.30140	0.77531	2.52189
2016	0.007605	526	0.01097	0.25243	0.66668	0.07506	0.84892
2017	0.029752	605	0.02849	0.65557	0.35699	0.32794	1.31052
2018	0.013913	575	0.01355	0.31192	0.49296	0.12272	0.79279
2019	0.003490	573	0.00365	0.08389	0.90822	0.01778	0.39568
2020	0.021739	230	0.01652	0.38027	0.61457	0.12258	1.17966
2021	0	473					

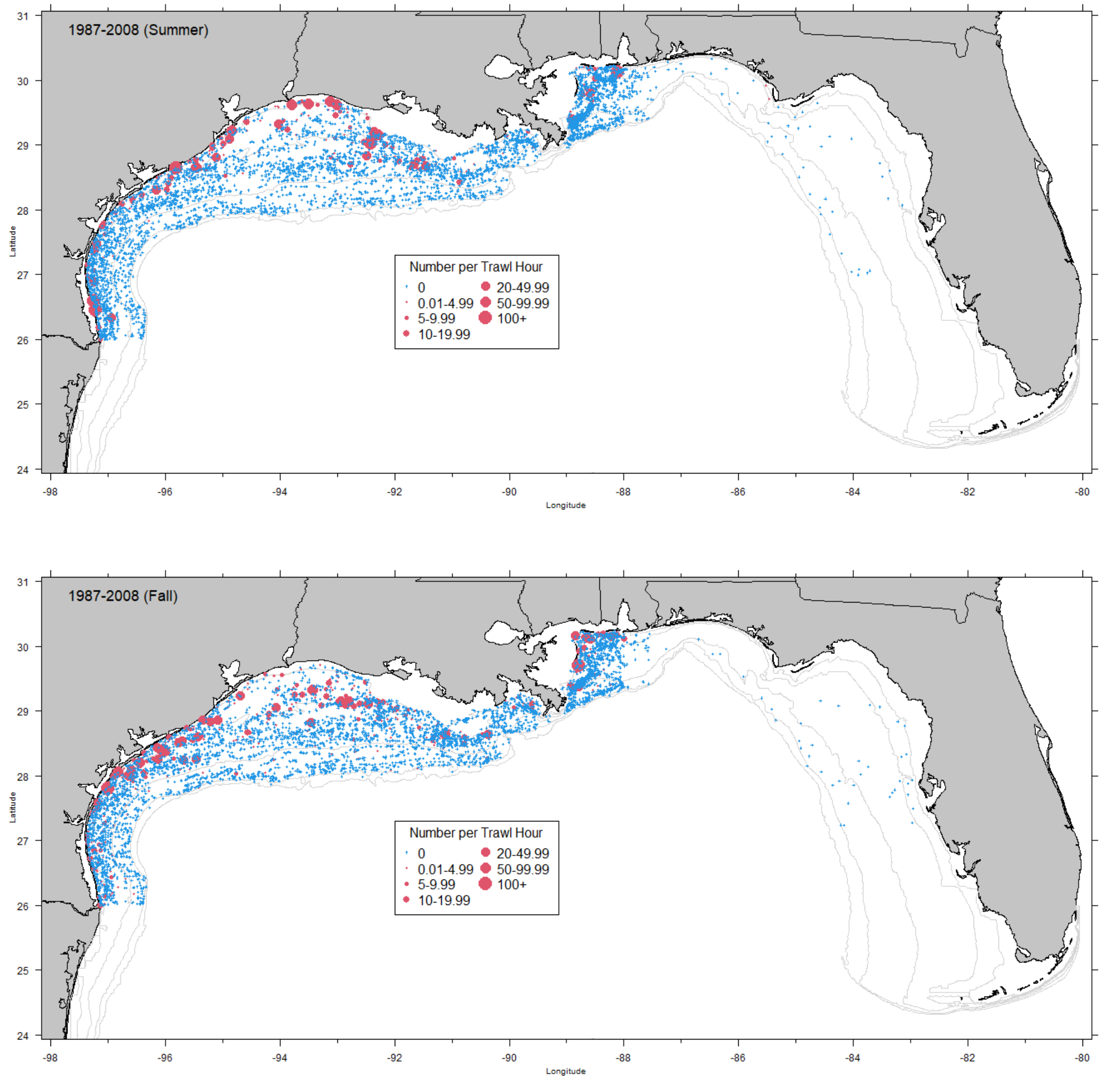


Figure 1. Stations sampled during the SEAMAP Summer (top) and Fall (bottom) Groundfish Surveys with the CPUE for Spanish mackerel from 1987-2008. Note that stations sampled east of 87° W were removed for analysis.

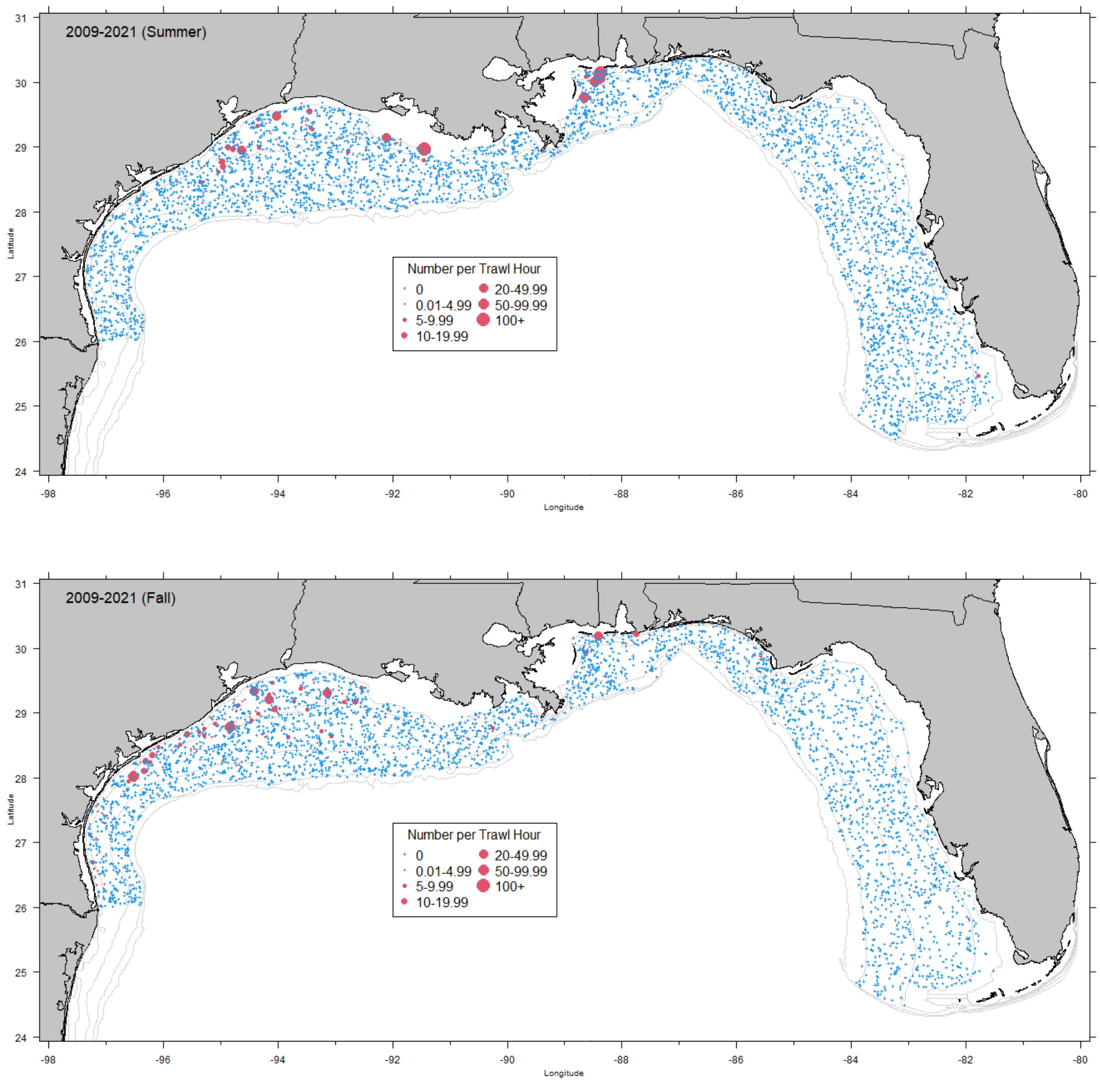


Figure 2. Stations sampled during the SEAMAP Summer (top) and Fall (bottom) Groundfish Surveys with the CPUE for Spanish mackerel from 2009-2021.

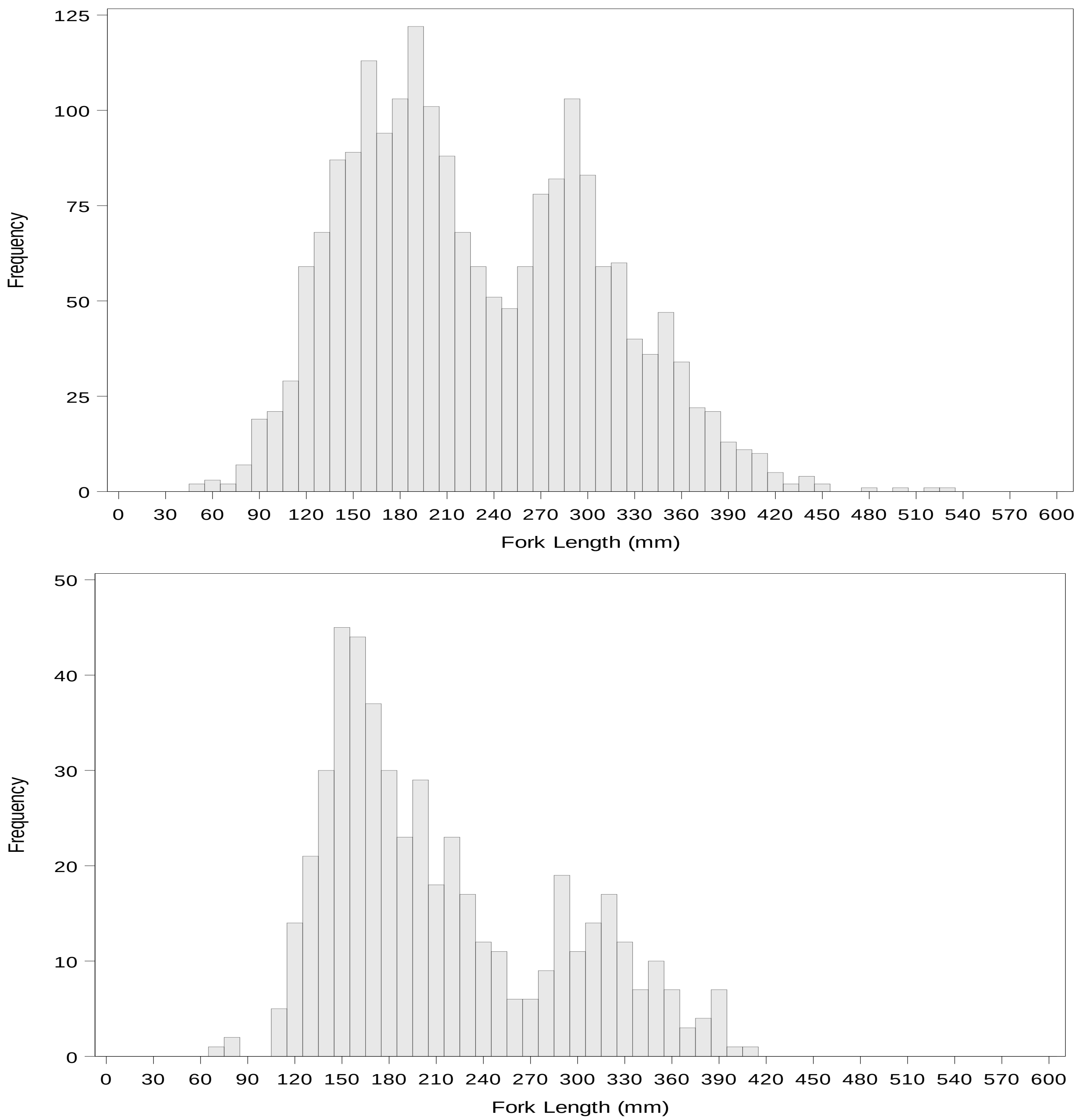


Figure 3. Length frequency histogram for Spanish mackerel captured during SEAMAP Summer and Fall Groundfish Surveys from 1987-2008 (top) and 2009-2021 (bottom).

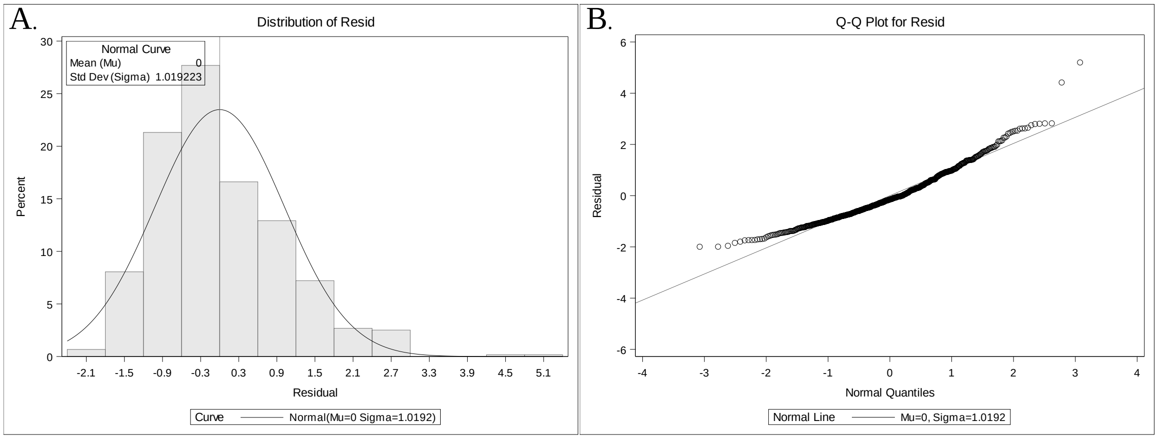


Figure 4. Diagnostic plots for lognormal component of the Spanish mackerel SEAMAP Summer and Fall Groundfish Surveys (1987-2008) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

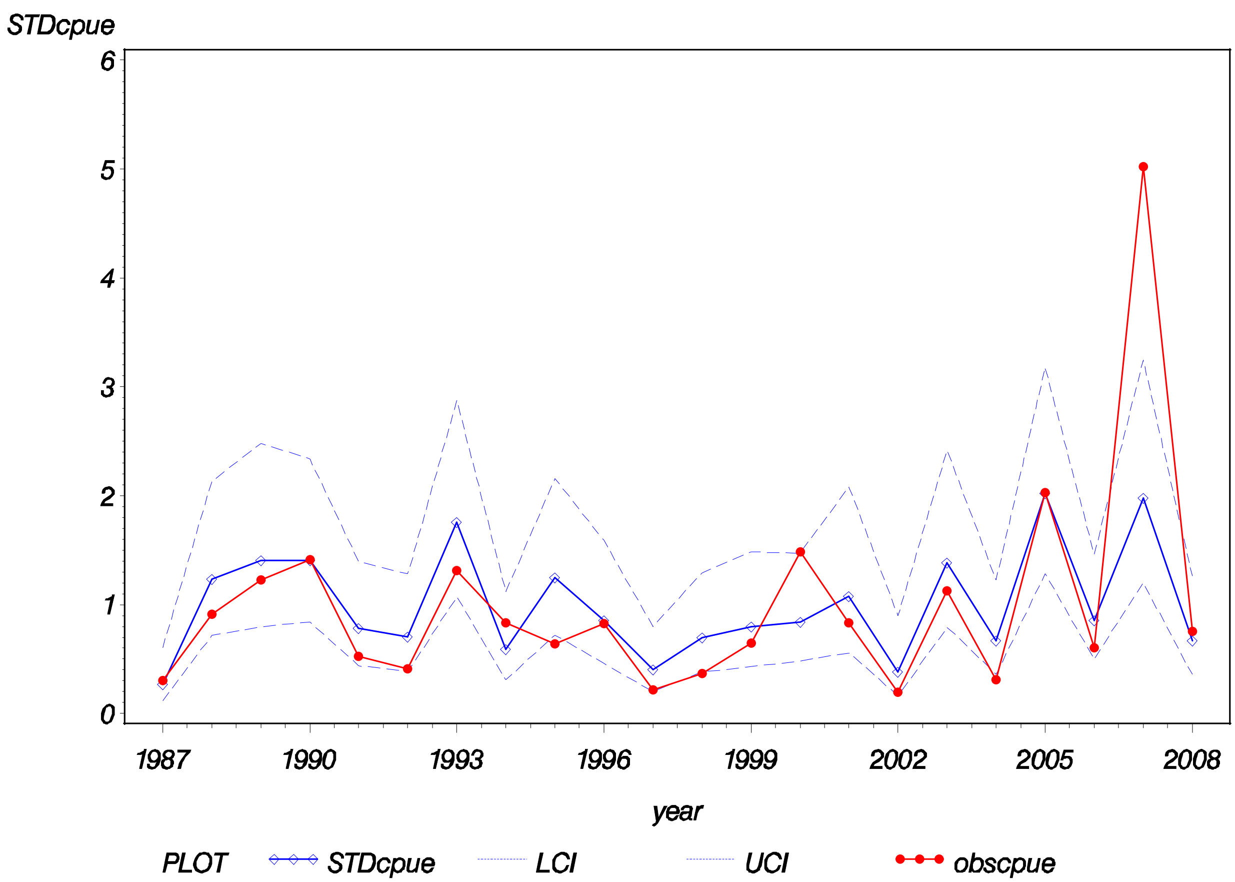


Figure 5. Annual index of abundance for Spanish mackerel from the SEAMAP Summer and Fall Groundfish Surveys from 1987-2008.

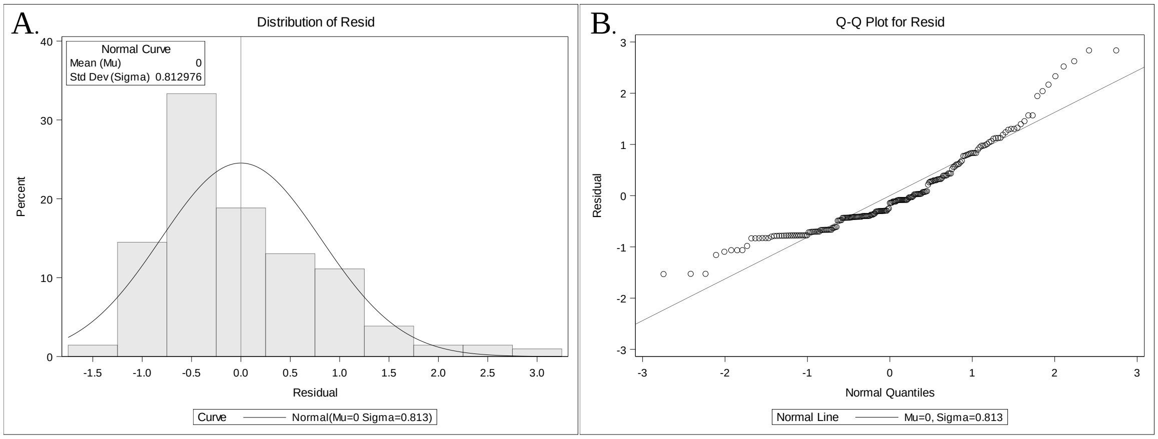


Figure 6. Diagnostic plots for lognormal component of the Spanish mackerel SEAMAP Summer and Fall Groundfish Surveys (2009-2021) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

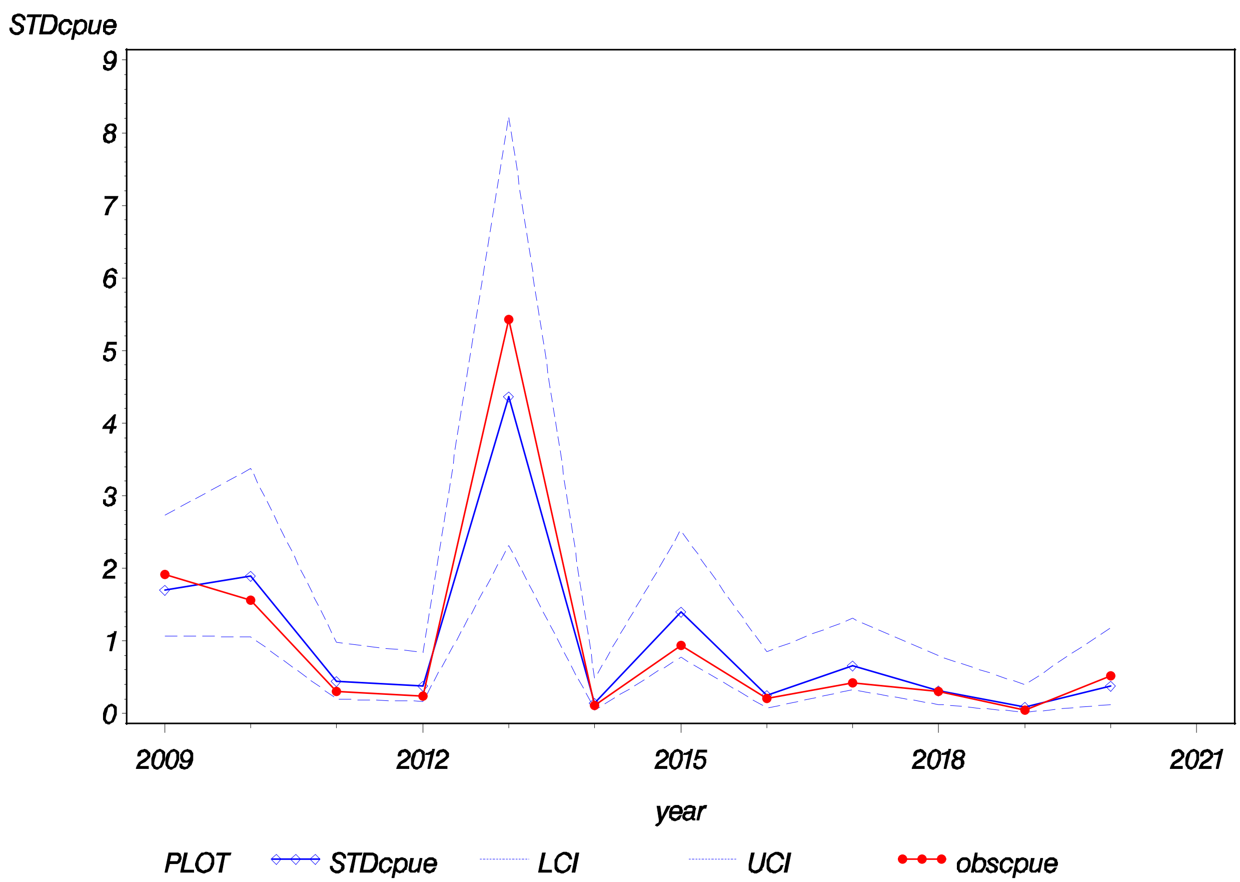


Figure 7. Annual index of abundance for Spanish mackerel from the SEAMAP Summer and Fall Groundfish Surveys from 2009-2021. Note that zero Spanish mackerel were captured in 2021.

Appendix

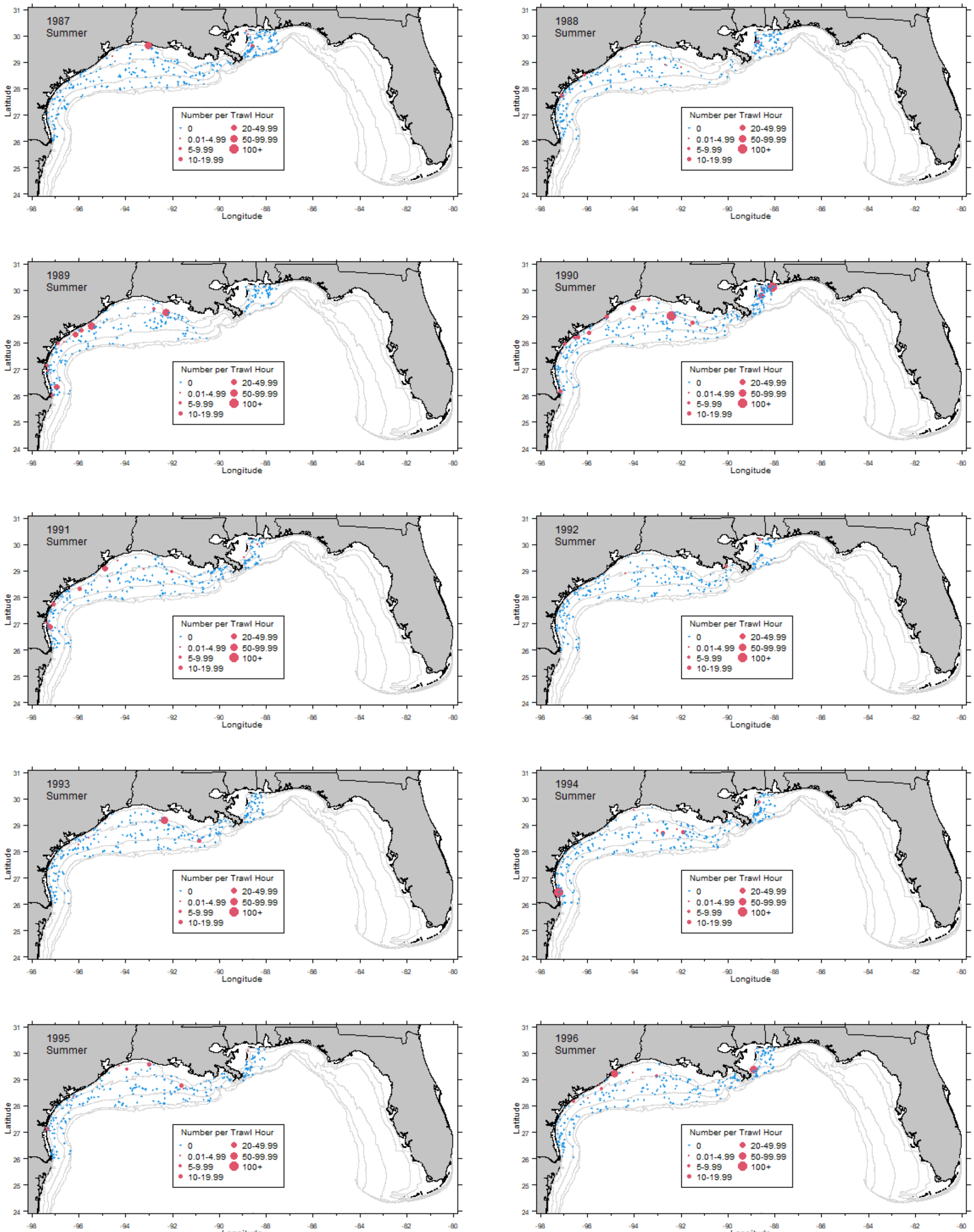
Appendix Table 1. Summary of the factors used in constructing the Spanish mackerel abundance index from the SEAMAP Summer and Fall Groundfish Surveys (1987-2008) data.

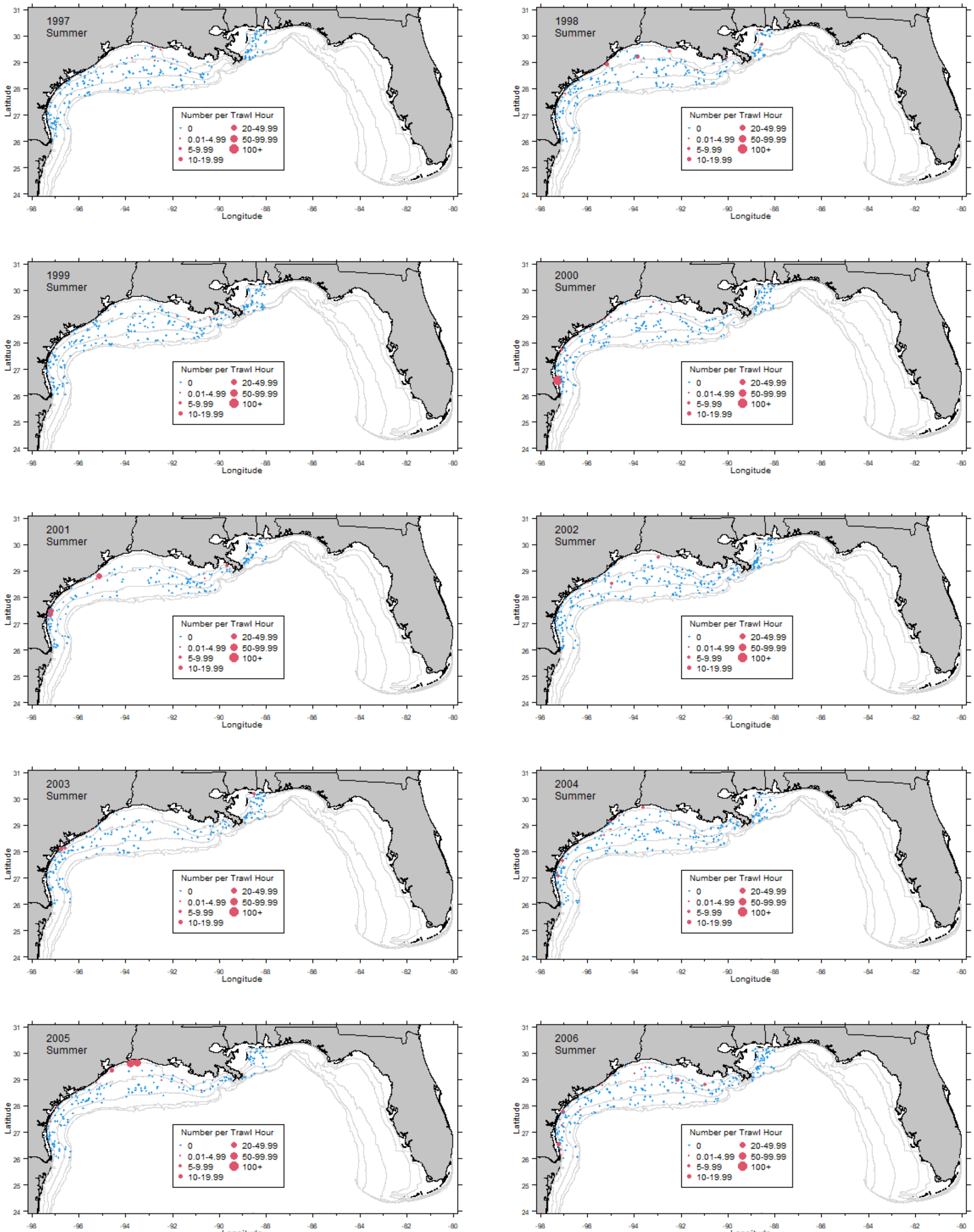
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Season	Fall	4979	408	0.08194	0.82641
Season	Summer	4720	188	0.03983	0.57685
Time of Day	Day	4878	402	0.08241	0.85580
Time of Day	Night	4821	194	0.04024	0.55234
Year	1987	436	12	0.02752	0.22011
Year	1988	424	31	0.07311	0.65760
Year	1989	415	28	0.06747	0.88466
Year	1990	465	36	0.07742	1.01719
Year	1991	453	27	0.05960	0.37995
Year	1992	436	25	0.05734	0.29513
Year	1993	469	40	0.08529	0.94466
Year	1994	465	21	0.04516	0.59988
Year	1995	434	31	0.07143	0.46241
Year	1996	445	23	0.05169	0.59578
Year	1997	427	19	0.04450	0.15529
Year	1998	427	24	0.05621	0.26654
Year	1999	446	23	0.05157	0.46528
Year	2000	436	30	0.06881	1.06673
Year	2001	377	20	0.05305	0.59711
Year	2002	458	11	0.02402	0.13847
Year	2003	437	30	0.06865	0.81161
Year	2004	420	24	0.05714	0.22145
Year	2005	409	48	0.11736	1.46016
Year	2006	443	32	0.07223	0.43252
Year	2007	399	39	0.09774	3.61575
Year	2008	578	22	0.03806	0.54233
Paired Statistical Zone	10 11	2026	70	0.03455	0.89842
Paired Statistical Zone	13 14 15	1894	84	0.04435	0.27250
Paired Statistical Zone	16 17	1910	152	0.07958	0.75310
Paired Statistical Zone	18 19	1741	157	0.09018	0.97075
Paired Statistical Zone	20 21	2128	133	0.06250	0.64502

Appendix Table 2. Summary of the factors used in constructing the Spanish mackerel abundance index from the SEAMAP Summer and Fall Groundfish Surveys (2009-2021) data.

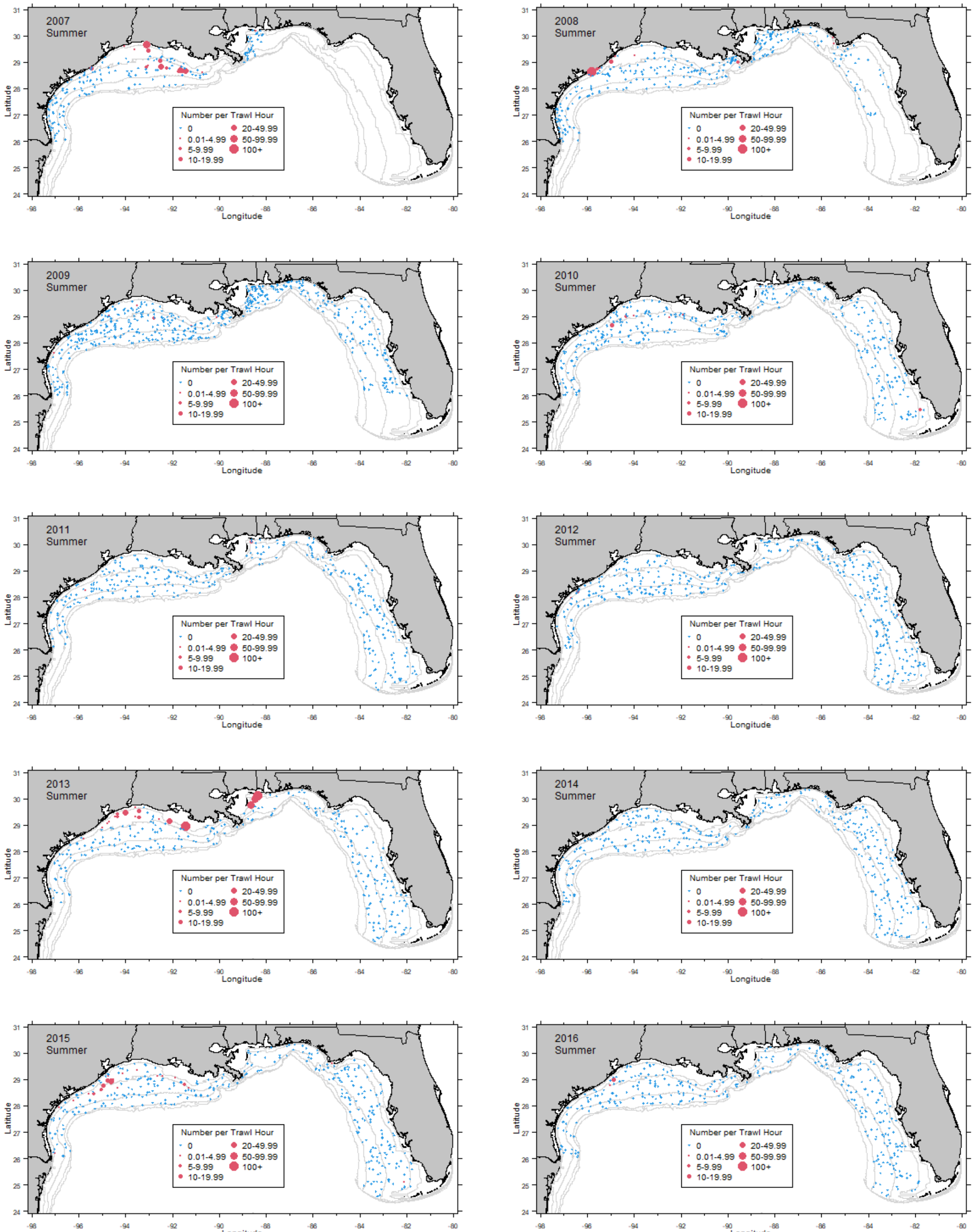
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Season	Fall	3229	129	0.039950	0.23735
Season	Summer	3882	78	0.020093	0.20623
Time of Day	Day	3810	150	0.039370	0.35699
Time of Day	Night	3301	57	0.017267	0.06267
Year	2009	968	60	0.061983	0.41747
Year	2010	682	31	0.045455	0.34065
Year	2011	547	12	0.021938	0.06559
Year	2012	599	12	0.020033	0.05307
Year	2013	474	23	0.048523	1.18083
Year	2014	658	4	0.006079	0.02427
Year	2015	674	28	0.041543	0.20415
Year	2016	526	4	0.007605	0.04548
Year	2017	605	18	0.029752	0.09216
Year	2018	575	8	0.013913	0.06603
Year	2019	573	2	0.003490	0.01043
Year	2020	230	5	0.021739	0.11297
Year	2021	473	0	0	0
Zone	Florida	2764	10	0.003618	0.01076
Zone	Mississippi/Alabama	626	20	0.031949	0.62940
Zone	Texas	1750	114	0.065143	0.42195
Zone	Louisiana	1971	63	0.031963	0.20539

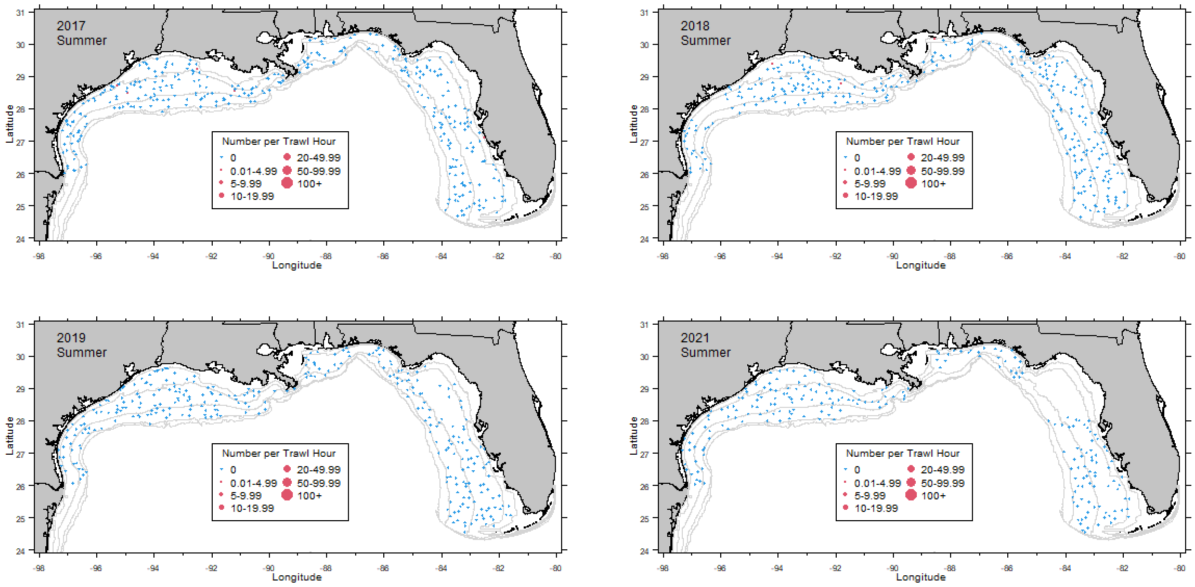
Appendix Figure 1. Annual survey effort and catch of Spanish mackerel from the SEAMAP Summer Groundfish between 1987 and 2021. Note there was no survey in 2020.



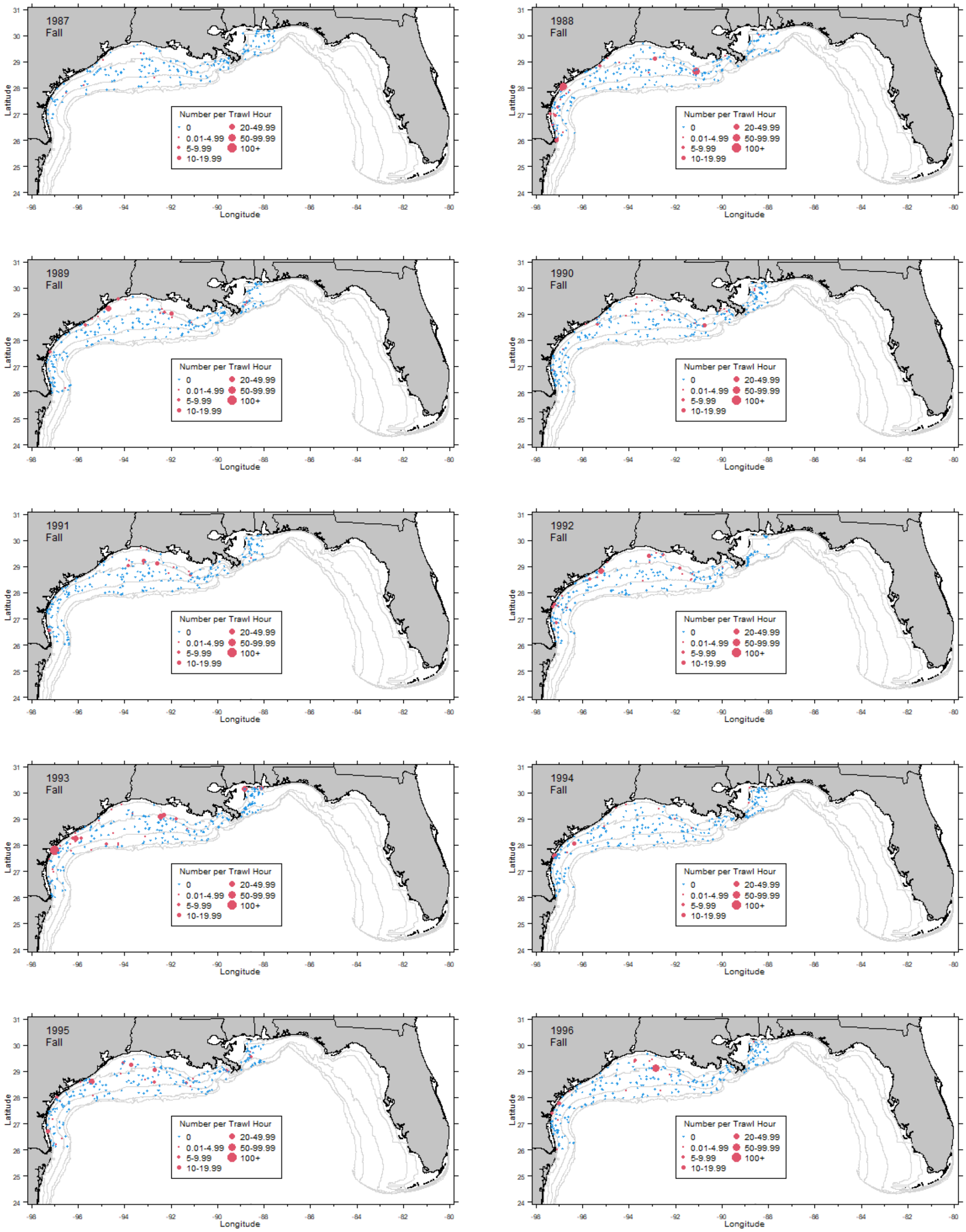


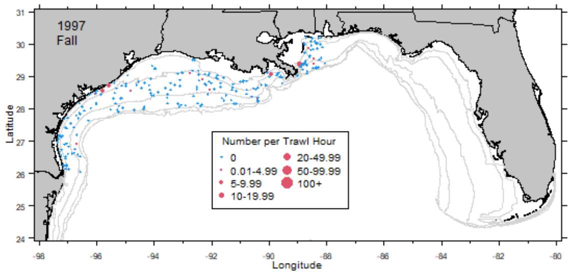
1997
Summer
1998
Summer
1999
Summer
2000
Summer
2001
Summer
2002
Summer
2003
Summer
2004
Summer
2005
Summer
2006
Summer
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2007
Summer
2008
Summer
2009
Summer
2010
Summer
2011
Summer
2012
Summer
2013
Summer
2014
Summer
2015
Summer
2016
Summer
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2017
Summer
2018
Summer
2019
Summer
2021
Summer
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

Appendix Figure 2. Annual survey effort and catch of Spanish mackerel from the SEAMAP Fall Groundfish between 1987 and 2021.




1997
Fall
Number per Trawl Hour
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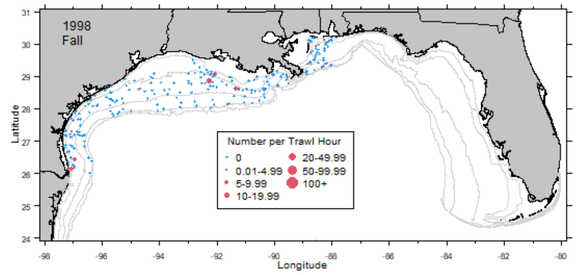
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


1998
Fall
Number per Trawl Hour
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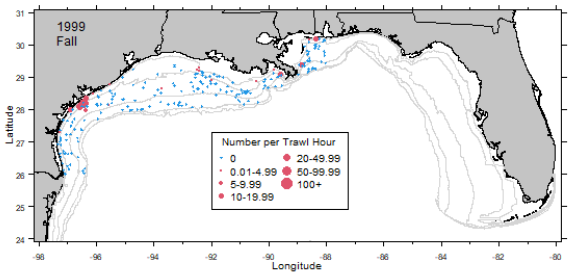
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


1999
Fall
Number per Trawl Hour
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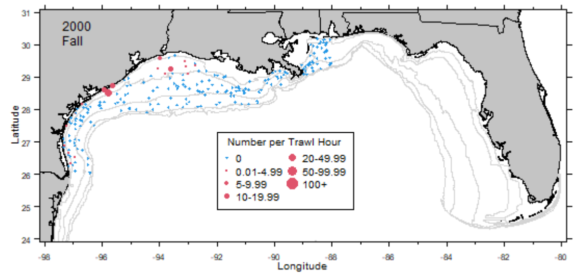
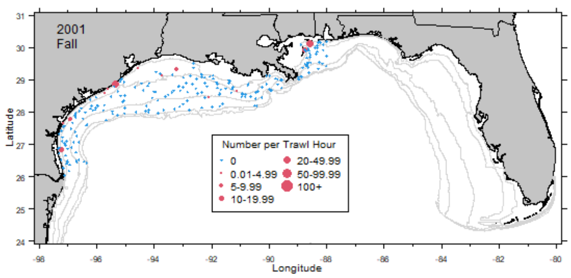
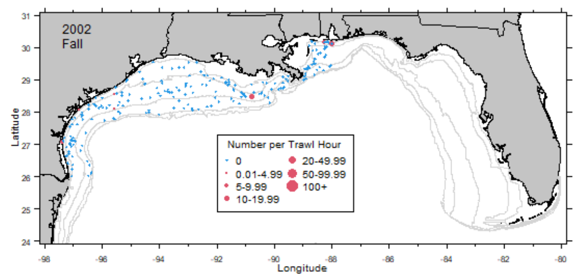
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2000
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2001
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2002
Fall
Number per Trawl Hour
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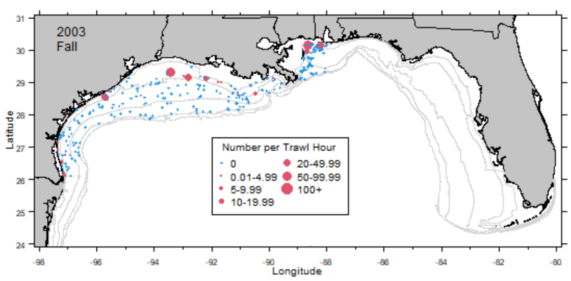
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude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Fall
Number per Trawl Hour
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10-19.99
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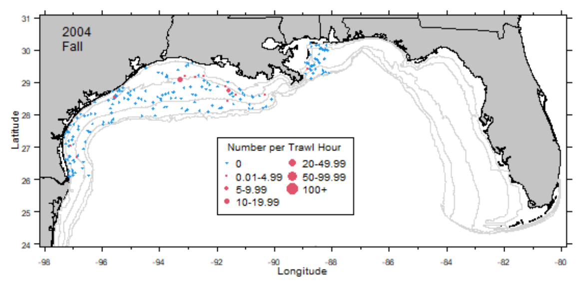
50-99.99
100+
Latitude
Longitude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Fall
Number per Trawl Hour
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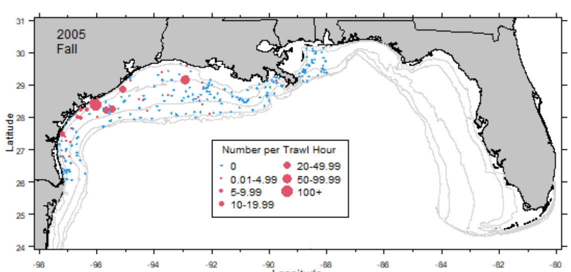
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude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Fall
Number per Trawl Hour
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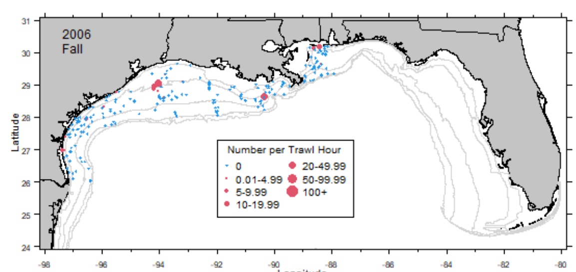
Longitude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Fall
Number per Trawl Hour
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50-99.99
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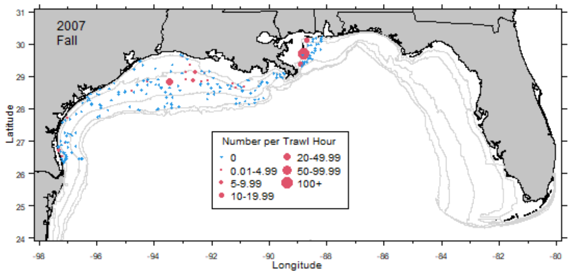
Latitude
Longitude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Fall
Number per Trawl Hour
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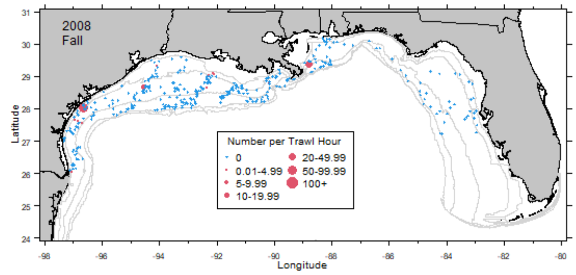
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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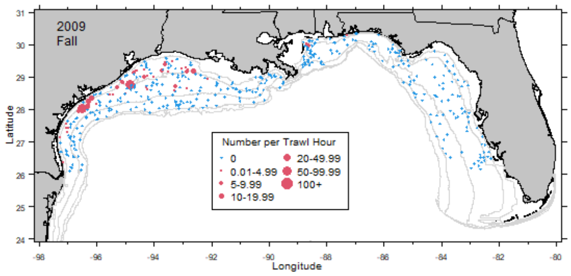
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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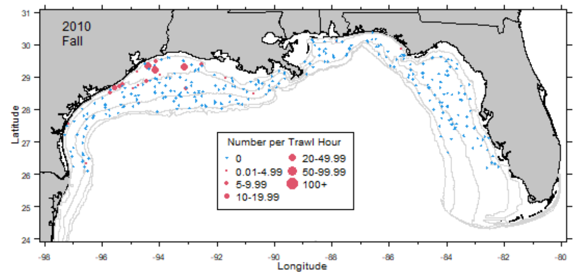
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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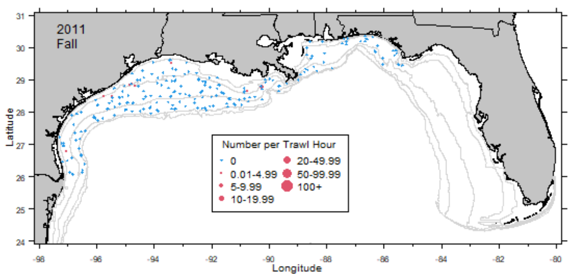
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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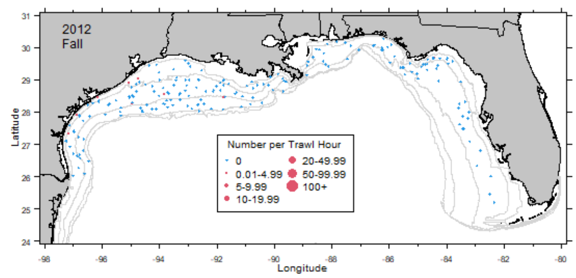
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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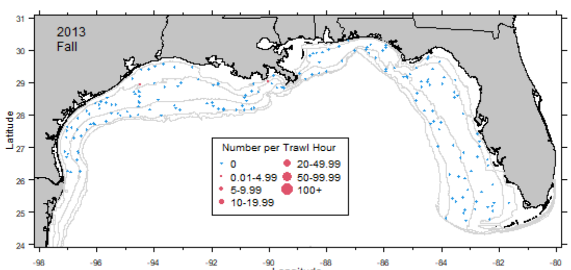
Longitude

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Number per Trawl Hour
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50-99.99
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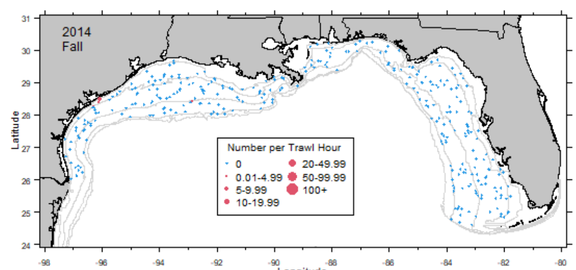
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Fall
Number per Trawl Hour
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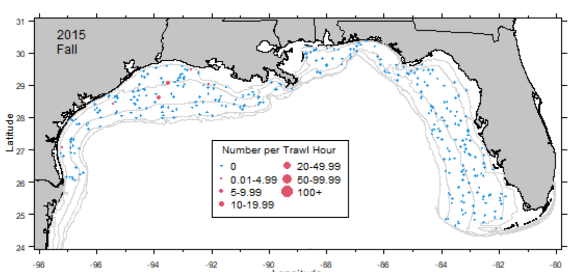
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude

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Fall
Number per Trawl Hour
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20-49.99
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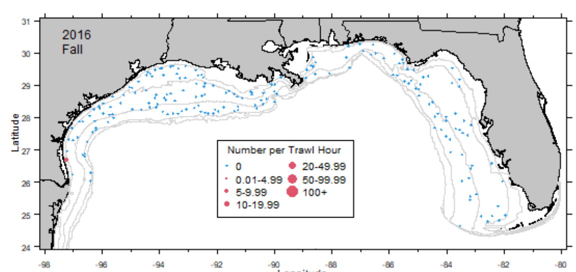
Longitude

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Fall
Number per Trawl Hour
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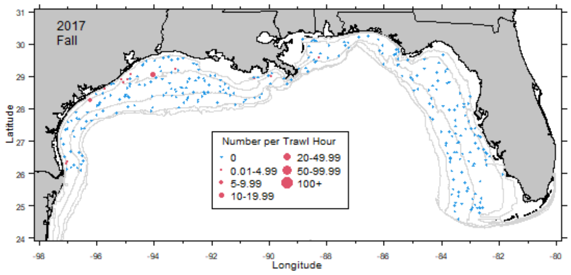
20-49.99
50-99.99
100+
Latitude
Longitude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Fall
Number per Trawl Hour
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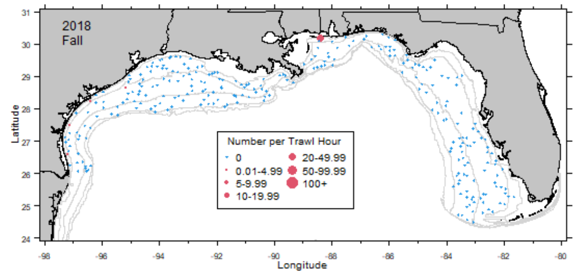
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude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Fall
Number per Trawl Hour
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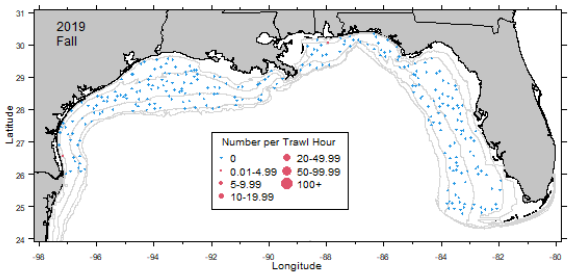
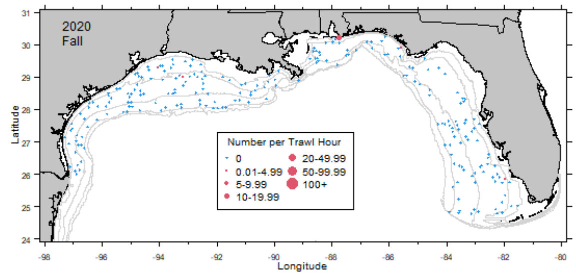
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2019
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude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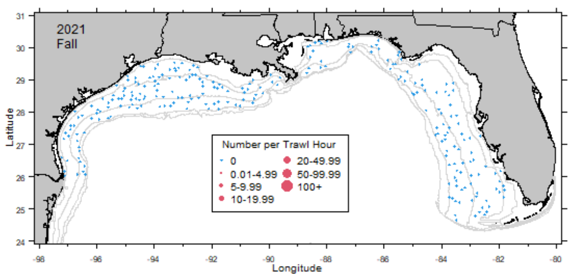
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude


2021
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100+
Latitude
Longitude