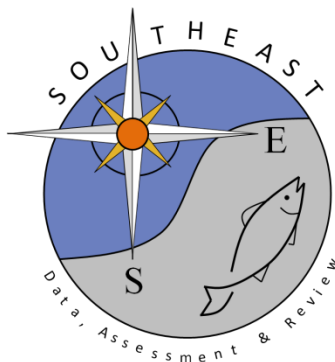


# King Mackerel Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of America

Adam G. Pollack and David S. Hanisko

SEDAR99-WP-18

4 May 2026



*This information is distributed solely for the purpose of pre-dissemination peer review. It does not represent and should not be construed to represent any agency determination or policy.*

Please cite this document as:

Pollack, Adam G. and David S. Hanisko. 2026. King Mackerel Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of America. SEDAR99-WP-18. SEDAR, North Charleston, SC. 32 pp.

# King Mackerel Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of America

Adam G. Pollack and David S. Hanisko

Trawl and Plankton Branch  
Population and Ecosystem Monitoring Division  
NOAA Fisheries - Southeast Fisheries Science Center

## **Abstract**

*The NOAA Fisheries - Southeast Fisheries Science Center - Population and Ecosystem Monitoring Division - Trawl and Plankton Branch and state partners have conducted groundfish surveys since 1972 in the northern Gulf of America during the summer and fall under two different sampling programs. In 1987, both groundfish surveys (summer and fall) were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP) and followed the same survey design and methodologies. These fisheries independent data were used to develop abundance indices for king mackerel (*Balistes capriscus*). For this assessment, only data from the SEAMAP Summer and Fall Groundfish Surveys were used in the analysis. Two abundance indices were produced with the first using data from shrimp statistical zones 10 – 21 from 1987 – 2008, and the second using data from shrimp statistical zones 2 – 21 from 2009 – 2024.*

## **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 America (Gulf) 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 Gulf. 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 Gulf. The purpose of this document is to provide abundance indices for king mackerel (*Scomberomorus cavalla*).

## **Methodology**

### ***Survey Design***

The survey methodologies and descriptions of the datasets used herein have been presented in detail by Nichols (2004) and Pollack et al. (2025). 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 fathoms), shrimp statistical zones (SSZ) (between 88° and 97° W longitude, 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 of Florida. For additional information on the survey design changes see Pollack et al. (2025).

### ***Data***

A total of 19,013 stations were sampled from 1987- 2024 with 9800 and 9213 stations sampled during the summer and fall survey, 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 Caveats***

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 et al. (2025).

### ***Data Exclusions***

Data was limited to stations where no problems were reported (i.e., net torn, doors crossed, etc.) and were sampled with a 40 ft shrimp trawl (data from the state of Texas was not utilized because of the use of a 20 ft shrimp trawl). Data was also limited to a timeframe of 1987 – 2024 due to the limited spatial coverages in surveys prior to 1987.

### ***Index Construction***

Delta-lognormal modeling methods were used to estimate relative abundance indices for king mackerel from the SEAMAP Summer and Fall Groundfish Surveys (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:

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

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:

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

and

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

respectively, where  $c$  is a vector of the positive catch data,  $p$  is a vector of the presence/absence data,  $X$  is the design matrix for main effects,  $\beta$  is the parameter vector for main effects, and  $\varepsilon$  is a vector of independent normally distributed errors with expectation zero and variance  $\sigma^2$ . 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

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

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:

***Abundance Index – West Gulf – SEAMAP Summer and Fall Groundfish (old design)***

Year: 1987 – 2008

Depth Zone: 23 levels (see Appendix Table 1 for full listing)

Combined SSZ: 10-11, 13-15, 16-17, 18-19, 20-21

Time of Day: Day and Night  
Season: Summer and Fall

***Abundance Index – Gulfwide – SEAMAP Summer and Fall Groundfish (new design)***

Year: 2009 – 2024  
Depth: 9 – 110 m (continuous variable)  
Combined SSZ: 2-3, 4-5, 6-7, 8-9, 10-11, 13-15, 16-17, 18-19, 20-21  
Time of Day: Day and Night  
Season: Summer and Fall

**Results**

***Distribution, Size and Age***

The distribution of king mackerel from the SEAMAP Summer and Fall Groundfish Surveys are presented in Figures 1 and 2, respectively, with seasonal/annual abundance and distribution presented in the Appendix Figures 1 and 2. The total number of king mackerel captured during the summer survey was 1557 individuals, with 960 being measured, while during the fall survey 1375 individuals were captured, with 983 being measured. The length frequency distribution of king mackerel captured is shown in Figure 3 for the 1987 - 2008 surveys and Figure 4 for the 2009 – 2024 surveys. Tables 3 – 6, present the breakdown of number collected and number measured by year, along with general information (minimum, maximum, and mean length) from the summer and fall surveys. Each table is representative of a survey design (old or new) and season.

***Abundance Index – West Gulf – SEAMAP Summer and Fall Groundfish (old design)***

For the SEAMAP Summer and Fall Groundfish Surveys (West Gulf, 1987-2008) abundance index of king mackerel, year, depth, combined SSZ, season, and TOD were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 7 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 64,965.4 and 1487.5, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 5. Annual abundance indices are presented in Table 8 and Figure 6.

***Abundance Index – Gulfwide – SEAMAP Summer and Fall Groundfish (new design)***

For the SEAMAP Summer and Fall Groundfish Surveys (Gulfwide, 2008-2024) abundance index of king mackerel, year, depth, combined SSZ, season and TOD were retained in the binomial submodel, while year and TOD were retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 2. Table 9 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 77,022.6 and 435.8,

respectively. Diagnostic plots for the lognormal submodels are shown in Figure 7. Annual abundance indices are presented in Table 10 and Figure 8.

## Discussion

During SEDAR 38 and subsequent updates, only data from the NMFS Fall Groundfish Survey (1972-1986) and SEAMAP Fall Groundfish Survey (1987 – present) were used as a combined abundance index in the stock assessment. For this assessment, the data from the NMFS Fall Groundfish Survey has been omitted due to the limited spatial coverage of the survey in the central Gulf (88°W – 91°W; see Pollack et al. 2025 for full description of the survey area and mapping) and possibility of missing the center of abundance that appears to be located off Texas based on the SEAMAP Groundfish Survey data (Figures 1 and 2). In addition, with the inclusion of the summer data, the 2009 – 2024 time series was able to cover the entire Gulf, as opposed to being limited to SSZ 10 – 21. This also helps fill in the time series in the later years of the surveys when king mackerel are becoming scarcer in the catches, which mostly eliminates all years with zero catches, except for 2020 when only a fall survey was conducted due to the COVID pandemic. Abundance indices using only the SEAMAP Fall Groundfish data were examined and showed a similar trend to the indices presented above. However, there were more breaks in the time series due to years with no catches of king mackerel.

## Literature Cited

- Bradu, D. and Y. Mundlak. 1970. Estimation in Lognormal Linear Models, *Journal of the American Statistical Association*, 65: 198-211.
- Lo, N.C.H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. *Canadian Journal of Fisheries and Aquatic Science* 49: 2515-2526.
- Nichols, S. 2004. Derivation of red snapper time series from SEAMAP and groundfish trawl surveys. SEDAR7-DW01.
- Ortiz, M. 2006. Standardized catch rates for gag grouper (*Mycteroperca microlepis*) from the marine recreational fisheries statistical survey (MRFSS). SEDAR10-DW-09.
- Pennington, M. 1983. Efficient Estimators of Abundance, for Fish and Plankton Surveys. *Biometrics*, 39: 281-286.
- Pollack, A.G., E.R. Hoffmayer, T.S. Switzer, D.S. Hanisko, J.M. Hendon, J. Mareska, et al. (2025). Assessing survey design changes of long-term fishery-independent groundfish trawl surveys in the Gulf of Mexico. *Front. Mar. Sci.* 12. doi: 10.3389/fmars.2025.1425362

Table 1. Number of stations sampled by shrimp statistical zone during the SEAMAP Summer Groundfish Survey from 1987-2024.

Year	Shrimp Statistical Zone																				Total
	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21		
1987									28	61	6	20	19	25	20	16	25	28	19	267	
1988									18	48	5	4	3	19	24	14	25	28	23	211	
1989									23	30		3	18	25	7	15	20	29	24	194	
1990										68	11	20	15	23	16	20	23	24	20	240	
1991										46	12	24	13	23	22	24	18	23	26	231	
1992									1	45	2	20	24	20	25	12	31	26	20	226	
1993										46	10	19	17	24	19	14	29	24	22	224	
1994										61	6	17	22	25	17	20	22	26	22	238	
1995										44	10	16	18	22	23	13	27	26	21	220	
1996										46	14	12	19	22	18	17	21	26	25	220	
1997										44		12	16	22	23	10	28	26	26	207	
1998										36	2	14	21	25	18	14	22	36	17	205	
1999										44	7	20	19	20	23	13	25	32	20	223	
2000										45	2	19	15	19	27	8	29	31	21	216	
2001										36	7	18	18	13	3	10	9	17	21	152	
2002										44	11	14	21	27	19	15	25	29	22	227	
2003										44	9	10	8	2	17	20	22	26	23	181	
2004										39	11	18	17	20	25	21	19	25	21	216	
2005										32	10	9	11	16	21	5	28	22	27	181	
2006										45	11	21	12	20	23	17	23	31	18	221	
2007										41		7	15	22	23	7	29	32	21	197	
2008				1	8	11	6	11	8	11	44	24	19	26	23	21	16	24	21	28	302
2009				36	23	29	15	16	18	24	67	25	20	36	39	46	50	33	29	23	529
2010			31	26	21	26	10	12	14	13	22	5	19	16	21	33	34	27	27	19	376
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	9	7	14	5	12	14	22	21	22	16	17	12	296	
2014	15	31	23	24	30	17	15	9	7	17	6	15	18	22	28	23	18	18	14	350	
2015	9	32	29	22	27	22	18	10	8	16	7	15	18	21	28	27	19	20	13	361	
2016	9	25	29	26	22	15	15	10	8	16	6	16	16	21	30	23	19	17	14	337	
2017	10	28	19	28	14	15	14	6	10	17	7	14	13	23	26	24	19	21	14	322	
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	
2022	6	23	21	20	24	2	11	9	6	11	5	17	15	18	20	21	15	15	9	268	

Shrimp Statistical Zone																				
Year	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
2023	8	26	28	24	17	8	9	7	6	15	5	13	13	19	27	23	19	17	11	295
2024	9	30	30	25	24	10	12	9	6	13	3	11	13	23	24	22	19	20	14	317
<i>Total</i>	126	401	397	357	343	170	211	156	219	1263	272	549	609	792	851	707	807	875	695	9800

Table 2. Number of stations sampled by shrimp statistical zone during the SEAMAP Fall Groundfish Survey from 1987-2024.

Year	Shrimp Statistical Zone																				Total
	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21		
1987									13	23	15	14	16	17	15	15	15	18	3	164	
1988									8	28	7	22	17	18	26	19	21	31	20	217	
1989										44	12	19	17	22	20	17	22	25	26	224	
1990										52	14	12	23	22	19	18	22	19	27	228	
1991										46	6	24	14	20	25	24	19	25	22	225	
1992										34	7	23	14	25	18	17	27	30	18	213	
1993										72	10	19	17	26	18	16	25	28	18	249	
1994										50	9	16	21	25	20	21	23	24	20	229	
1995										40	10	17	18	24	19	14	26	30	19	217	
1996										45	9	18	19	17	28	13	25	29	24	227	
1997										44	10	17	20	26	19	18	23	22	24	223	
1998										44	10	22	14	34	11	15	24	29	22	225	
1999										43	10	17	18	29	18	12	28	29	22	226	
2000										43	10	14	22	20	26	12	30	25	21	223	
2001										44	10	17	19	26	20	14	27	28	23	228	
2002									1	51	10	13	22	22	23	14	26	30	21	233	
2003									1	76	9	16	21	24	22	20	23	25	23	260	
2004										43		11	18	17	27	14	24	30	21	205	
2005										45	11	20	16	33	18	14	23	24	27	231	
2006									1	46	7	22	14	18	28	13	23	32	19	223	
2007										33	9	20	17	18	28	17	20	18	26	206	
2008				15	14	4	4	3	4	35	17	28	34	42	46	44	19	36	20	365	
2009			20	21	25	11	21	13	12	50	12	23	23	30	49	47	31	36	22	446	
2010			9	25	27	17	16	11	14	15	7	15	18	26	30	29	18	19	14	310	
2011							9	11	7	15	6	15	16	27	31	28	21	18	15	219	
2012		2	3	6	6	17	10	7	5	12	5	11	13	19	23	22	13	15	11	200	
2013	4	14	10	10	11	10	10	6	5	10	5	11	9	3	12	16	12	14	9	181	
2014	8	31	25	22	23	13	12	7	7	16	5	13	14	21	27	22	15	17	12	310	
2015	10	28	25	25	21	14	12	9	11	16	6	13	13	19	27	21	16	17	12	315	
2016	5	4	8	11	9	6	13	5	4	8	4	12	11	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	6	12	4	11	12	19	25	22	16	16	12	251	
2022	6	22	20	14	16	9	10	7	6	10	2	10		2	11	11	16	16	12	200	

Year	Shrimp Statistical Zone																				Total
	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21		
2023	8	26	25	21	17	9	7	2	6	12	6	13	11	15	25	22	13	15	9	262	
2024	8	23	27	17	21	13	14	9	3	15	5	12	14	18	15	6	4			224	
<i>Total</i>	93	253	271	276	264	153	194	126	147	1224	298	599	615	823	888	728	762	846	653	9213	

Table 3. Summary of the king mackerel length data collected during SEAMAP Summer Groundfish Surveys conducted between 1987 and 2007 (West Gulf).

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
1987	267	23	11	133	175	162	11
1988	211	6	6	75	208	126	49
1989	194	136	45	90	368	176	48
1990	240	65	38	88	805	152	113
1991	231	106	48	108	525	186	114
1992	226	2	1	475	475	475	.
1993	224	9	7	142	466	264	140
1994	238	144	71	118	414	163	33
1995	220	110	89	113	246	155	34
1996	220	12	9	76	780	231	252
1997	207	9	4	88	448	335	167
1998	205	48	17	65	269	118	56
1999	223	15	6	106	197	145	38
2000	216	31	30	65	1123	276	184
2001	152	34	32	120	158	141	11
2002	227	27	26	129	441	209	52
2003	181	5	5	221	425	271	87
2004	216	154	79	104	420	160	43
2005	181	18	18	120	402	260	73
2006	221	30	30	94	501	256	135
2007	197	227	70	85	255	172	49
2008	302	79	69	77	452	177	109
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
22	4799	1290	711			180	

Table 4. Summary of the king mackerel length data collected during SEAMAP Summer Groundfish Surveys conducted between 2009 and 2024 (West Gulf).

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
2009	529	4	4	69	367	254	142
2010	376	34	15	147	266	209	29
2011	329	11	6	75	492	336	150
2012	399	3	3	350	544	420	107
2013	296	139	92	63	407	139	59
2014	350	2	2	80	348	214	190
2015	361	45	45	84	194	152	27
2016	337	3	3	75	109	92	17
2017	322	1	1	528	528	528	.
2018	302	7	7	109	884	272	280
2019	297	0					
2020	0						
2021	223	0					
2022	268	19	18	140	327	179	41
2023	295	5	4	67	121	90	23
2024	317	0					
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
16	5001	273	200			240	

Table 5. Summary of the king mackerel length data collected during SEAMAP Fall Groundfish Surveys conducted between 1987 and 2007 (West Gulf).

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
1987	164	1	0				
1988	217	15	13	101	314	201	50
1989	224	12	12	115	400	202	95
1990	228	54	24	208	465	325	70
1991	225	9	8	315	593	416	92
1992	213	12	11	119	193	147	24
1993	249	87	54	108	408	273	73
1994	229	29	29	181	418	304	56
1995	217	27	11	108	720	273	166
1996	227	19	17	124	330	225	66
1997	223	34	28	122	368	211	78
1998	225	28	22	160	368	262	52
1999	226	28	26	138	432	270	88
2000	223	16	16	111	353	192	71
2001	228	37	31	100	392	249	90
2002	233	46	43	120	377	215	68
2003	260	148	100	97	777	210	81
2004	205	73	73	132	451	260	76
2005	231	158	69	137	536	235	81
2006	223	56	47	86	458	188	78
2007	206	139	100	159	392	267	60
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured	Overall Mean Fork Length (mm)			
21	4676	1028	734	243			

Table 6. Summary of the king mackerel length data collected during SEAMAP Fall Groundfish Surveys conducted between 2008 and 2024 (West Gulf).

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
2008	365	12	12	206	393	270	48
2009	446	98	88	115	377	197	62
2010	310	109	32	118	858	241	152
2011	219	4	3	220	638	384	223
2012	200	27	27	125	325	208	55
2013	181	25	17	209	401	284	56
2014	310	14	14	152	244	195	24
2015	315	21	21	218	449	305	51
2016	191	14	14	89	365	301	67
2017	284	0					
2018	273	7	7	220	355	291	47
2019	276	21	18	255	340	286	24
2020	230	0					
2021	251	1	1	870	870	870	.
2022	200	5	5	226	342	292	45
2023	262	0					
2024	224	2	2	247	288	268	29
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
17	4537	360	261			242	

Table 7. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel SEAMAP Summer and Fall Groundfish Surveys index of relative abundance from 1987 to 2008 (West Gulf).

<i>Model Run #1</i>	<i>Binomial Submodel Type 3 Tests (AIC 64,965.4)</i>						<i>Lognormal Submodel Type 3 Tests (AIC 1487.5)</i>			
	<i>Num DF</i>	<i>Den DF</i>	<i>Chi-Square</i>	<i>F Value</i>	<i>Pr &gt; ChiSq</i>	<i>Pr &gt; F</i>	<i>Num DF</i>	<i>Den DF</i>	<i>F Value</i>	<i>Pr &gt; F</i>
<i>Year</i>	21	9705	106.84	5.09	<.0001	<.0001	21	476	1.42	0.1015
<i>Depth Zone</i>	22	9705	74.62	3.39	<.0001	<.0001	22	476	5.69	<.0001
<i>Combined Statistical Zone</i>	4	9705	76.35	19.09	<.0001	<.0001	4	476	5.92	0.0001
<i>Time of Day</i>	1	9705	205.56	205.56	<.0001	<.0001	1	476	8.68	0.0034
<i>Season</i>	1	9705	38.54	38.54	<.0001	<.0001	1	476	22.93	<.0001

Table 8. Indices of king mackerel abundance developed using the delta-lognormal (DL) model for SEAMAP Summer and Fall Groundfish Surveys from 1987-2008 (West Gulf). 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	0.01856	431	0.07607	0.42026	0.51614	0.15900	1.11079
1988	0.02570	428	0.07349	0.40603	0.44431	0.17373	0.94892
1989	0.04785	418	0.23326	1.28875	0.33828	0.66721	2.48926
1990	0.05983	468	0.21293	1.17642	0.28921	0.66739	2.07367
1991	0.04167	456	0.11832	0.65371	0.34555	0.33394	1.27968
1992	0.01822	439	0.02821	0.15583	0.51612	0.05896	0.41186
1993	0.06765	473	0.23358	1.29048	0.26979	0.75948	2.19271
1994	0.03854	467	0.16920	0.93481	0.35281	0.47122	1.85450
1995	0.05492	437	0.21667	1.19710	0.31097	0.65197	2.19801
1996	0.03356	447	0.08557	0.47278	0.38506	0.22475	0.99454
1997	0.04419	430	0.09687	0.53521	0.34303	0.27468	1.04285
1998	0.04419	430	0.13477	0.74458	0.34451	0.38109	1.45477
1999	0.04454	449	0.12661	0.69953	0.33740	0.36275	1.34897
2000	0.05011	439	0.07819	0.43197	0.32211	0.23043	0.80977
2001	0.06053	380	0.17596	0.97215	0.31552	0.52499	1.80016
2002	0.04565	460	0.14866	0.82133	0.33073	0.43119	1.56445
2003	0.08163	441	0.31565	1.74391	0.25998	1.04567	2.90840
2004	0.09026	421	0.33583	1.85538	0.24982	1.13428	3.03492
2005	0.09466	412	0.29089	1.60714	0.24818	0.98560	2.62065
2006	0.07658	444	0.18565	1.02569	0.26258	0.61197	1.71910
2007	0.13648	403	0.55443	3.06314	0.21082	2.01853	4.64833
2008	0.02921	582	0.09119	0.50383	0.36369	0.24897	1.01958

Table 9. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel SEAMAP Summer and Fall Groundfish Surveys index of relative abundance from 2009 to 2024 (Gulfwide).

<b>Model Run #1</b>	<i>Binomial Submodel Type 3 Tests (AIC 77,022.6)</i>						<i>Lognormal Submodel Type 3 Tests (AIC 434.5)</i>			
<i>Effect</i>	<i>Num DF</i>	<i>Den DF</i>	<i>Chi-Square</i>	<i>F Value</i>	<i>Pr &gt; ChiSq</i>	<i>Pr &gt; F</i>	<i>Num DF</i>	<i>Den DF</i>	<i>F Value</i>	<i>Pr &gt; F</i>
<i>Year</i>	14	8917	63.68	4.55	<.0001	<.0001	14	158	2.74	0.0012
<i>Time of Day</i>	1	8917	50.93	50.93	<.0001	<.0001	1	158	2.48	0.1172
<i>Combined Statistical Zone</i>	8	8917	102.76	12.84	<.0001	<.0001	8	158	1.33	0.2309
<i>Season</i>	1	8917	36.24	36.24	<.0001	<.0001	1	158	1.49	0.2241
<i>Depth</i>	1	8917	42.46	42.46	<.0001	<.0001	1	158	2.66	0.1052
<b>Model Run #2</b>	<i>Binomial Submodel Type 3 Tests (AIC 77,022.6)</i>						<i>Lognormal Submodel Type 3 Tests (AIC 442.8)</i>			
<i>Effect</i>	<i>Num DF</i>	<i>Den DF</i>	<i>Chi-Square</i>	<i>F Value</i>	<i>Pr &gt; ChiSq</i>	<i>Pr &gt; F</i>	<i>Num DF</i>	<i>Den DF</i>	<i>F Value</i>	<i>Pr &gt; F</i>
<i>Year</i>	14	8917	63.68	4.55	<.0001	<.0001	14	166	2.60	0.0020
<i>Time of Day</i>	1	8917	50.93	50.93	<.0001	<.0001	1	166	8.27	0.0046
<i>Combined Statistical Zone</i>	8	8917	102.76	12.84	<.0001	<.0001	Dropped			
<i>Season</i>	1	8917	36.24	36.24	<.0001	<.0001	1	166	0.64	0.4254
<i>Depth</i>	1	8917	42.46	42.46	<.0001	<.0001	1	166	1.06	0.3045
<b>Model Run #3</b>	<i>Binomial Submodel Type 3 Tests (AIC 77,022.6)</i>						<i>Lognormal Submodel Type 3 Tests (AIC 441.5)</i>			
<i>Effect</i>	<i>Num DF</i>	<i>Den DF</i>	<i>Chi-Square</i>	<i>F Value</i>	<i>Pr &gt; ChiSq</i>	<i>Pr &gt; F</i>	<i>Num DF</i>	<i>Den DF</i>	<i>F Value</i>	<i>Pr &gt; F</i>
<i>Year</i>	14	8917	63.68	4.55	<.0001	<.0001	14	167	2.63	0.0018
<i>Time of Day</i>	1	8917	50.93	50.93	<.0001	<.0001	1	167	8.47	0.0041
<i>Combined Statistical Zone</i>	8	8917	102.76	12.84	<.0001	<.0001	Dropped			
<i>Season</i>	1	8917	36.24	36.24	<.0001	<.0001	Dropped			
<i>Depth</i>	1	8917	42.46	42.46	<.0001	<.0001	1	167	2.05	0.1545
<b>Model Run #4</b>	<i>Binomial Submodel Type 3 Tests (AIC 77,022.6)</i>						<i>Lognormal Submodel Type 3 Tests (AIC 435.8)</i>			
<i>Effect</i>	<i>Num DF</i>	<i>Den DF</i>	<i>Chi-Square</i>	<i>F Value</i>	<i>Pr &gt; ChiSq</i>	<i>Pr &gt; F</i>	<i>Num DF</i>	<i>Den DF</i>	<i>F Value</i>	<i>Pr &gt; F</i>
<i>Year</i>	14	8917	63.68	4.55	<.0001	<.0001	14	168	3.06	0.0003
<i>Time of Day</i>	1	8917	50.93	50.93	<.0001	<.0001	1	168	8.46	0.0041
<i>Combined Statistical Zone</i>	8	8917	102.76	12.84	<.0001	<.0001	Dropped			
<i>Season</i>	1	8917	36.24	36.24	<.0001	<.0001	Dropped			
<i>Depth</i>	1	8917	42.46	42.46	<.0001	<.0001	Dropped			

Table 10. Indices of king mackerel abundance developed using the delta-lognormal (DL) model for SEAMAP Summer and Fall Groundfish Surveys from 2009-2024 (Gulfwide). 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	0.031795	975	0.03547	1.02400	0.31860	0.54983	1.9071
2010	0.039359	686	0.10065	2.90600	0.33351	1.51780	5.5639
2011	0.014599	548	0.01179	0.34052	0.51919	0.12817	0.9046
2012	0.018364	599	0.02497	0.72087	0.46120	0.29951	1.7350
2013	0.058700	477	0.18896	5.45560	0.31893	2.92754	10.1668
2014	0.015152	660	0.01536	0.44333	0.47233	0.18069	1.0877
2015	0.031065	676	0.05376	1.55221	0.35775	0.77538	3.1073
2016	0.018939	528	0.02111	0.60959	0.47764	0.24620	1.5094
2017	0.001650	606	0.00104	0.02989	1.30772	0.00406	0.2202
2018	0.017391	575	0.01487	0.42939	0.47508	0.17418	1.0585
2019	0.022688	573	0.02210	0.63805	0.42795	0.28096	1.4490
2020							
2021	0.002110	474	0.00076	0.02200	1.30561	0.00299	0.1617
2022	0.017094	468	0.02156	0.62246	0.52582	0.23172	1.6721
2023	0.005386	557	0.00443	0.12785	0.79676	0.03146	0.5196
2024	0.003697	541	0.00271	0.07826	0.95257	0.01569	0.3904

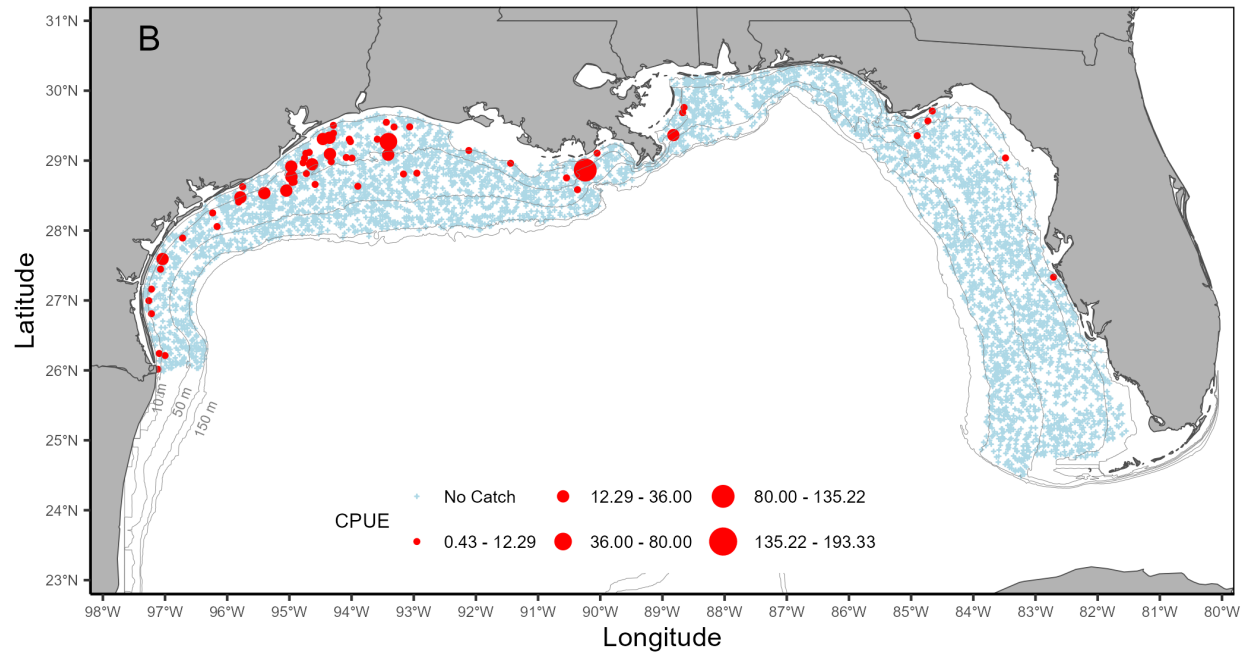
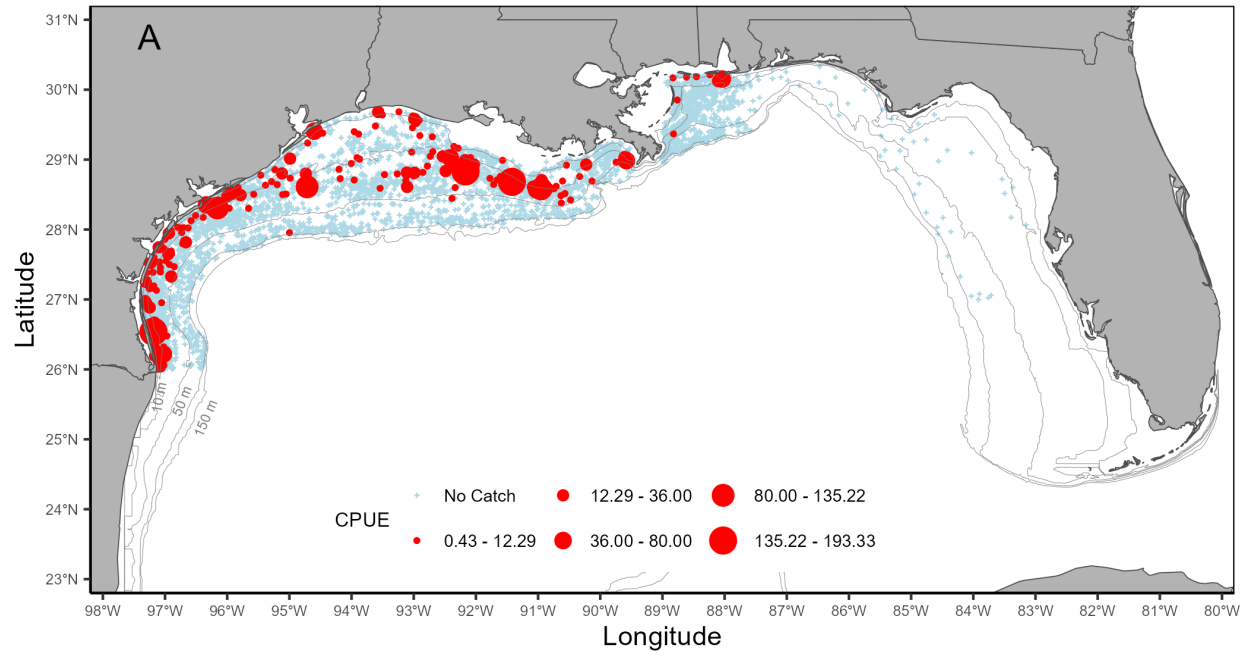


Figure 1. Stations sampled during the SEAMAP Summer Groundfish Survey with the CPUE for king mackerel from **A.** 1987 – 2008 and **B.** 2009 – 2024.

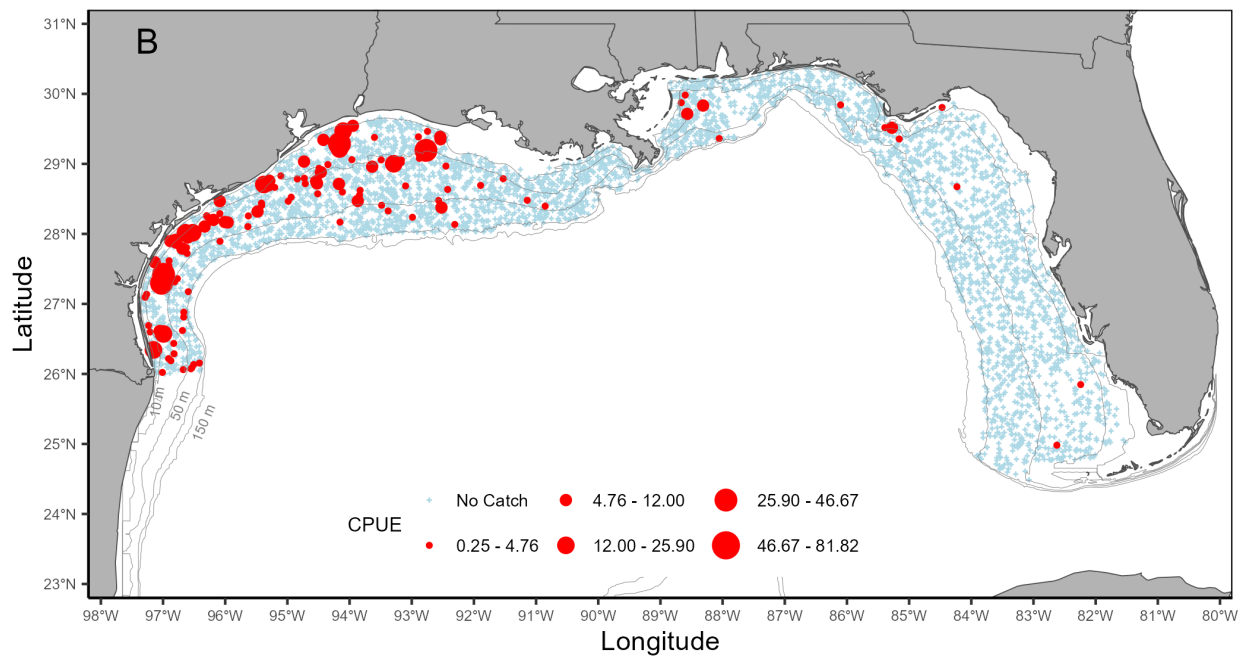
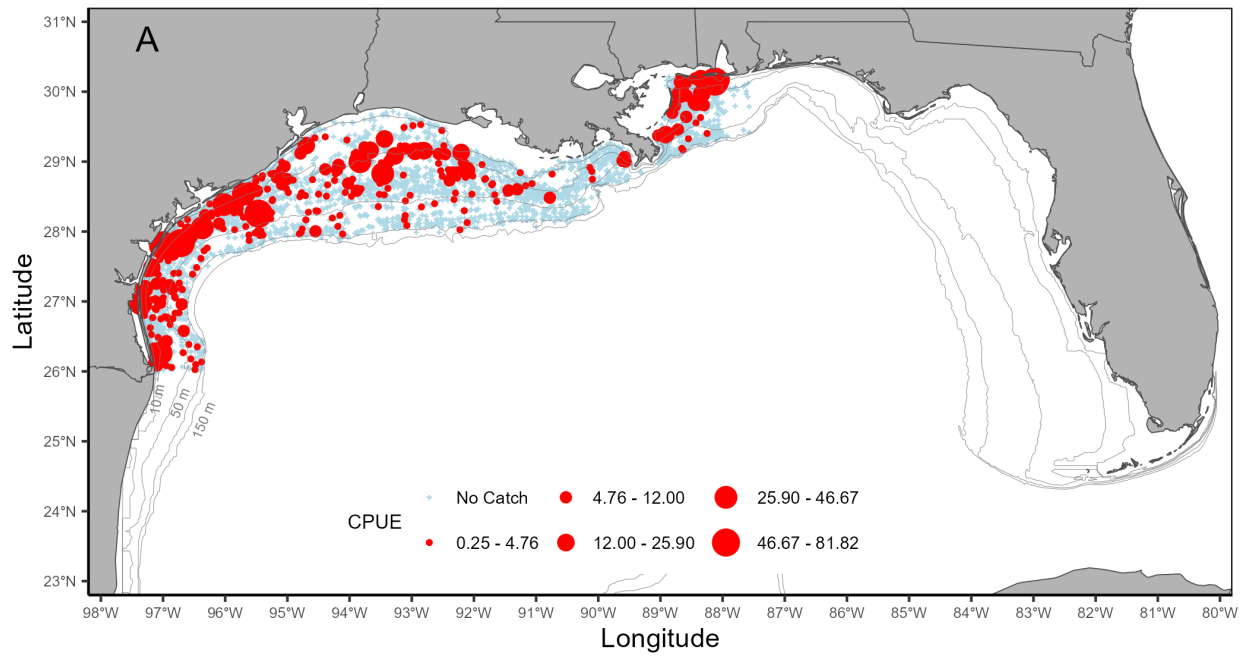


Figure 2. Stations sampled during the SEAMAP Fall Groundfish Survey with the CPUE (number per trawl hour) for king mackerel from **A.** 1987 – 2007 and **B.** 2008 – 2024.

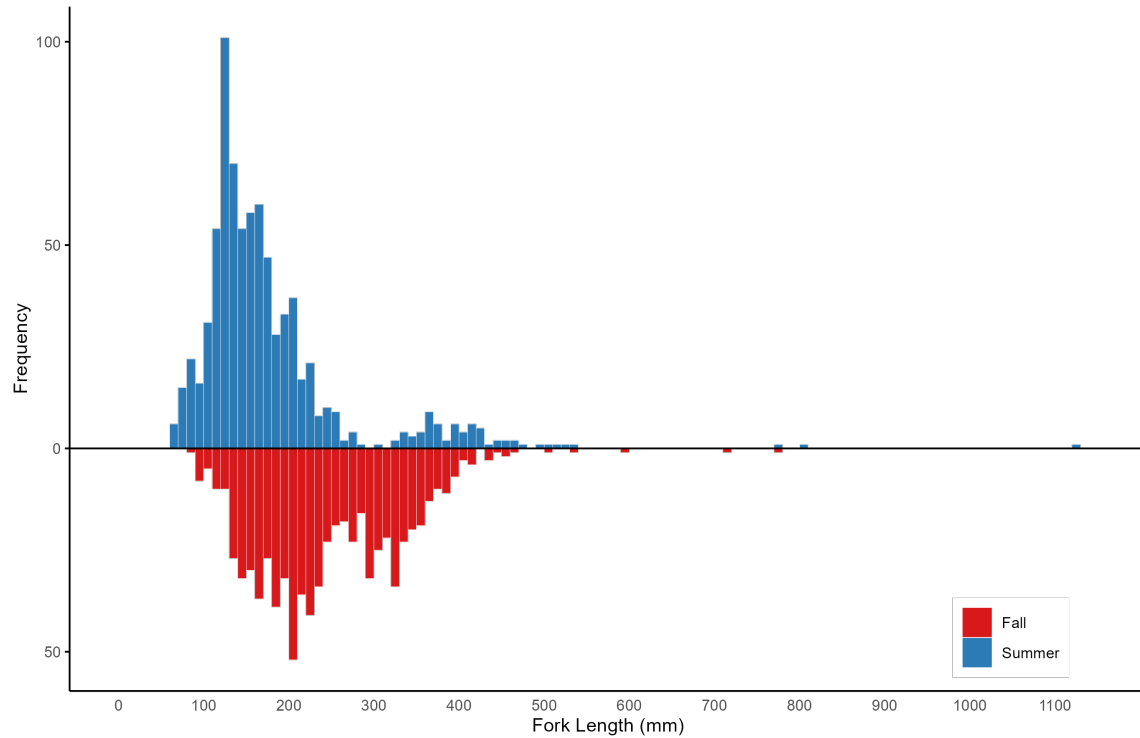


Figure 3. Length frequency histograms for king mackerel captured during SEAMAP Summer and Fall Groundfish Surveys from 1987-2008.

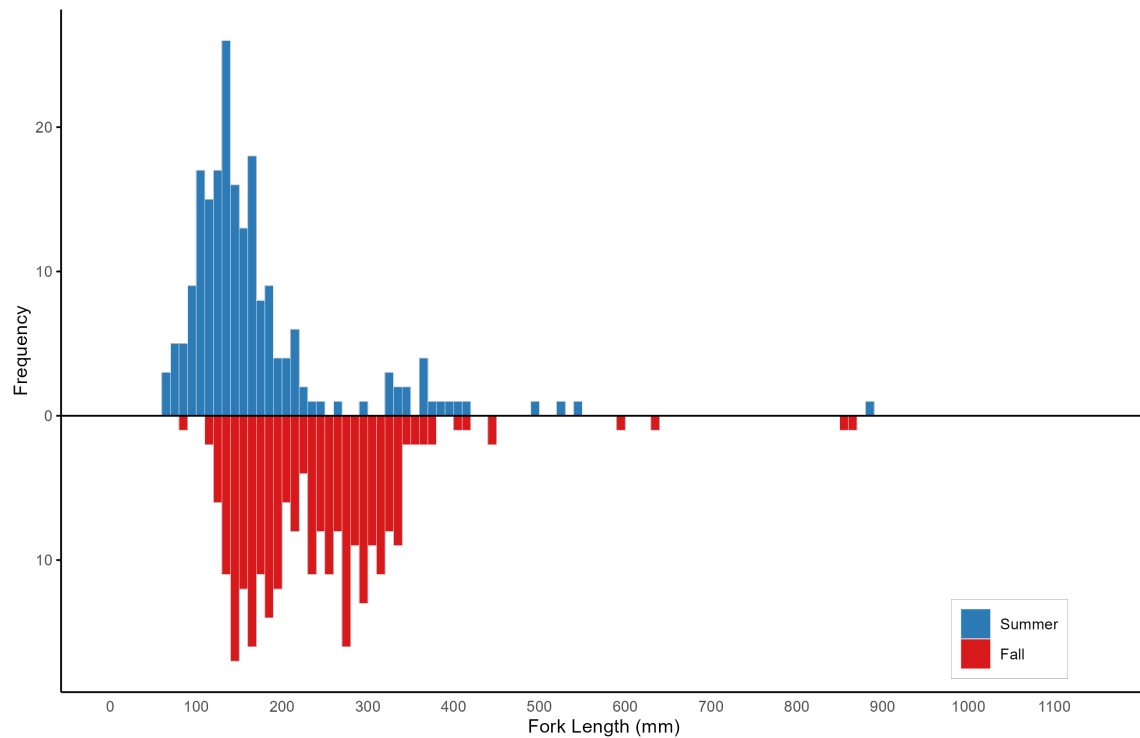


Figure 4. Length frequency histograms for king mackerel captured during SEAMAP Summer and Fall Groundfish Surveys from 2009-2024.

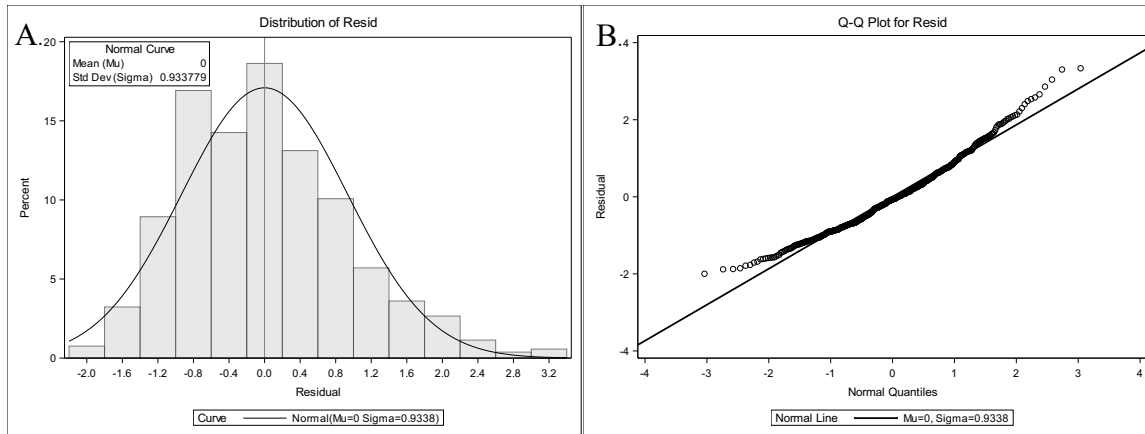


Figure 5. Diagnostic plots for lognormal component of the king mackerel SEAMAP Summer and Fall Groundfish Surveys (West Gulf - 1987-2008) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

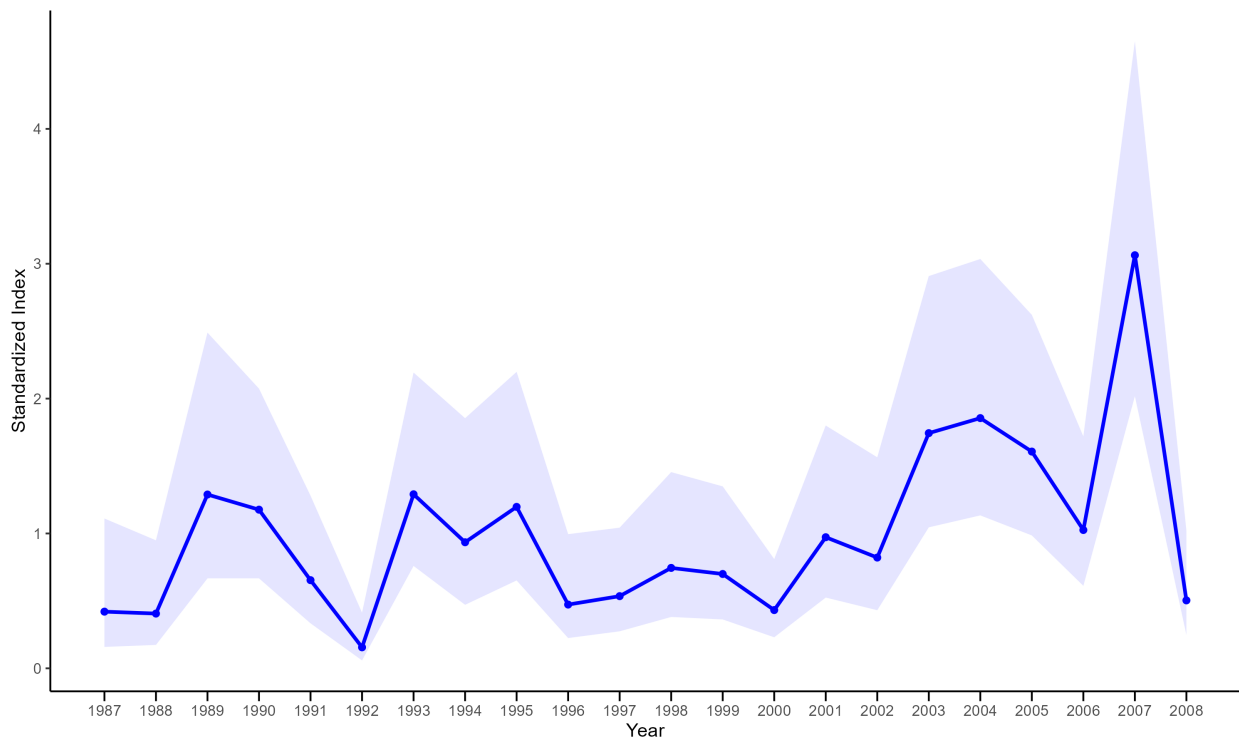


Figure 6. Annual index of abundance for king mackerel from the SEAMAP Summer and Fall Groundfish Surveys from 1987 – 2008 (West Gulf).

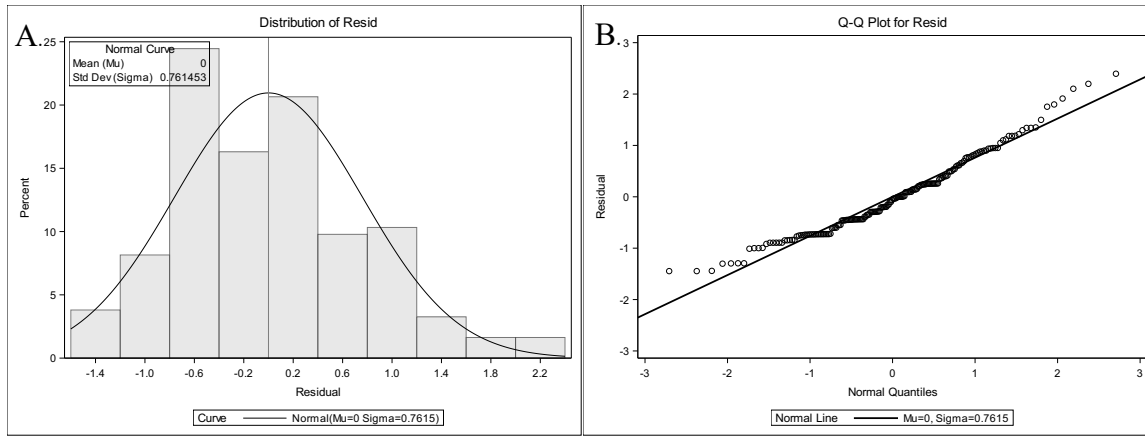


Figure 7. Diagnostic plots for lognormal component of the king mackerel SEAMAP Summer and Fall Groundfish Surveys (Gulfwide - 2009 - 2024) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

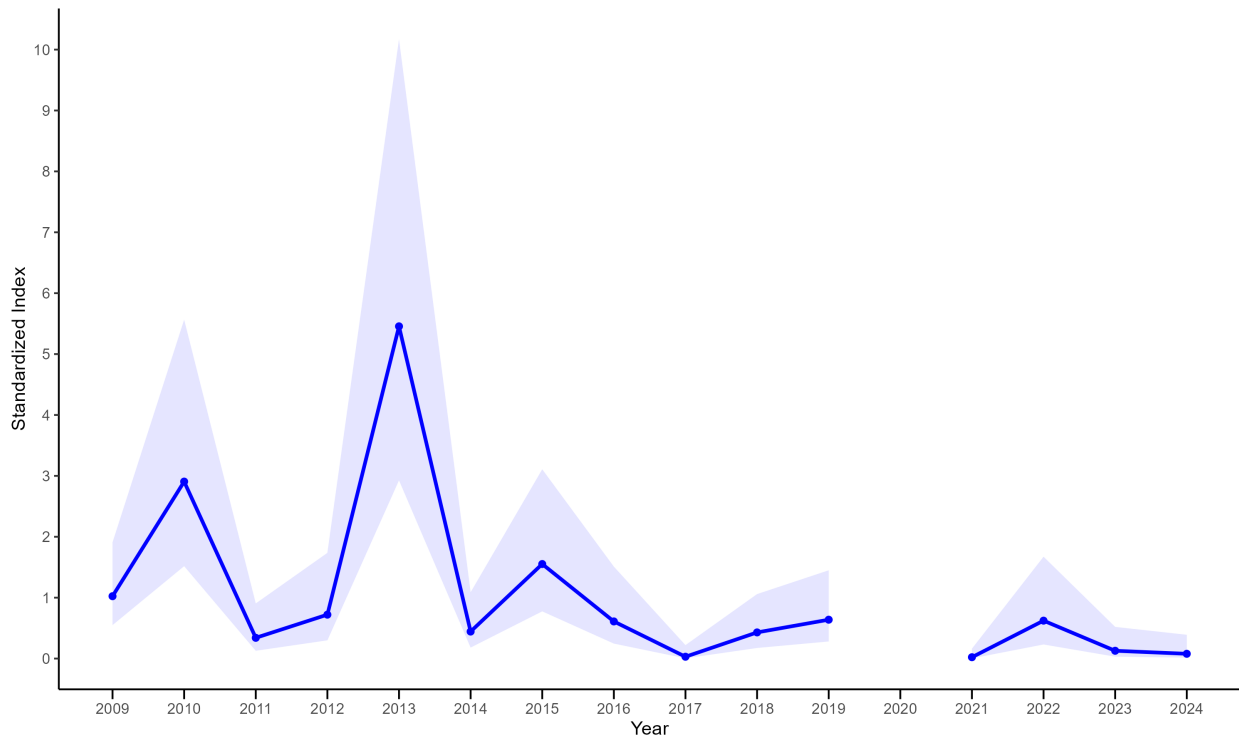


Figure 8. Annual index of abundance for king mackerel from the SEAMAP Summer and Fall Groundfish Surveys from 2009 – 2024 (Gulfwide).

# **Appendix**

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

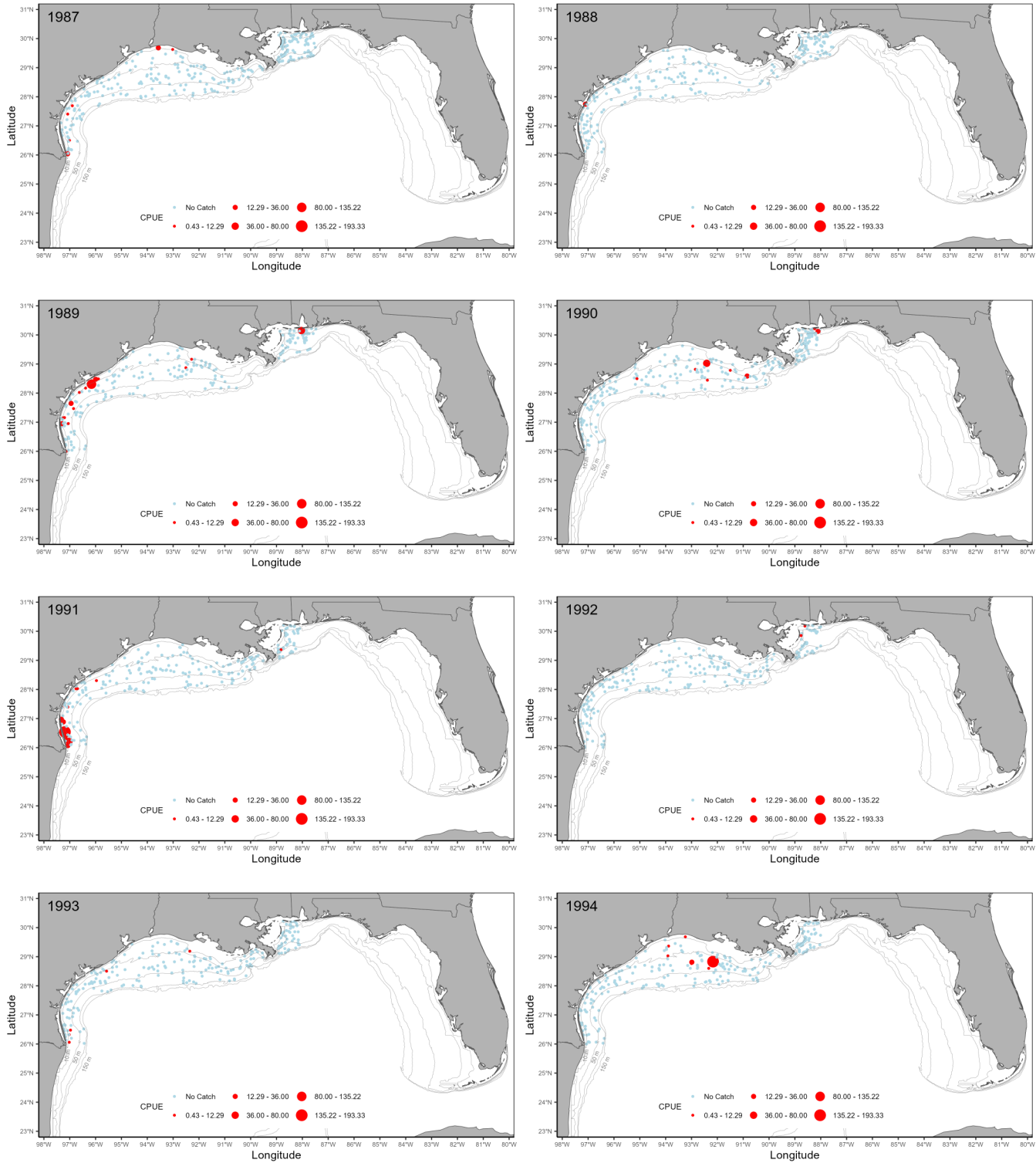
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	4898	450	0.09187	0.80776
Time of Day	Night	4857	76	0.01565	0.09085
Year	1987	431	8	0.01856	0.16975
Year	1988	428	11	0.02570	0.15720
Year	1989	418	20	0.04785	0.77344
Year	1990	468	28	0.05983	0.42751
Year	1991	456	19	0.04167	0.77460
Year	1992	439	8	0.01822	0.05835
Year	1993	473	32	0.06765	0.42903
Year	1994	467	18	0.03854	0.65122
Year	1995	437	24	0.05492	0.74526
Year	1996	447	15	0.03356	0.19597
Year	1997	430	19	0.04419	0.16548
Year	1998	430	19	0.04419	0.27203
Year	1999	449	20	0.04454	0.24358
Year	2000	439	22	0.05011	0.17386
Year	2001	380	23	0.06053	0.30531
Year	2002	460	21	0.04565	0.46476
Year	2003	441	36	0.08163	0.53895
Year	2004	421	38	0.09026	0.89068
Year	2005	412	39	0.09466	0.65114
Year	2006	444	34	0.07658	0.41823
Year	2007	403	55	0.13648	1.27635
Year	2008	582	17	0.02921	0.25779
Depth Zone	0506	427	24	0.05621	0.66602
Depth Zone	0607	499	28	0.05611	0.73998
Depth Zone	0708	429	22	0.05128	0.43263
Depth Zone	0809	361	36	0.09972	0.62248
Depth Zone	0910	444	27	0.06081	0.52328
Depth Zone	1011	516	42	0.08140	0.99118
Depth Zone	1112	445	35	0.07865	0.92494
Depth Zone	1213	357	34	0.09524	0.86456
Depth Zone	1314	519	34	0.06551	0.85802
Depth Zone	1415	429	25	0.05828	0.62435
Depth Zone	1516	383	31	0.08094	0.58109
Depth Zone	1617	429	24	0.05594	0.93374
Depth Zone	1718	488	26	0.05328	0.29806
Depth Zone	1819	424	15	0.03538	0.21740
Depth Zone	1920	382	13	0.03403	0.12435

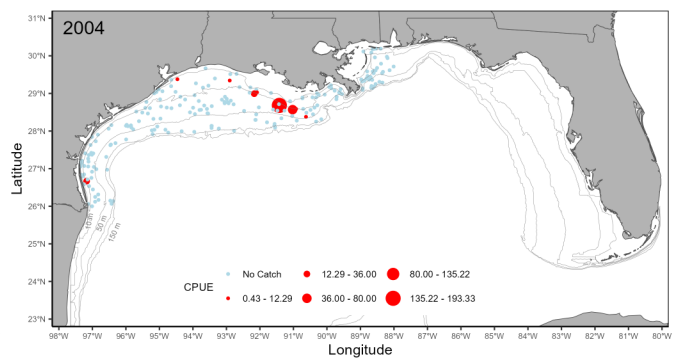
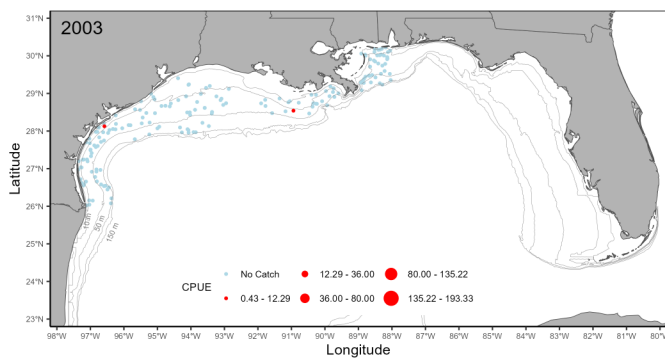
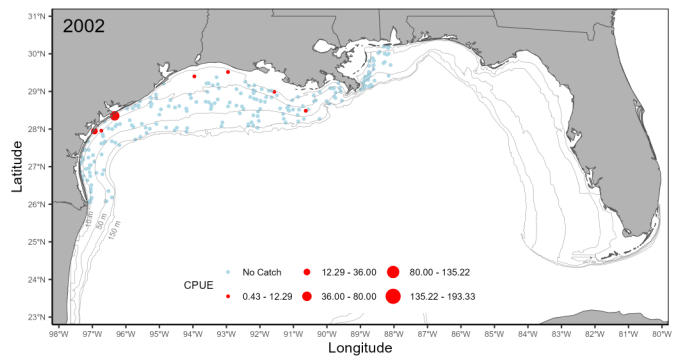
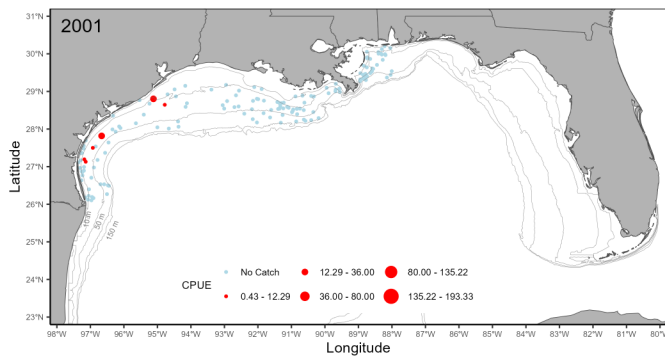
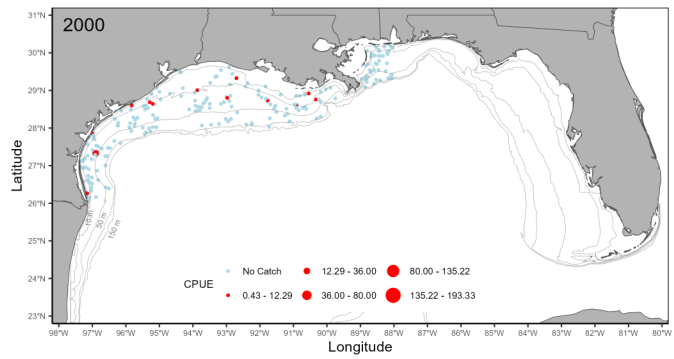
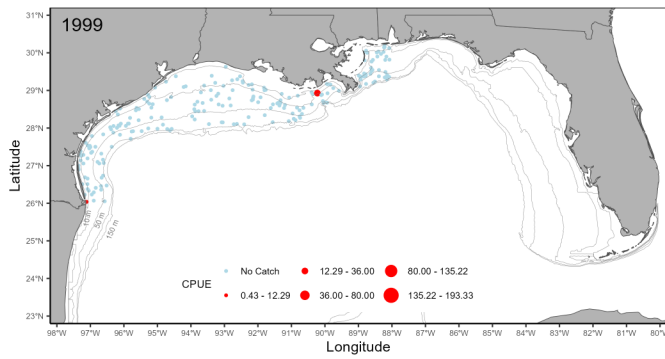
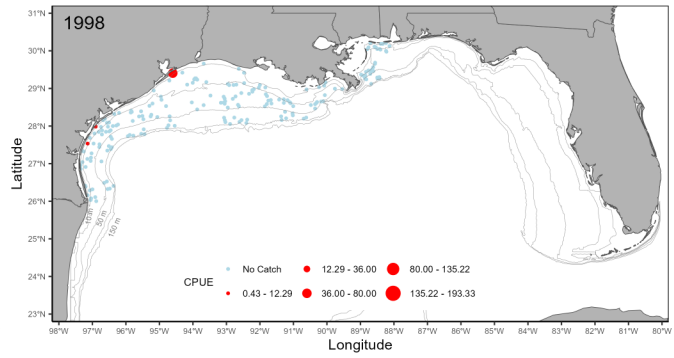
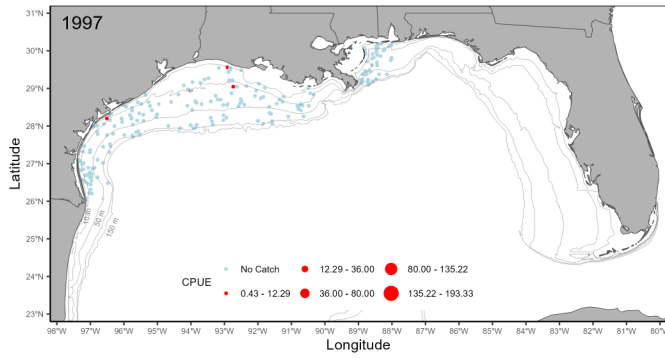
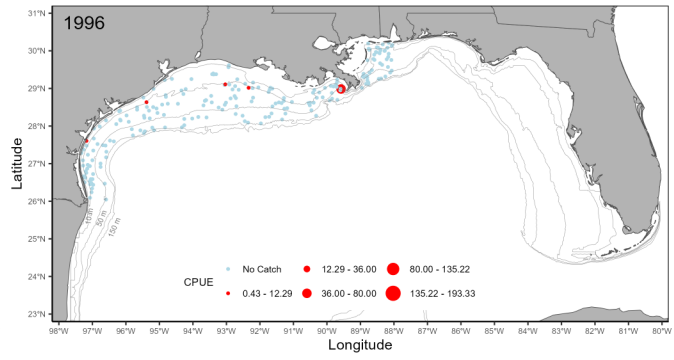
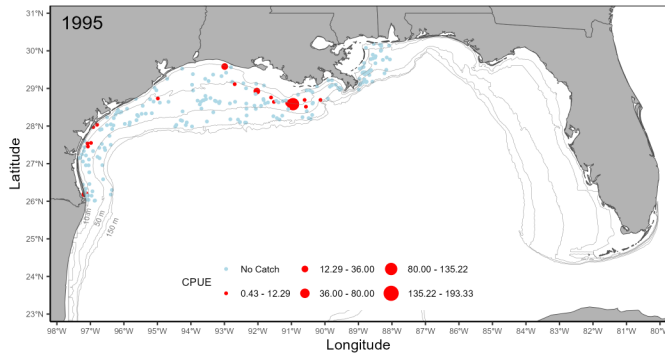
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Depth Zone	2022	455	20	0.04396	0.14303
Depth Zone	2225	427	13	0.03044	0.10596
Depth Zone	2530	413	24	0.05811	0.09015
Depth Zone	3035	440	22	0.05000	0.06291
Depth Zone	3540	408	15	0.03676	0.11435
Depth Zone	4045	393	6	0.01527	0.02051
Depth Zone	4550	380	7	0.01842	0.03765
Depth Zone	5060	307	3	0.00977	0.01290
Season	Fall	5001	341	0.06819	0.36644
Season	Summer	4754	185	0.03891	0.53956
Combined Statistical Zone	1011	2079	54	0.02597	0.23148
Combined Statistical Zone	1315	1897	63	0.03321	0.33817
Combined Statistical Zone	1617	1910	117	0.06126	0.48260
Combined Statistical Zone	1819	1741	129	0.07410	0.57503
Combined Statistical Zone	2021	2128	163	0.07660	0.63533

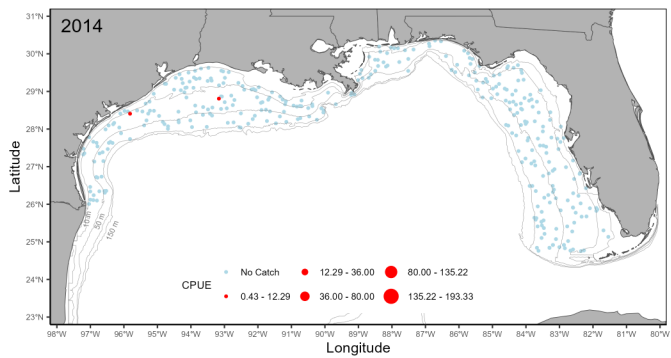
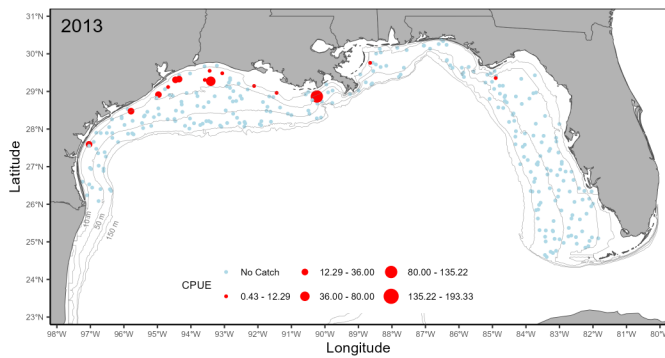
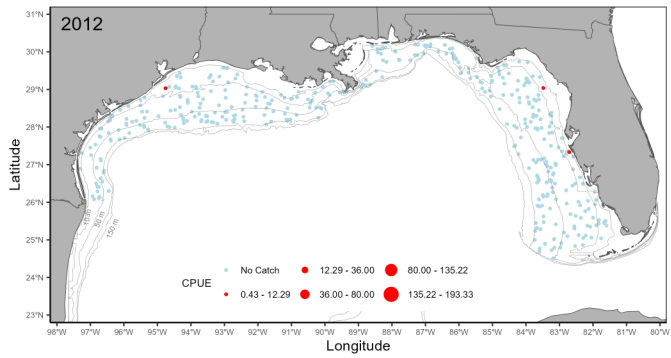
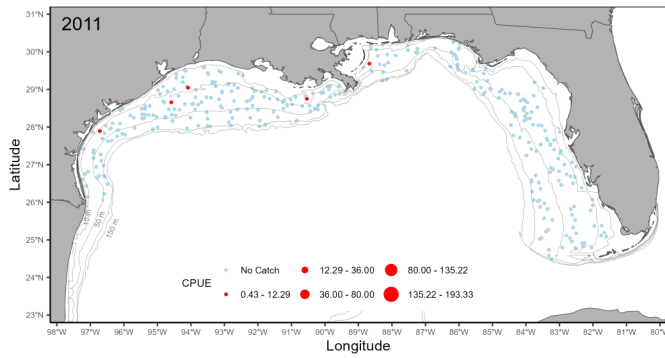
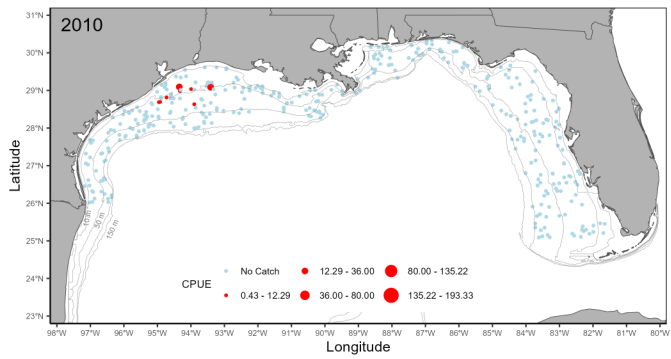
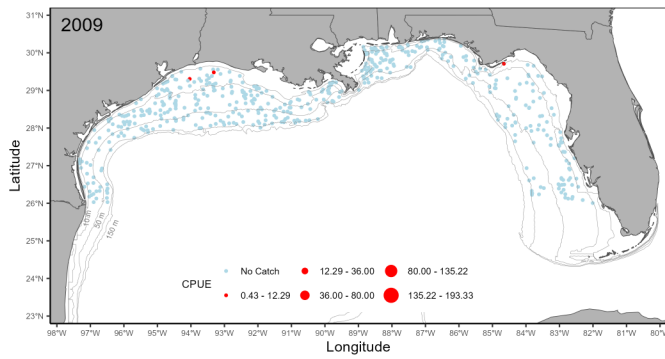
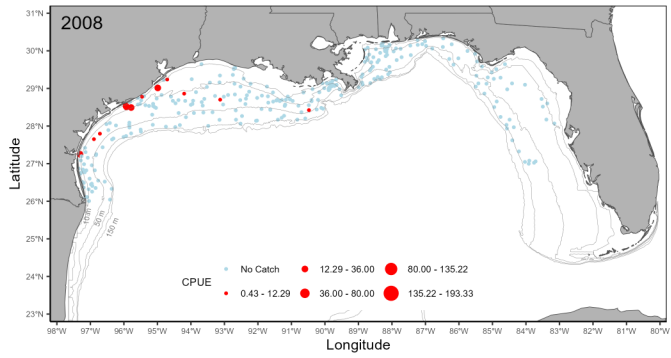
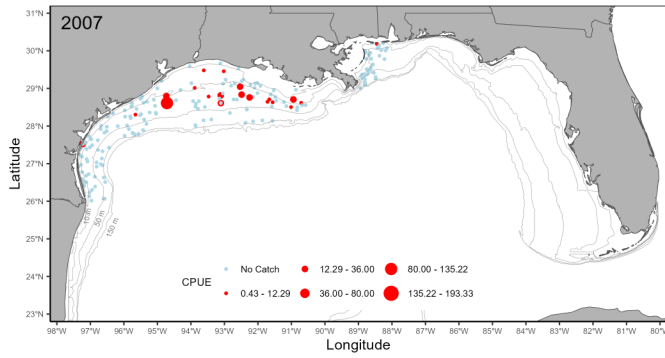
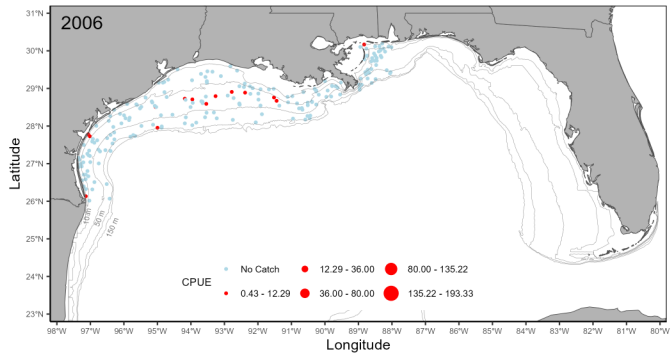
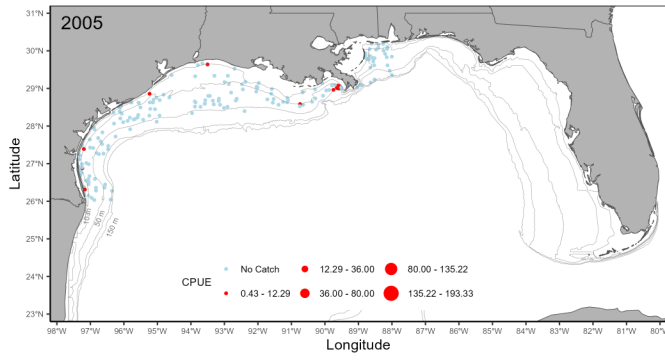
Appendix Table 2. Summary of the factors used in constructing the king mackerel abundance index from the SEAMAP Summer and Fall Groundfish Surveys (Gulfwide - 20098-2024) data.

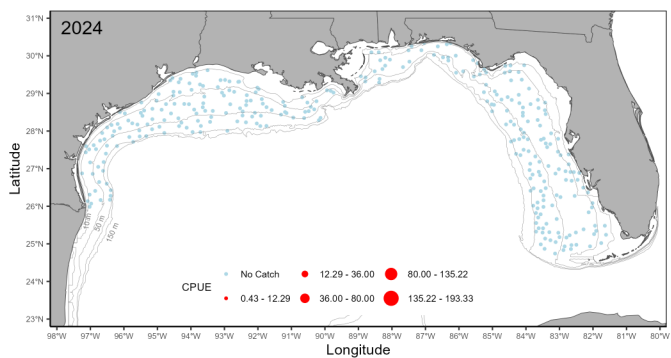
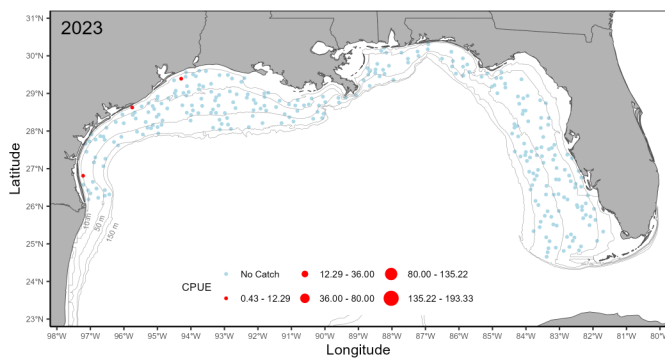
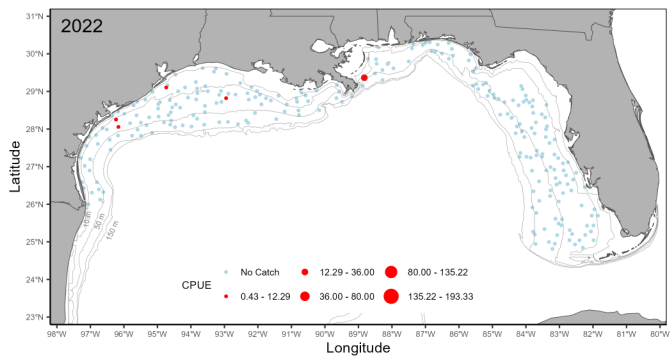
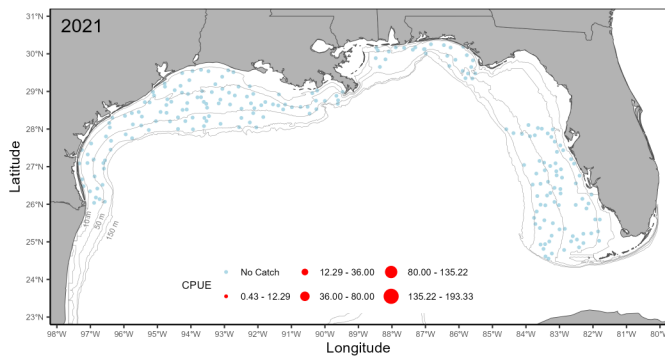
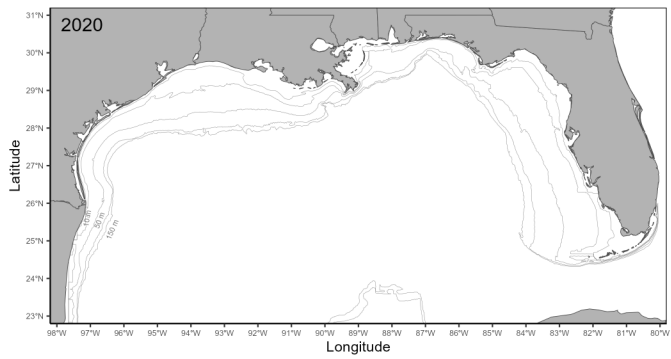
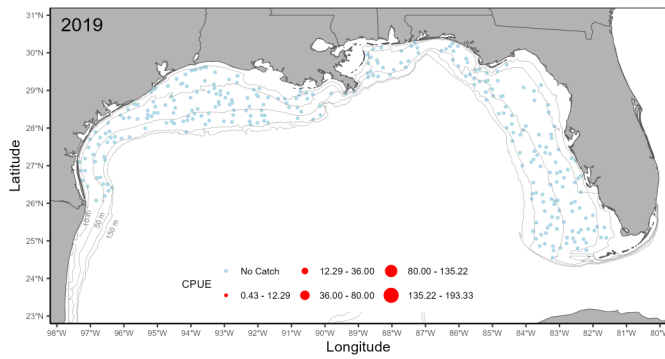
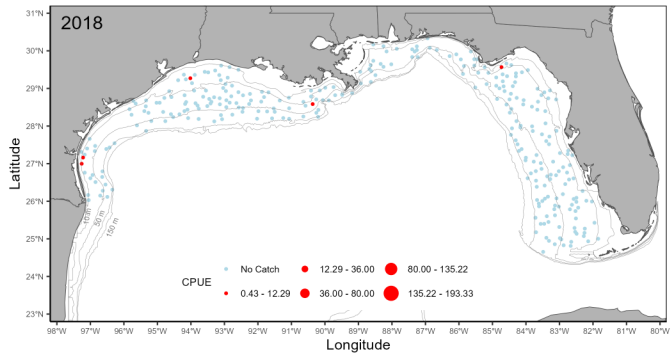
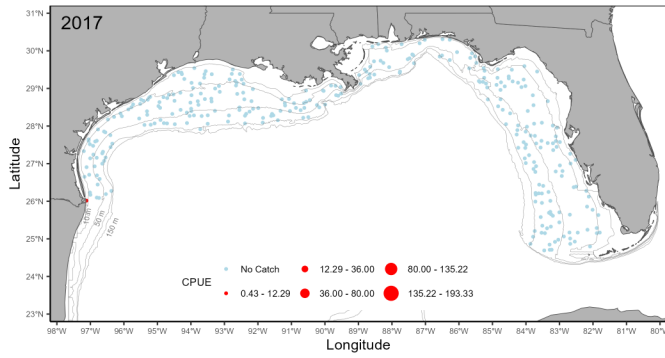
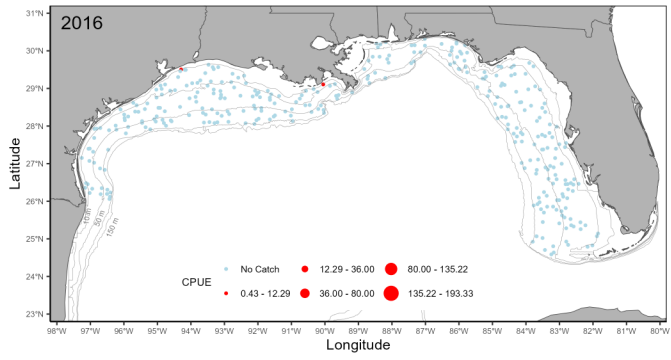
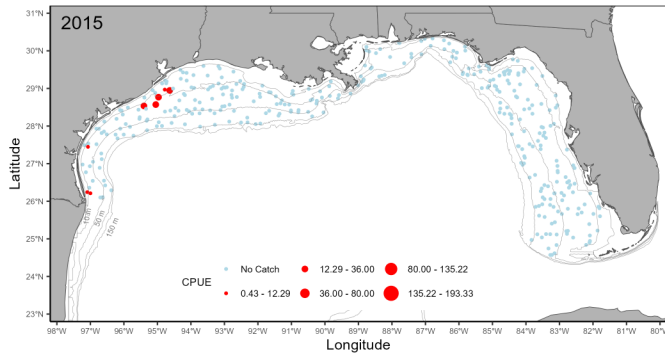
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Combined Statistical Zone	0203	849	2	0.002356	0.00471
Combined Statistical Zone	0405	1240	1	0.000806	0.00161
Combined Statistical Zone	0607	883	6	0.006795	0.01586
Combined Statistical Zone	0809	646	4	0.006192	0.02774
Combined Statistical Zone	1011	753	7	0.009296	0.06906
Combined Statistical Zone	1315	1022	10	0.009785	0.10168
Combined Statistical Zone	1617	1404	39	0.027778	0.17883
Combined Statistical Zone	1819	1230	68	0.055285	0.41083
Combined Statistical Zone	2021	916	47	0.051310	0.31076
Time of Day	Day	4817	148	0.030725	0.22205
Time of Day	Night	4126	36	0.008725	0.04006
Season	Fall	3942	121	0.030695	0.17518
Season	Summer	5001	63	0.012597	0.10885
Year	2009	975	31	0.031795	0.20646
Year	2010	686	27	0.039359	0.41412
Year	2011	548	8	0.014599	0.05441
Year	2012	599	11	0.018364	0.09909
Year	2013	477	28	0.058700	0.68592
Year	2014	660	10	0.015152	0.04839
Year	2015	676	21	0.031065	0.19455
Year	2016	528	10	0.018939	0.06428
Year	2017	606	1	0.001650	0.00328
Year	2018	575	10	0.017391	0.04858
Year	2019	573	13	0.022688	0.07306
Year	2020				
Year	2021	474	1	0.002110	0.00421
Year	2022	468	8	0.017094	0.10257
Year	2023	557	3	0.005386	0.01792
Year	2024	541	2	0.003697	0.00739

Appendix Figure 1. Annual survey effort and catch of king mackerel from the SEAMAP Summer Groundfish Survey.









Appendix Figure 2. Annual survey effort and catch of king mackerel from the SEAMAP Fall Groundfish Survey.

