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

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Abstract

The Southeast Fisheries Science Center Mississippi Laboratories and state partners have conducted groundfish surveys since 1972 in the northern Gulf of Mexico during the summer and fall under several sampling programs. In 1987, both groundfish surveys were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent data were used to develop abundance indices for king mackerel (Scomberomorus cavalla). Separate indices were produced using the fall SEAMAP groundfish survey data and combined (summer and fall) SEAMAP groundfish survey data. A continuity run was also produced that mirrored the methodology used for SEDAR 16. Annual abundance indices were showing an increase during SEDAR 16 through 2007. Subsequently, since 2007, the indices are showing a decline in king mackerel abundance.

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories and state partners have conducted standardized 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. The Southeast Area Monitoring and Assessment Program 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 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 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 fathoms), shrimp statistical zones (between 88° and 97° W longitude, statistical zones 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 shrimp statistical zone with a weighting by area. Other notable changes included a standardized 30 minute 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. Recently, a new modification was added to the survey design, a depth stratification of 5 - 20 fathoms and 20 – 60 fathoms.

Data

A total of 17,919 stations were sampled from 1972- 2012 with 7767 and 10,595 stations sampled during the summer and fall survey, respectively (Tables 1 and 2). Trawl data was obtained from the MSLABS trawl unit leader (Gilmore Pellegrin) 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 was limited to only those stations that did not indicate a problem with the tow, and were outside of shrimp statistical zone 12, and between 5 and 60 fathoms. In addition, data collected by Texas was excluded because of the use of a different gear type (20 foot shrimp trawl vs. the 40 foot shrimp trawl). Data from shrimp statistical zones 2-9 were excluded from the analysis due to the limited sampling (only during the last 5 years). It also became necessary to exclude this data because of the limited catch of king mackerel (6 stations with positive catch) caused the models not to converge.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for king mackerel (Lo *et al*. 1992). 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 (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) 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 as:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\mathrm{Cov}(c, p) \approx \rho_{\mathrm{c,p}}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denotes correlation of *c* and *p* among years.

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 α = 0.05. 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. Variables that could be included in the submodels were:

Submodel Variables (Continuity)

Year: 1972 – 2012
Shrimp Statistical Zone: 21-20, 19-18, 17-16, 15-13 and 12-10
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 and 50-60 fathoms

Submodel Variables (Fall SEAMAP Groundfish Survey)

Year: 1972 – 2012
Region: Texas, West Louisiana, East Louisiana, Mississippi/Alabama, West Florida, East Florida (Figure 1)
Depth: 5 – 60 (continuous)
Time of Day: Day, Night

Submodel Variables (Summer and Fall SEAMAP Groundfish Survey)

Year: 1972 – 2012
Region: Texas, West Louisiana, East Louisiana, Mississippi/Alabama, West Florida, East Florida (Figure 1)
Depth: 5 – 60 (continuous)
Time of Day: Day, Night
Season: Summer, Fall

During SEDAR 16, only the fall SEAMAP groundfish survey data (Ingram 2008) was used to construct the index, however, no mention was made as to why only this data set was used. Therefore, we decided to produce two indices in addition to the continuity run. One index was constructed using the fall dataset, with a different set of variables from the continuity run that took into account the changes in survey design over time. The second index used both the summer and fall data in a combined index. The difference in the area variables between the continuity run and other runs was due to the design of the fall survey prior to 1987. During these years, the areas of East Louisiana and Mississippi/Alabama (Figure 1) were considered the primary sampling area, areas directly west and east of the primary were designated the secondary sampling areas. East Florida and Texas were not sampled during these early years. A variable representing survey design (Early: 1972-1986, Old: 1987-2007 and New: 2008-2012) was considered for inclusion in the submodels. However, when this variable was added to the submodels, the models failed to converge, thus it was removed.

Results and Discussion

Age and Size

The distribution of king mackerel is presented in Figure 2, with seasonal/annual abundance and distribution presented in the Appendix Figure 1. The total number of king mackerel captured ranged from 0 to 144 in the summer (Table 3) and 0 to 110 in the fall (Table 4). Of the 1225 king mackerel captured during the summer survey, a total of 757 were measured from 1987 – 2012 with an average total length of 184 mm. While during the fall survey 1129 king mackerel were captured, with 894 measured, with an average total length of 239 mm. The length frequency distribution of king mackerel captured is shown in Figures 3 and 4. Aging of otoliths (42) from 2009 to 2012 by the NFMS Panama City Laboratory revealed that the majority of king mackerel collected during the survey were age 0 (37), ranging in size from 120 mm to 354 mm. There were also five age 1 king mackerel collected ranging in size from 384 mm to 470 mm and one age 5 fish (855 mm).

Continuity Model

For the continuity run, the variables: year, shrimp statistical zone and depth zone were used in the submodels to replicate the methodology used in SEDAR 16. Year, shrimp statistical zone and depth zone were retained in both the binomial and lognormal submodels. Table 5 summarizes the final set of variables used in the submodels and their significance. The diagnostic plots for the binomial and lognormal submodels indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 6 and Figure 4, with a comparison between the index values from SEDAR 16 and the continuity run in Figure 5.

SEAMAP Fall Groundfish

For the Fall SEAMAP abundance index of king mackerel, the nominal CPUE and number of stations with a positive catch are presented in Figure 6. Year, region, time of day and depth 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 final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 66,270.5 and 1108.3, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 7-9, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 8 and Figure 10.

SEAMAP Summer and Fall Groundfish

For the combined (summer and fall) SEAMAP abundance index of king mackerel, the nominal CPUE and number of stations with a positive catch are presented in Figure 11. Year, region, season, time of day and depth were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 2. Table 9 summarizes backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 113,935.6 and 1773.4, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 12-14, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 10 and Figure 15.

Literature Cited

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Table 1. Number of stations sampled by shrimp statistical zone during the Summer SEAMAP groundfish survey from 1982-2012.

	Shrimp Statistical Zone																			
Year	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1982									14	36	24	26	8	1	11	30	10	3	23	***186***
1983							5	19	8	26		6	16	19	25	24	21	5	17	***191***
1984									13	36	10	16	16	22	17	15	23	28	14	***210***
1985									10	48	11	27	12	10	7	7	12	11	10	***165***
1986									17	49	4	20	14	8	11	8	11	14	6	***162***
1987									27	58	8	34	21	25	20	16	25	28	19	***281***
1988									17	46	10	14	9	19	24	14	25	28	23	***229***
1989									21	30	8	13	18	25	7	15	20	29	24	***210***
1990										65	18	31	17	23	16	20	23	24	20	***257***
1991										44	16	41	13	23	22	24	18	23	26	***250***
1992									1	44	2	36	30	20	25	12	31	26	20	***247***
1993										44	22	29	19	24	19	14	29	24	22	***246***
1994										60	12	27	28	25	17	20	22	26	22	***259***
1995										42	12	26	24	22	23	13	27	26	21	***236***
1996										46	14	34	19	22	18	17	21	26	25	***242***
1997										42	4	26	22	22	23	10	28	26	26	***229***
1998										34	6	28	27	25	18	14	22	36	17	***227***
1999										43	11	31	26	20	23	13	25	32	20	***244***
2000										43	11	27	19	19	27	8	29	31	21	***235***
2001										34	15	24	28	13	3	10	9	17	21	***174***
2002										44	15	34	21	27	19	15	25	29	22	***251***
2003										42	17	26	8	2	17	20	22	26	23	***203***
2004										38	19	28	21	20	25	21	19	25	21	***237***
2005										31	10	9	23	16	21	5	28	22	27	***192***
2006										45	17	29	16	20	23	17	23	31	18	***239***
2007										40	12	10	23	22	23	7	29	32	21	***219***
2008			1	8	11	6	11	8	11	42	24	19	27	23	22	17	24	21	29	***304***
2009			36	23	29	16	17	18	24	67	25	20	36	39	46	53	33	29	23	***534***
2010		31	26	21	26	10	12	14	15	22	5	20	16	21	33	34	27	27	19	***379***
2011	11	24	22	20	29	2	15	11	8	16	7	14	17	24	29	29	18	21	13	***330***
2012	12	39	33	29	30	19	16	17	13	16	7	15	17	25	29	27	20	20	15	***399***
Total	***23***	***94***	***118***	***101***	***125***	***53***	***76***	***87***	***199***	***1273***	***376***	***740***	***611***	***626***	***643***	***549***	***699***	***746***	***628***	***7767***

Table 2. Number of stations sampled by shrimp statistical zone during the Fall SEAMAP groundfish survey from 1972-2012.

	Shrimp Statistical Zone																		
Year	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1972								10	55	27	41	34	17						***184***
1973							11	17	98	34	71	39	2						***272***
1974								12	92	35	73	31							***243***
1975									93	33	80	35	32	7					***280***
1976									108	42	79	56	22						***307***
1977									97	31	76	38							***242***
1978								36	101	32	67	58	25						***319***
1979									109	35	72	55	2						***273***
1980								24	85	22	70	32							***233***
1981								21	85	33	66	49	25						***279***
1982								21	102	41	72	37							***273***
1983								17	82	35	63	25							***222***
1984									82	32	64	47	1						***226***
1985								30	63	23	37	53	32	10	20	20	19	19	***326***
1986						20	10	25	34	13	27	14	27	35	26	23	22	21	***297***
1987								13	22	29	29	26	17	15	15	15	18	3	***202***
1988								8	27	10	28	24	18	26	19	21	31	20	***232***
1989									43	16	31	23	22	20	17	22	25	26	***245***
1990									52	20	22	27	22	19	18	22	19	27	***248***
1991									45	16	32	18	20	25	24	19	25	22	***246***
1992									32	15	31	14	25	18	17	27	30	18	***227***
1993									70	14	35	19	26	18	16	25	28	18	***269***
1994									49	17	24	27	25	20	21	23	24	20	***250***
1995									39	14	29	24	24	19	14	26	30	19	***238***
1996									43	11	36	21	17	28	13	25	29	24	***247***
1997									43	18	31	20	26	19	18	23	22	24	***244***
1998									43	28	50	14	34	11	15	24	29	22	***270***
1999									42	9	38	18	29	18	12	28	29	22	***245***
2000									42	10	27	28	20	26	12	30	25	21	***241***
2001									21	14	30	22	26	20	14	27	28	23	***225***
2002								1	49	16	27	26	22	23	14	26	30	21	***255***
2003								1	74	20	20	21	24	22	20	23	26	23	***274***
2004									43	6	23	24	17	27	14	24	30	21	***229***
2005									43	21	30	18	33	18	14	23	24	27	***251***
2006								1	46	7	22	14	18	28	13	23	33	19	***224***
2007									31	15	27	26	18	28	17	20	18	26	***226***

Year	Shrimp Statistical Zone																		Total
	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	
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	27	27	18	16	11	14	16	7	15	18	26	31	29	18	19	14	***315***
2011						9	11	6	11	6	15	17	27	31	28	21	19	15	***216***
2012	2	3	6	6	17	10	7	4	9	5	11	13	19	22	22	13	14	11	***194***
Total	***2***	***32***	***69***	***72***	***50***	***80***	***66***	***277***	***2302***	***840***	***1672***	***1162***	***812***	***679***	***553***	***641***	***718***	***568***	***10595***

Table 3. Summary of the king mackerel length data collected during Summer SEAMAP groundfish surveys conducted between 1982 and 2012. (Note that prior to 1987, no length data for king mackerel is available.)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
1982	186	0					
1983	191	0					
1984	210	37					
1985	165	4					
1986	162	0					
1987	281	23	11	133	175	162	11
1988	229	6	6	75	208	126	49
1989	210	143	47	90	368	175	48
1990	257	66	39	88	805	162	127
1991	250	106	48	108	525	186	114
1992	247	2	1	475	475	475	.
1993	246	9	7	142	466	264	140
1994	259	144	71	118	414	163	33
1995	236	122	101	113	560	166	60
1996	242	12	9	76	780	231	252
1997	229	9	4	88	448	335	167
1998	227	48	17	65	269	118	56
1999	244	15	6	106	197	145	38
2000	235	31	30	65	1123	276	184
2001	174	38	33	120	158	140	11
2002	251	26	26	129	441	209	52
2003	203	5	5	221	425	271	87
2004	237	134	79	104	420	160	43
2005	192	18	18	120	402	260	73
2006	239	30	30	94	501	256	135
2007	219	95	72	85	255	171	49
2008	304	74	69	77	452	177	109
2009	534	4	4	69	367	254	142
2010	379	15	15	147	266	209	29
2011	330	6	6	75	492	336	150
2012	399	3	3	350	544	420	107

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
31	7767	1225	757			184	

Table 4. Summary of the king mackerel length data collected during Fall SEAMAP groundfish surveys conducted between 1972 and 2012. (Note that prior to 1988, no length data for king mackerel is available.)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
1972	184	39					
1973	272	0					
1974	243	34					
1975	280	0					
1976	307	2					
1977	242	0					
1978	319	4					
1979	273	18					
1980	233	1					
1981	279	3					
1982	273	1					
1983	222	0					
1984	226	12					
1985	326	8					
1986	297	3					
1987	202	1					
1988	232	15	13	101	314	201	50
1989	245	9	9	115	400	219	105
1990	248	54	24	208	465	325	70
1991	246	9	8	315	593	416	92
1992	227	12	11	119	193	147	24
1993	269	86	53	108	408	271	73
1994	250	29	29	181	418	304	56
1995	238	27	11	108	720	273	166
1996	247	19	17	124	330	225	66
1997	244	34	28	122	368	211	78
1998	270	28	22	160	368	262	52
1999	245	24	24	138	432	273	90
2000	241	16	16	111	353	192	71
2001	225	37	31	100	392	249	90
2002	255	43	43	120	377	215	68
2003	274	110	104	97	777	214	82
2004	229	73	73	132	451	260	76
2005	251	65	69	137	536	235	81
2006	224	47	47	86	458	188	78

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
2007	226	104	100	159	392	267	60
2008	363	12	12	206	393	270	48
2009	443	88	88	115	377	197	62
2010	315	32	32	118	858	241	152
2011	216	3	3	220	638	384	223
2012	194	27	27	125	325	208	55

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
31	10595	1129	894			239	

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel Fall SEAMAP groundfish survey (continuity run) index of relative abundance from 1972 to 2012.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 62472.8)*						*Lognormal Submodel Type 3 Tests (AIC 1075.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	36	9156	170.81	4.74	<.0001	<.0001	36	372	1.13	0.2817
Shrimp Statistical Zone	4	9156	111.90	27.98	<.0001	<.0001	4	372	5.53	0.0002
Depth Zone	22	9156	50.82	2.31	0.0005	0.0005	22	372	6.46	<.0001

Table 6. Indices of king mackerel abundance developed using the delta-lognormal model for Fall SEAMAP groundfish survey (continuity run) from 1972-2012. 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
1972	0.05435	184	0.60976	3.49575	0.36505	1.72315	7.09182
1973	0	272	0				
1974	0.01646	243	0.22593	1.29525	0.57364	0.44574	3.76377
1975	0	280	0				
1976	0.00326	307	0.01176	0.06741	1.09620	0.01141	0.39843
1977	0	242	0				
1978	0.00940	319	0.15031	0.86171	0.66590	0.25654	2.89447
1979	0.02198	273	0.19325	1.10787	0.47492	0.44954	2.73030
1980	0.00429	233	0.01128	0.06465	1.09687	0.01093	0.38240
1981	0.00717	279	0.03490	0.20010	0.79900	0.04908	0.81578
1982	0.00366	273	0.01649	0.09455	1.09896	0.01595	0.56057
1983	0	222	0				
1984	0.01770	226	0.14380	0.82442	0.57827	0.28160	2.41360
1985	0.01534	326	0.04782	0.27417	0.52561	0.10210	0.73624
1986	0.00749	267	0.08853	0.50753	0.79532	0.12513	2.05853
1987	0.00495	202	0.01079	0.06184	1.09950	0.01042	0.36687
1988	0.04310	232	0.10918	0.62591	0.36663	0.30764	1.27342
1989	0.01633	245	0.07126	0.40853	0.57001	0.14142	1.18017
1990	0.08065	248	0.25313	1.45116	0.26217	0.86651	2.43028
1991	0.02846	246	0.03798	0.21773	0.43920	0.09400	0.50433
1992	0.02643	227	0.05157	0.29562	0.46945	0.12109	0.72172
1993	0.09665	269	0.40925	2.34623	0.22822	1.49503	3.68208
1994	0.04400	250	0.15194	0.87104	0.35008	0.44127	1.71938
1995	0.02941	238	0.10623	0.60900	0.43492	0.26490	1.40005
1996	0.04049	247	0.10403	0.59641	0.36700	0.29295	1.21422
1997	0.06148	244	0.20101	1.15240	0.29976	0.64093	2.07202
1998	0.05926	270	0.17489	1.00265	0.29075	0.56717	1.77250
1999	0.06531	245	0.17300	0.99183	0.29204	0.55969	1.75761
2000	0.03320	241	0.08830	0.50623	0.40881	0.23061	1.11125
2001	0.07556	225	0.24912	1.42820	0.28348	0.81904	2.49043
2002	0.05490	255	0.21611	1.23897	0.31329	0.67188	2.28472
2003	0.13139	274	0.43358	2.48571	0.19581	1.68642	3.66383
2004	0.11790	229	0.38108	2.18474	0.22403	1.40341	3.40107
2005	0.11952	251	0.25269	1.44865	0.21365	0.94942	2.21040

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2006	0.09375	224	0.27676	1.58665	0.25645	0.95779	2.62841
2007	0.15487	226	0.46227	2.65021	0.19720	1.79317	3.91685
2008	0.01238	323	0.03996	0.22907	0.57330	0.07887	0.66527
2009	0.08133	332	0.26181	1.50095	0.23091	0.95147	2.36775
2010	0.08696	207	0.20096	1.15208	0.27970	0.66542	1.99463
2011	0.01531	196	0.05432	0.31141	0.65971	0.09359	1.03619
2012	0.04895	143	0.14885	0.85337	0.44041	0.36764	1.98084

Table 7. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel Fall SEAMAP groundfish survey index of relative abundance from 1972 to 2012.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 66270.5)*						*Lognormal Submodel Type 3 Tests (AIC 1108.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	36	9177	171.16	4.75	<.0001	<.0001	36	393	0.92	0.6059
Time of Day	1	9177	185.76	185.76	<.0001	<.0001	1	393	7.44	0.0067
Region	3	9177	119.58	39.86	<.0001	<.0001	3	393	4.16	0.0064
Depth	1	9177	14.83	14.83	0.0001	0.0001	1	393	89.92	<.0001

Table 8. Indices of king mackerel abundance developed using the delta-lognormal model for Fall SEAMAP groundfish survey 1972-2012. 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
1972	0.05435	184	0.40897	3.63637	0.37664	1.75512	7.53405
1973	0	272	0				
1974	0.01646	243	0.16693	1.48425	0.58348	0.50274	4.38203
1975	0	280	0				
1976	0.00326	307	0.01032	0.09178	1.11184	0.01526	0.55203
1977	0	242	0				
1978	0.00940	319	0.06872	0.61105	0.66941	0.18095	2.06349
1979	0.02198	273	0.12166	1.08178	0.48303	0.43289	2.70333
1980	0.00429	233	0.01018	0.09050	1.11377	0.01501	0.54548
1981	0.00717	279	0.02117	0.18821	0.81063	0.04543	0.77973
1982	0.00366	273	0.01008	0.08960	1.11141	0.01490	0.53864
1983	0	222	0				
1984	0.01770	226	0.10388	0.92367	0.58902	0.31009	2.75133
1985	0.01534	326	0.02897	0.25755	0.53210	0.09488	0.69912
1986	0.00749	267	0.03687	0.32787	0.80891	0.07933	1.35510
1987	0.00495	202	0.00532	0.04726	1.11218	0.00786	0.28438
1988	0.04310	232	0.07237	0.64350	0.38275	0.30718	1.34806
1989	0.01633	245	0.02877	0.25578	0.58545	0.08636	0.75754
1990	0.08065	248	0.14906	1.32541	0.27964	0.76563	2.29447
1991	0.02846	246	0.02414	0.21468	0.45246	0.09056	0.50890
1992	0.02643	227	0.03329	0.29599	0.48531	0.11799	0.74256
1993	0.09665	269	0.24181	2.15002	0.24622	1.32348	3.49274
1994	0.04400	250	0.07387	0.65679	0.36499	0.32378	1.33228
1995	0.02941	238	0.06380	0.56726	0.45088	0.23995	1.34102
1996	0.04049	247	0.05801	0.51581	0.38201	0.24656	1.07911
1997	0.06148	244	0.10509	0.93441	0.31733	0.50291	1.73613
1998	0.05926	270	0.13020	1.15768	0.30761	0.63448	2.11232
1999	0.06531	245	0.10714	0.95265	0.30799	0.52173	1.73946
2000	0.03320	241	0.04916	0.43709	0.42315	0.19411	0.98421
2001	0.07556	225	0.15706	1.39653	0.30097	0.77496	2.51665
2002	0.05490	255	0.13522	1.20231	0.32811	0.63428	2.27906
2003	0.13139	274	0.29962	2.66405	0.21271	1.74915	4.05749
2004	0.11790	229	0.23184	2.06138	0.24436	1.27344	3.33688
2005	0.11952	251	0.17426	1.54943	0.23269	0.97885	2.45260

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2006	0.09375	224	0.16668	1.48200	0.27365	0.86584	2.53664
2007	0.15487	226	0.32550	2.89422	0.21618	1.88757	4.43771
2008	0.01238	323	0.02835	0.25210	0.58416	0.08530	0.74509
2009	0.08133	332	0.19730	1.75430	0.24341	1.08572	2.83460
2010	0.08696	207	0.14495	1.28886	0.29720	0.72028	2.30627
2011	0.01531	196	0.03996	0.35528	0.67280	0.10467	1.20596
2012	0.04895	143	0.13075	1.16257	0.45478	0.48845	2.76708

Table 9. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel combined (summer and fall) SEAMAP groundfish survey index of relative abundance from 1972 to 2012.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 113935.6)*						*Lognormal Submodel Type 3 Tests (AIC 1773.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	36	16099	188.21	5.23	<.0001	<.0001	36	603	1.67	0.0096
Region	3	16099	152.43	269.06	<.0001	<.0001	3	603	7.71	<.0001
Season	1	16099	62.18	50.81	<.0001	<.0001	1	603	23.77	<.0001
Time of Day	1	16099	269.06	62.18	<.0001	<.0001	1	603	5.19	0.0231
Depth	1	16099	66.69	66.69	<.0001	<.0001	1	603	88.63	<.0001

Table 10. Indices of king mackerel abundance developed using the delta-lognormal model for combined (summer and fall) SEAMAP groundfish survey 1972-2012. 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
1972	0.05435	184	0.39213	3.31528	0.38069	1.58847	6.91932
1973	0	272	0				
1974	0.01646	243	0.15528	1.31281	0.58528	0.44338	3.88709
1974	0	280	0				
1976	0.00326	307	0.00780	0.06594	1.09666	0.01115	0.38997
1977	0	242	0				
1978	0.00940	319	0.06102	0.51591	0.66846	0.15299	1.73968
1979	0.02198	273	0.11041	0.93345	0.48546	0.37199	2.34239
1980	0.00429	233	0.00846	0.07151	1.09687	0.01209	0.42297
1981	0.00717	279	0.01909	0.16139	0.80603	0.03920	0.66440
1982	0.00218	459	0.00634	0.05362	1.09427	0.00909	0.31624
1983	0	389	0				
1984	0.01835	436	0.22053	1.86447	0.41697	0.83712	4.15260
1985	0.01222	491	0.03591	0.30361	0.48659	0.12076	0.76334
1986	0.00466	429	0.03292	0.27833	0.80400	0.06780	1.14259
1987	0.01656	483	0.06871	0.58088	0.42075	0.25907	1.30245
1988	0.02386	461	0.05976	0.50524	0.36217	0.25036	1.01960
1989	0.04396	455	0.18735	1.58399	0.27591	0.92148	2.72283
1990	0.05743	505	0.15871	1.34182	0.23089	0.85064	2.11664
1991	0.03831	496	0.10984	0.92863	0.28078	0.53527	1.61107
1992	0.01688	474	0.02384	0.20154	0.42070	0.08989	0.45185
1993	0.06019	515	0.17964	1.51873	0.22292	0.97769	2.35918
1994	0.03536	509	0.12326	1.04211	0.28676	0.59394	1.82845
1995	0.05274	474	0.20153	1.70383	0.24863	1.04400	2.78069
1996	0.03067	489	0.07205	0.60914	0.31187	0.33120	1.12032
1997	0.04017	473	0.07253	0.61320	0.27997	0.35399	1.06219
1998	0.03823	497	0.11233	0.94969	0.27985	0.54837	1.64472
1999	0.03885	489	0.09879	0.83526	0.27980	0.48234	1.44640
2000	0.04622	476	0.06364	0.53806	0.26181	0.32150	0.90048
2001	0.06015	399	0.17876	1.51131	0.25249	0.91923	2.48474
2002	0.04150	506	0.11482	0.97073	0.26691	0.57444	1.64042
2003	0.07966	477	0.21455	1.81392	0.20459	1.20985	2.71959
2004	0.08155	466	0.23577	1.99336	0.20367	1.33192	2.98328
2005	0.08804	443	0.15127	1.27893	0.20193	0.85744	1.90760

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2006	0.07559	463	0.14773	1.24899	0.21133	0.82225	1.89721
2007	0.12584	445	0.33507	2.83288	0.17036	2.01984	3.97320
2008	0.02921	582	0.07903	0.66812	0.29581	0.37436	1.19240
2009	0.03989	727	0.11799	0.99755	0.22985	0.63366	1.57041
2010	0.05830	446	0.11856	1.00236	0.24365	0.62007	1.62036
2011	0.02041	392	0.02897	0.24490	0.42066	0.10924	0.54901
2012	0.02305	347	0.07198	0.60853	0.42127	0.27115	1.36570

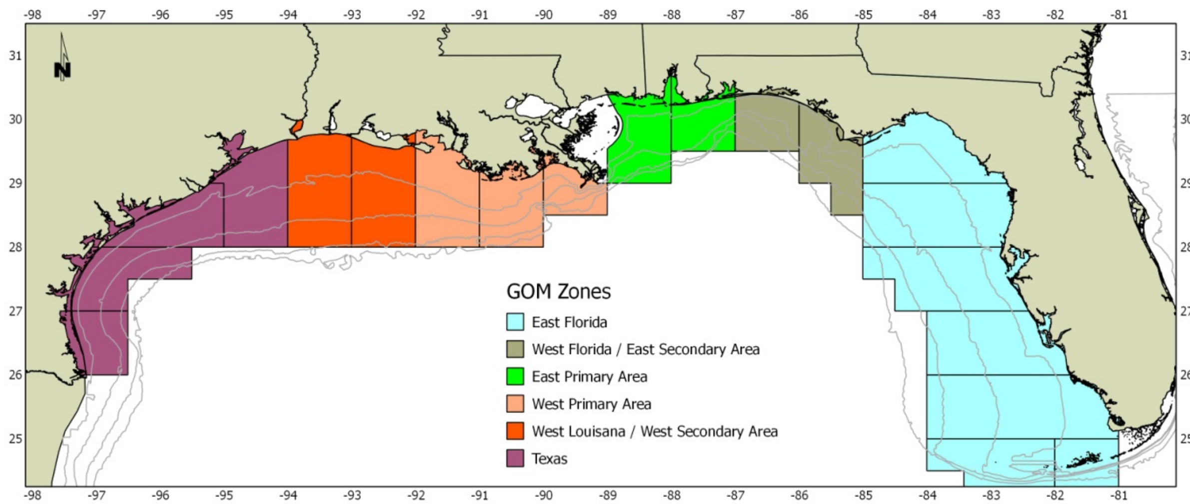
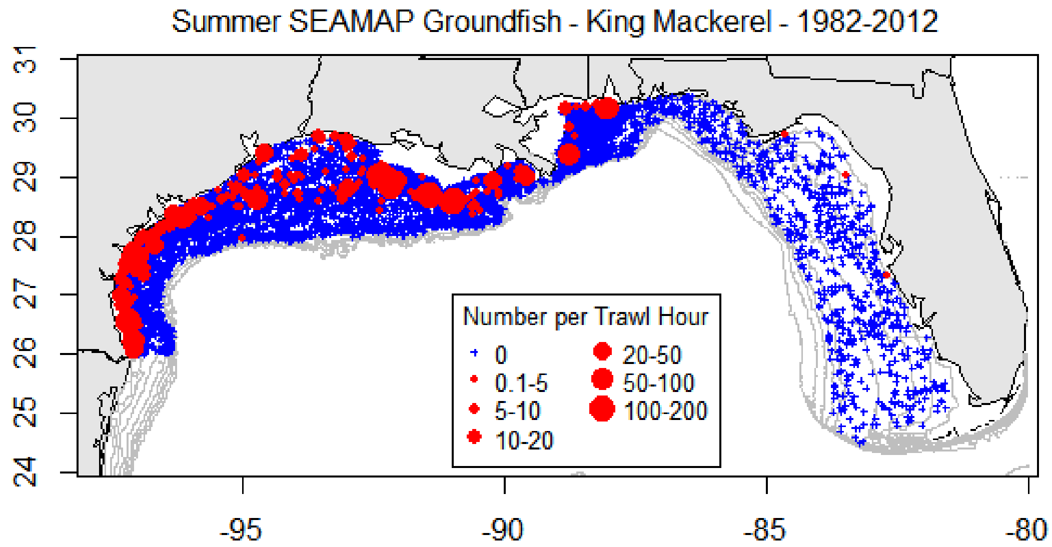


Figure 1. Combined areas for the Fall SEAMAP groundfish survey.



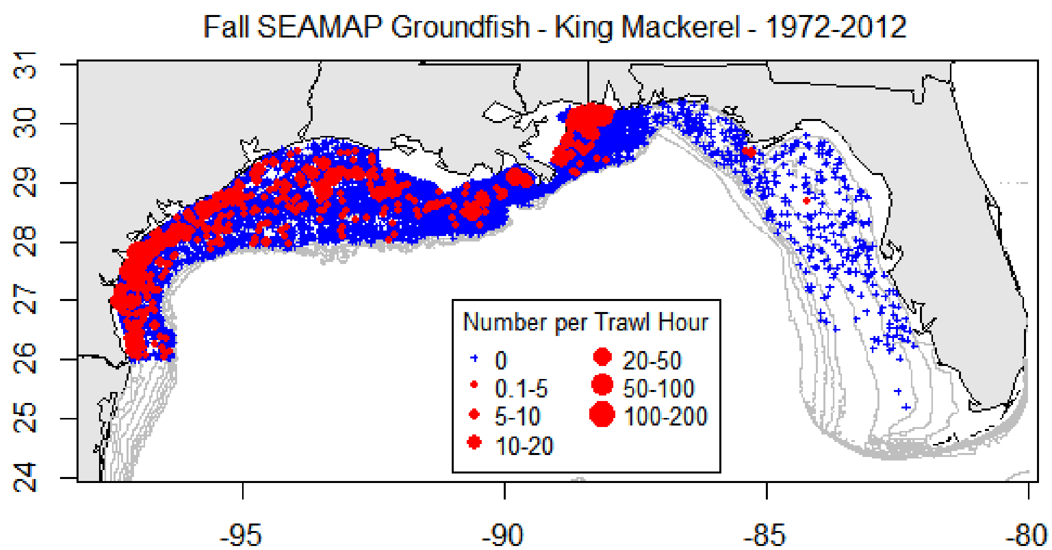


Figure 2. Stations sampled from 1982 to 2012 during the Summer (top) and from 1972 to 2012 during the Fall (bottom) SEAMAP Groundfish Survey with the CPUE for king mackerel.

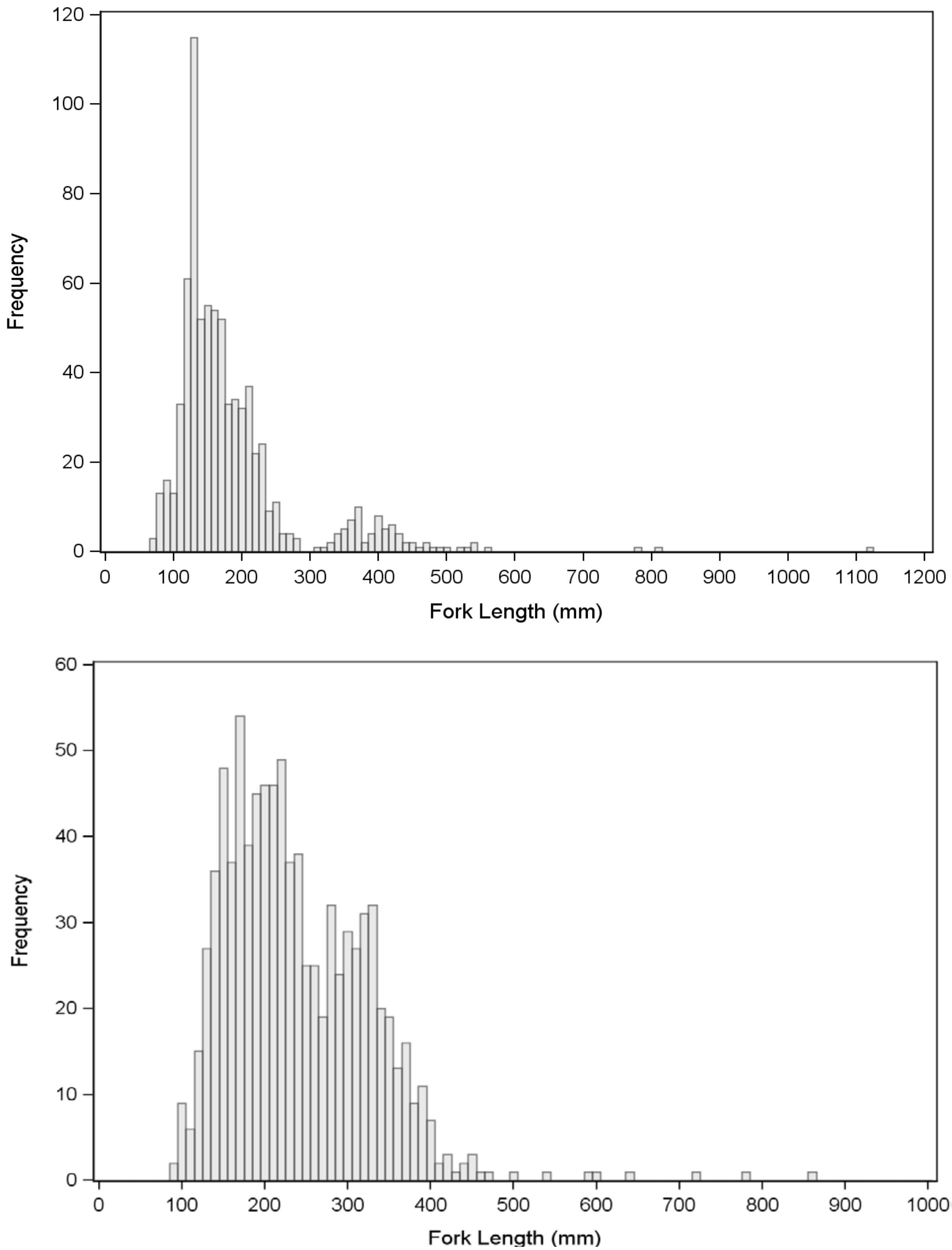


Figure 3. Length frequency histograms for king mackerel captured Summer (top) and Fall (bottom) SEAMAP Groundfish surveys from 1987-2012.

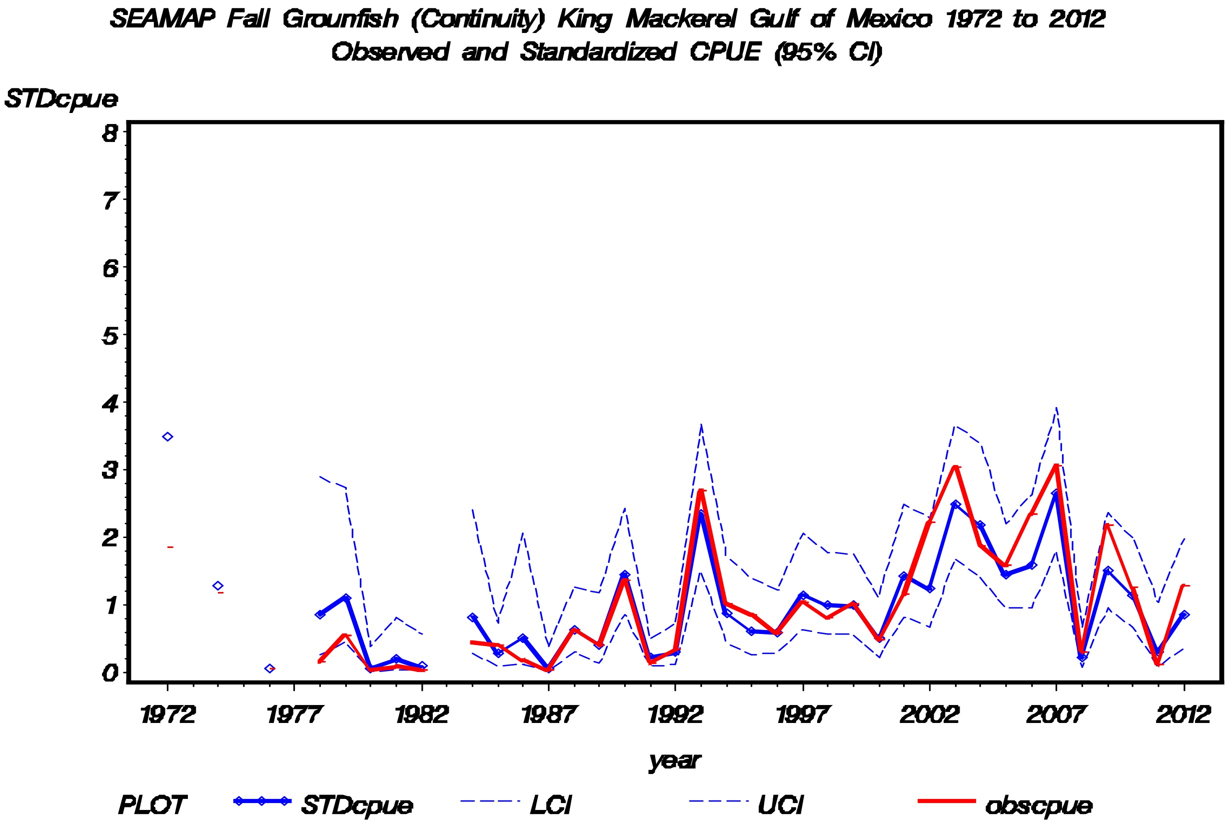


Figure 4. Annual index of abundance for king mackerel from the Fall SEAMAP Groundfish Survey (Continuity Run) from 1982 – 2012. (Note that the survey has been conducted annually since 1972, in 1973, 1975, 1977 and 1983 no king mackerel were captured during the survey.)

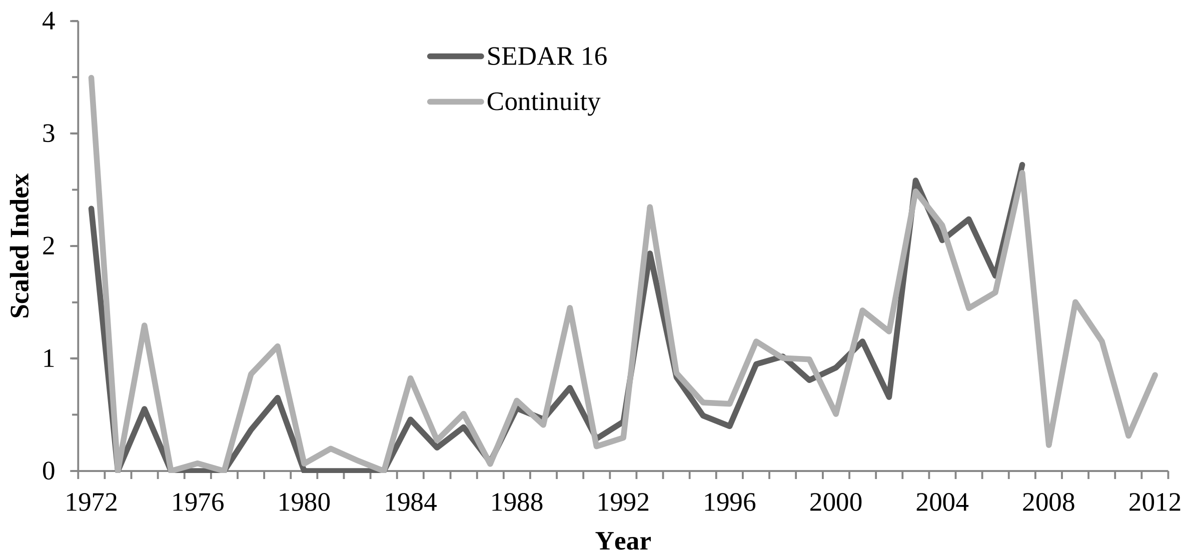


Figure 5. Comparison of annual indices of abundance from the SEDAR 16 (Ingram 2008) and the continuity run from the Fall SEAMAP Groundfish survey.

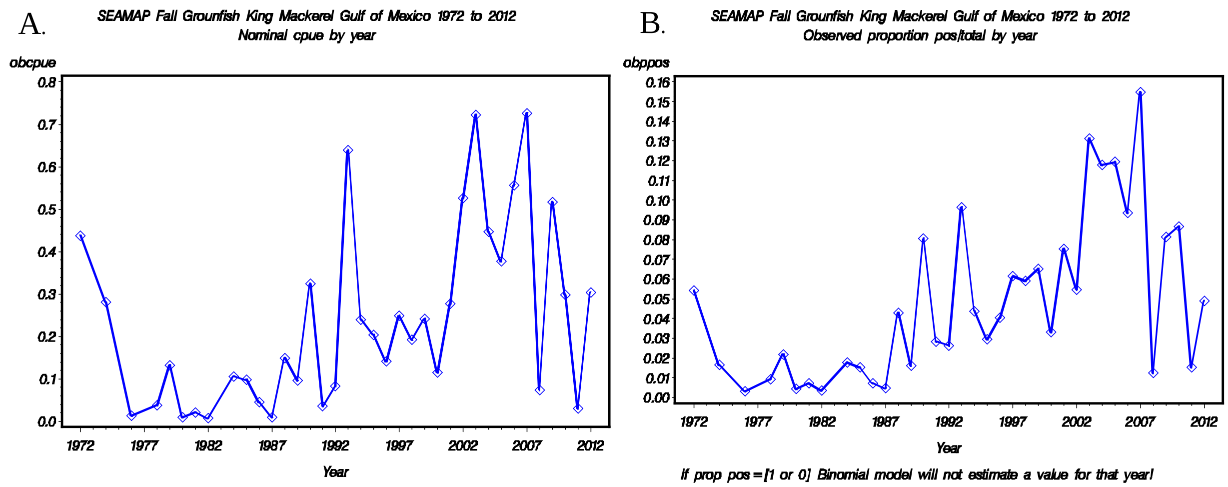


Figure 6. Annual trends for king mackerel captured during Fall SEAMAP Groundfish Surveys from 1972 to 2012 in **A.** nominal CPUE and **B.** proportion of positive stations.

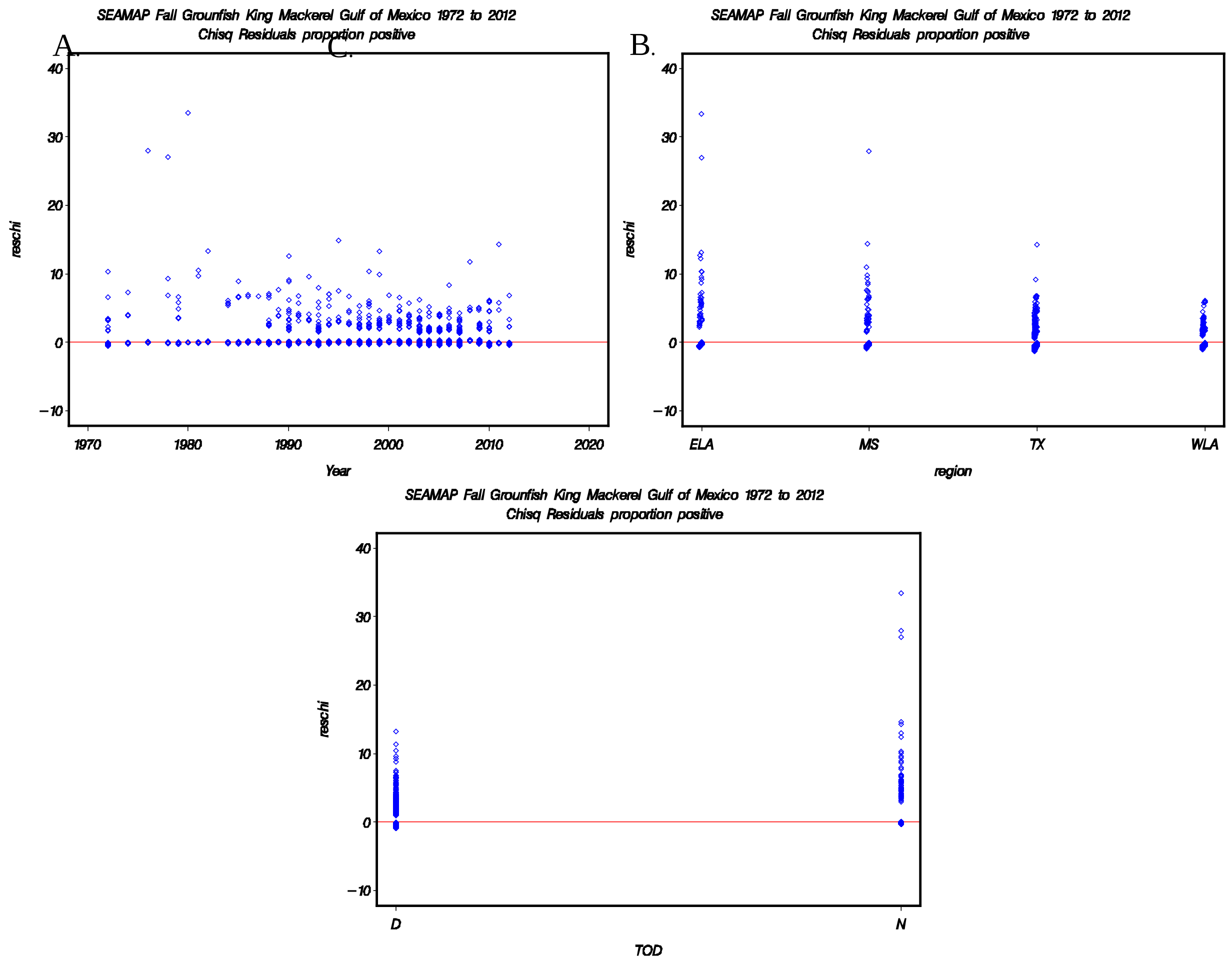


Figure 7. Diagnostic plots for binomial component of the king mackerel Fall SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, and **C.** the Chi-Square residuals by time of day.

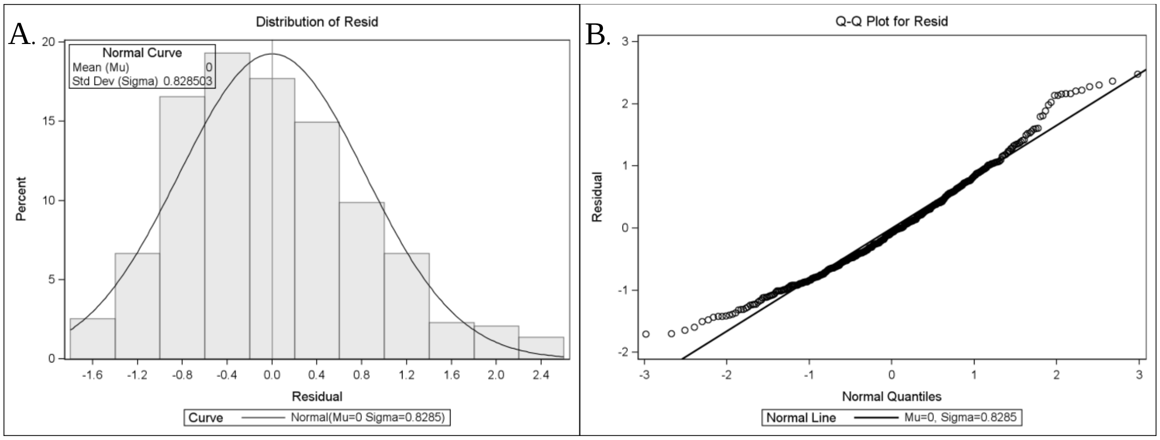


Figure 8. Diagnostic plots for lognormal component of the king mackerel Fall SEAMAP Groundfish Survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

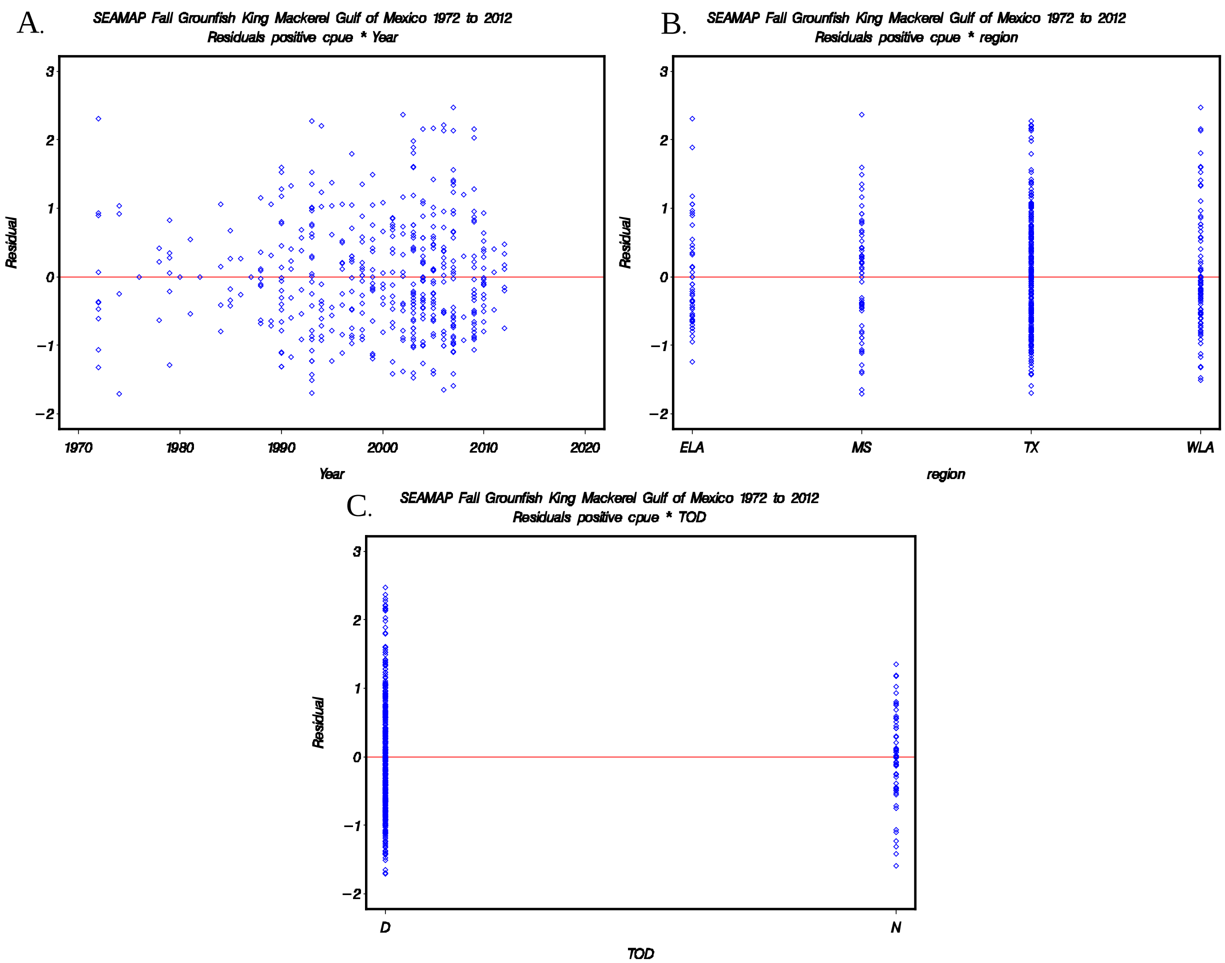


Figure 9. Diagnostic plots for lognormal component of the king mackerel Fall SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, and **B.** the Chi-Square residuals by area.

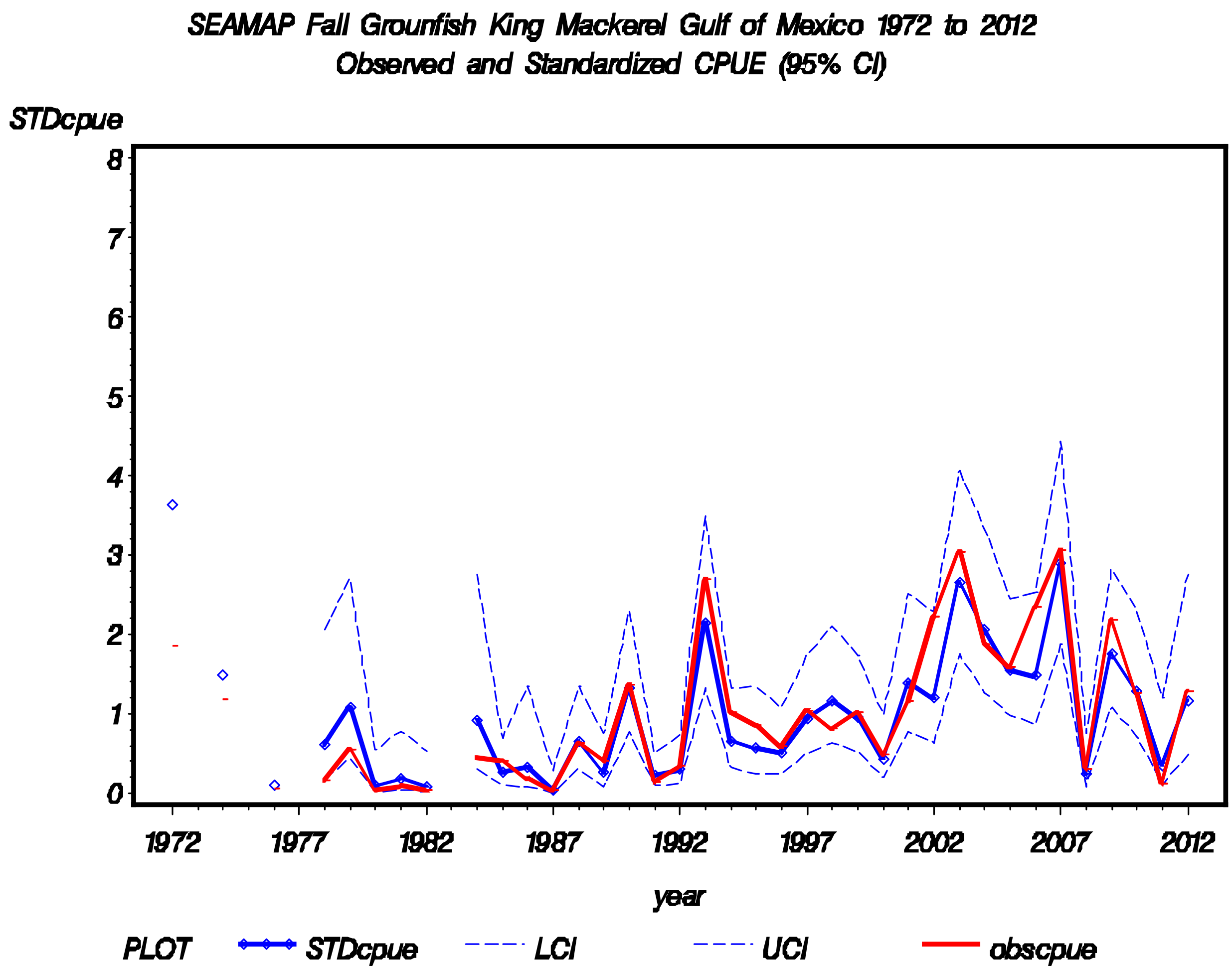


Figure 10. Annual index of abundance for king mackerel from the Fall SEAMAP Groundfish Survey from 1972 – 2012. (Note that the survey has been conducted annually since 1972, in 1973, 1975, 1977 and 1983 no king mackerel were captured during the survey.)

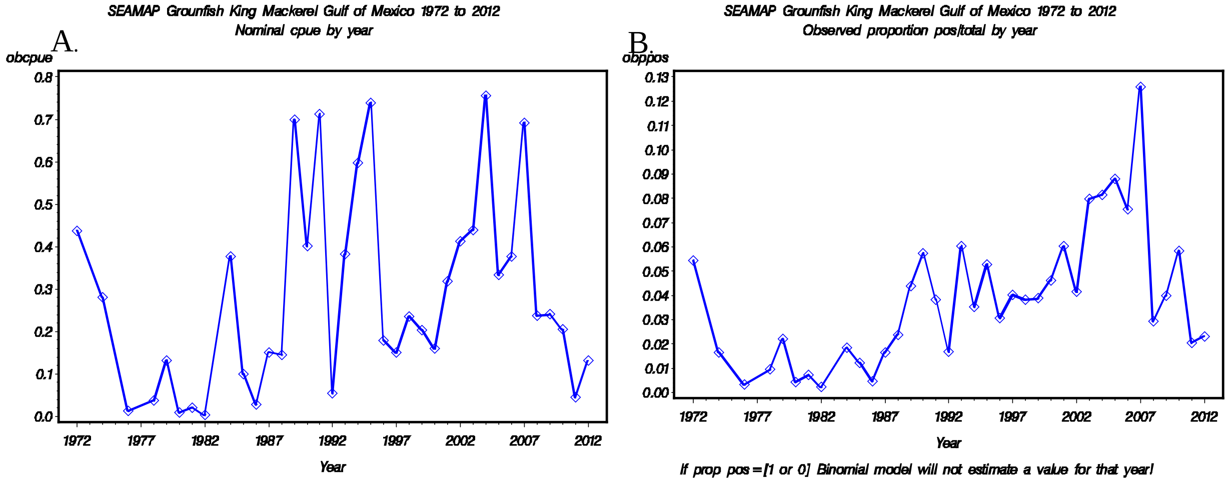


Figure 11. Annual trends for king mackerel captured during combined (summer and fall) SEAMAP Groundfish Surveys from 1972 to 2012 in **A.** nominal CPUE and **B.** proportion of positive stations.

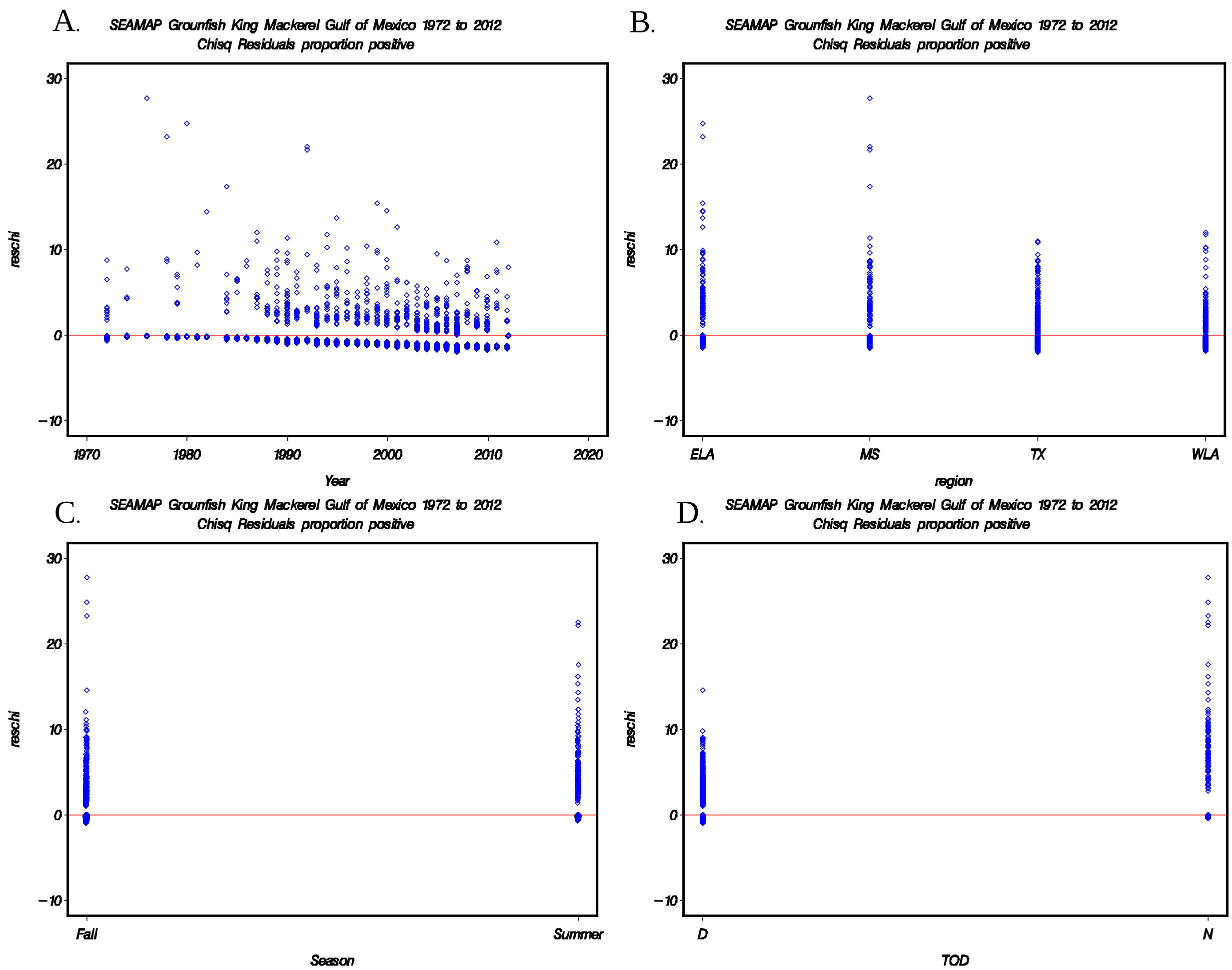


Figure 12. Diagnostic plots for binomial component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, **C.** the Chi-Square residuals by season and **D.** the Chi-Square residuals by time of day.

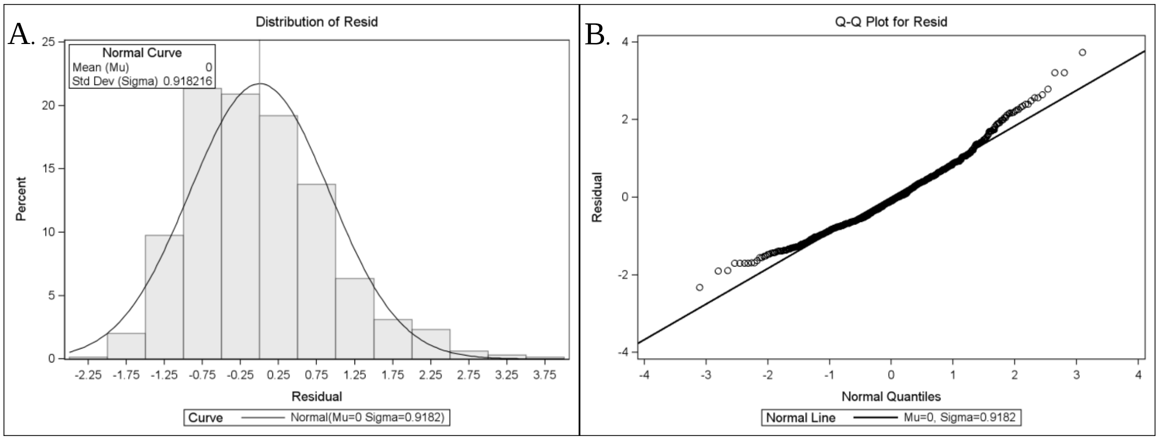


Figure 13. Diagnostic plots for lognormal component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

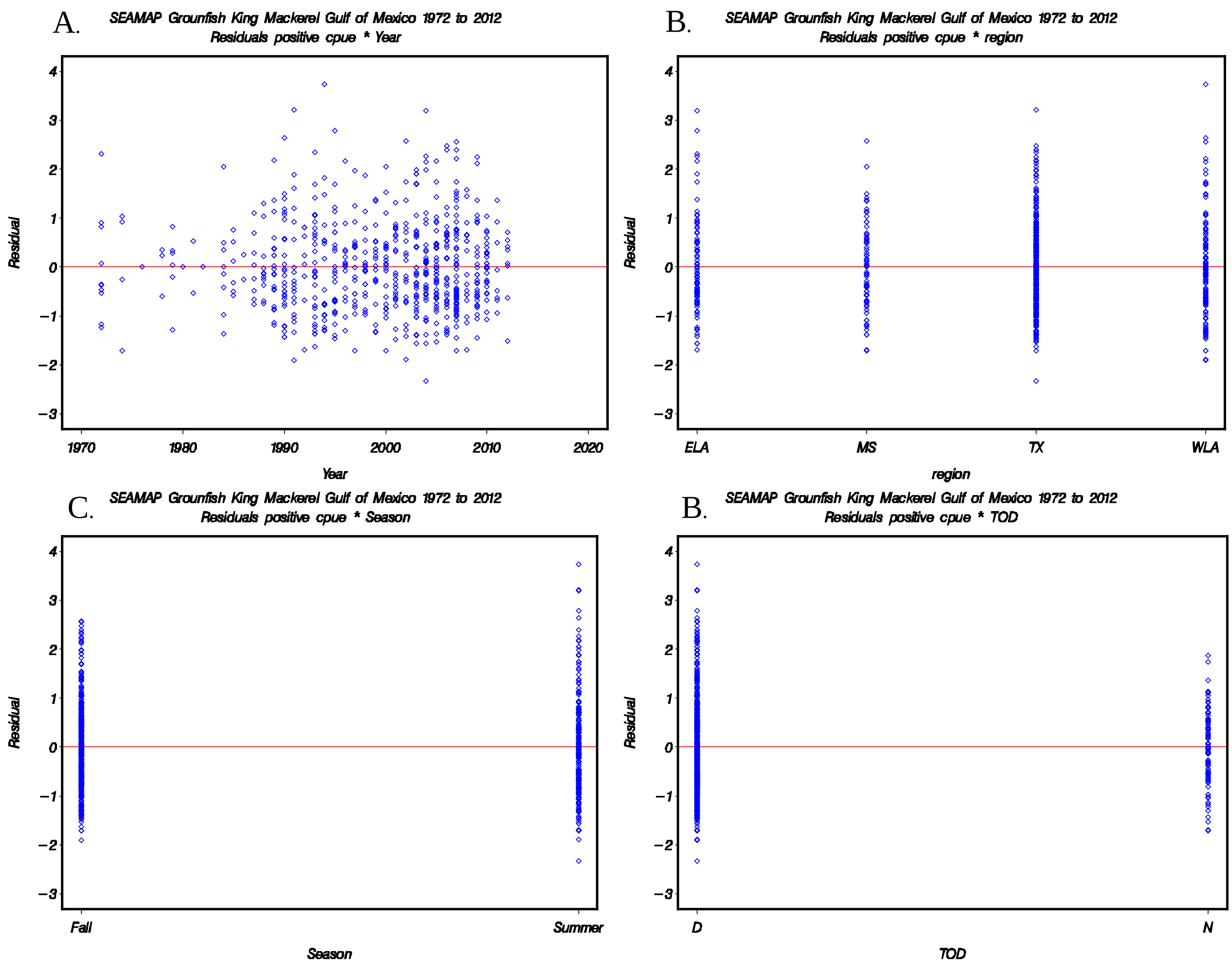


Figure 14. Diagnostic plots for lognormal component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, **C.** the Chi-Square residuals by season and **D.** the Chi-Square residuals by time of day.

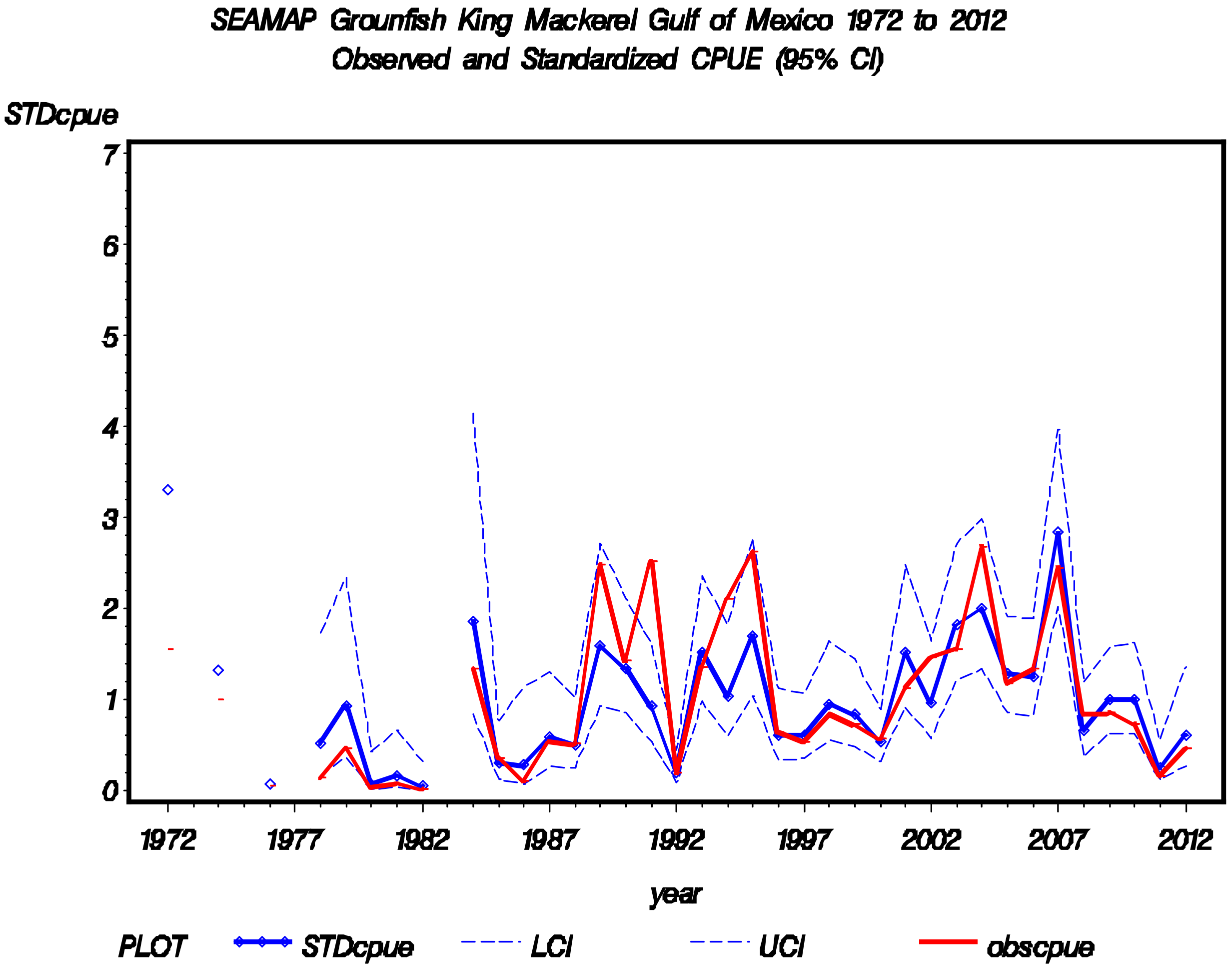


Figure 15. Annual index of abundance for king mackerel from the Fall SEAMAP Groundfish Survey from 1972 – 2012. (Note that the survey has been conducted annually since 1972, in 1973, 1975, 1977 and 1983 no king mackerel were captured during the survey.)

Appendix

Appendix Table 1. Summary of the factors used in constructing the king mackerel abundance index from the Fall SEAMAP groundfish survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	1972	184	10	0.05435	0.43750
Year	1974	243	4	0.01646	0.27984
Year	1976	307	1	0.00326	0.01303
Year	1978	319	3	0.00940	0.03762
Year	1979	273	6	0.02198	0.13187
Year	1980	233	1	0.00429	0.00858
Year	1981	279	2	0.00717	0.02151
Year	1982	273	1	0.00366	0.00733
Year	1984	226	4	0.01770	0.10619
Year	1985	326	5	0.01534	0.09816
Year	1986	267	2	0.00749	0.04494
Year	1987	202	1	0.00495	0.00958
Year	1988	232	10	0.04310	0.14893
Year	1989	245	4	0.01633	0.09642
Year	1990	248	20	0.08065	0.32374
Year	1991	246	7	0.02846	0.03541
Year	1992	227	6	0.02643	0.08274
Year	1993	269	26	0.09665	0.63811
Year	1994	250	11	0.04400	0.24005
Year	1995	238	7	0.02941	0.20327
Year	1996	247	10	0.04049	0.14034
Year	1997	244	15	0.06148	0.24788
Year	1998	270	16	0.05926	0.19160
Year	1999	245	16	0.06531	0.24078
Year	2000	241	8	0.03320	0.11513
Year	2001	225	17	0.07556	0.27677
Year	2002	255	14	0.05490	0.52632
Year	2003	274	36	0.13139	0.72186
Year	2004	229	27	0.11790	0.44598
Year	2005	251	30	0.11952	0.37612
Year	2006	224	21	0.09375	0.55615
Year	2007	226	35	0.15487	0.72602

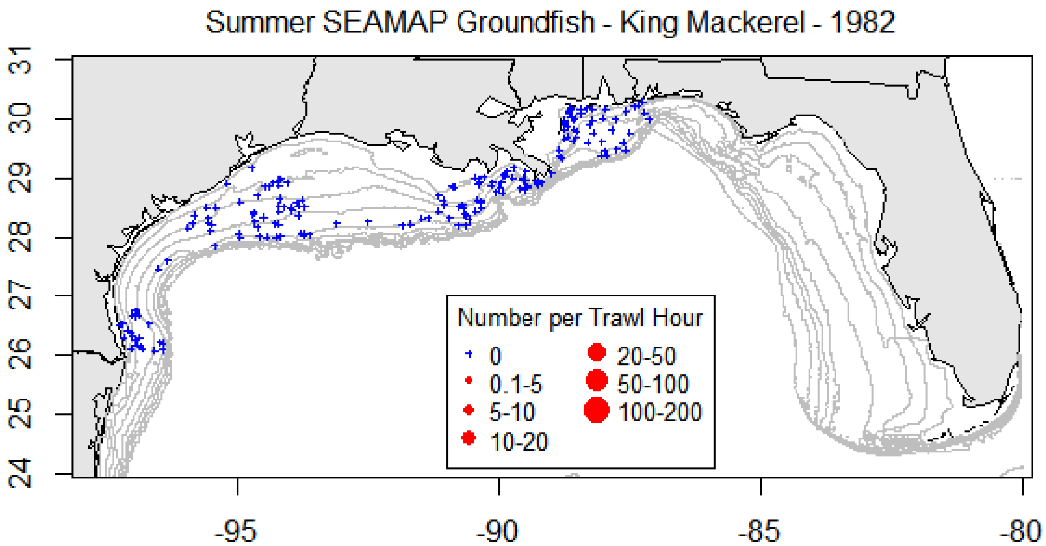
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2008	323	4	0.01238	0.07416
Year	2009	332	27	0.08133	0.51626
Year	2010	207	18	0.08696	0.29685
Year	2011	196	3	0.01531	0.03034
Year	2012	143	7	0.04895	0.30374
Time of Day	Day	4502	380	0.08441	0.44019
Time of Day	Night	4717	55	0.01166	0.03476
Region	ELA	3114	46	0.01477	0.06906
Region	MS	2175	59	0.02713	0.21654
Region	TX	2480	245	0.09879	0.46184
Region	WLA	1450	85	0.05862	0.21675

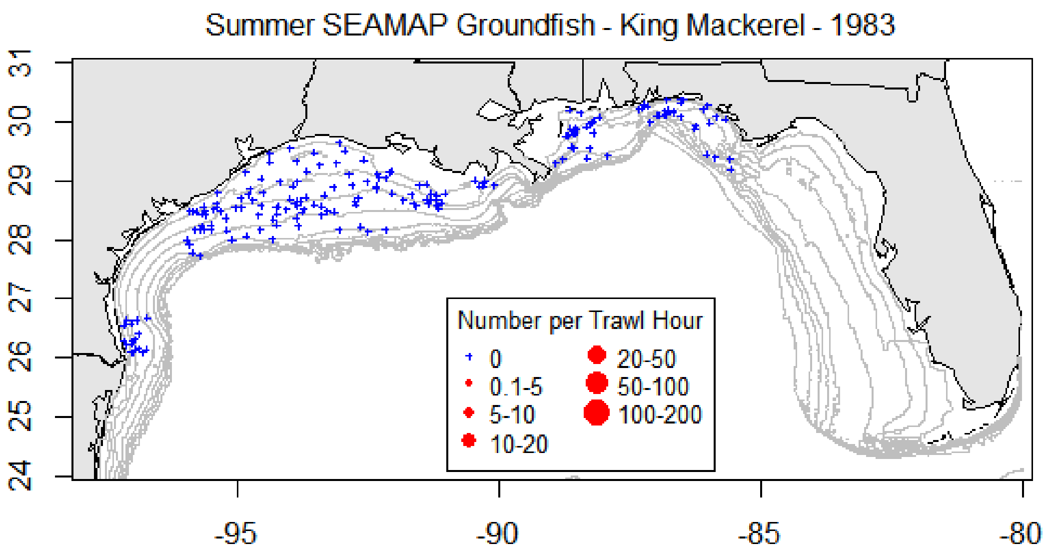
Appendix Table 2. Summary of the factors used in constructing the king mackerel abundance index from the combined (summer and fall) SEAMAP groundfish survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	1972	184	10	0.05435	0.43750
Year	1974	243	4	0.01646	0.27984
Year	1976	307	1	0.00326	0.01303
Year	1978	319	3	0.00940	0.03762
Year	1979	273	6	0.02198	0.13187
Year	1980	233	1	0.00429	0.00858
Year	1981	279	2	0.00717	0.02151
Year	1982	459	1	0.00218	0.00436
Year	1984	436	8	0.01835	0.37751
Year	1985	491	6	0.01222	0.10009
Year	1986	429	2	0.00466	0.02797
Year	1987	483	8	0.01656	0.15147
Year	1988	461	11	0.02386	0.14594
Year	1989	455	20	0.04396	0.69983
Year	1990	505	29	0.05743	0.40159
Year	1991	496	19	0.03831	0.71214
Year	1992	474	8	0.01688	0.05404
Year	1993	515	31	0.06019	0.38239
Year	1994	509	18	0.03536	0.59748
Year	1995	474	25	0.05274	0.73947
Year	1996	489	15	0.03067	0.17914
Year	1997	473	19	0.04017	0.15044
Year	1998	497	19	0.03823	0.23536
Year	1999	489	19	0.03885	0.20403
Year	2000	476	22	0.04622	0.16034
Year	2001	399	24	0.06015	0.31812
Year	2002	506	21	0.04150	0.41236
Year	2003	477	38	0.07966	0.43981
Year	2004	466	38	0.08155	0.75653
Year	2005	443	39	0.08804	0.33368
Year	2006	463	35	0.07559	0.37667
Year	2007	445	56	0.12584	0.69190

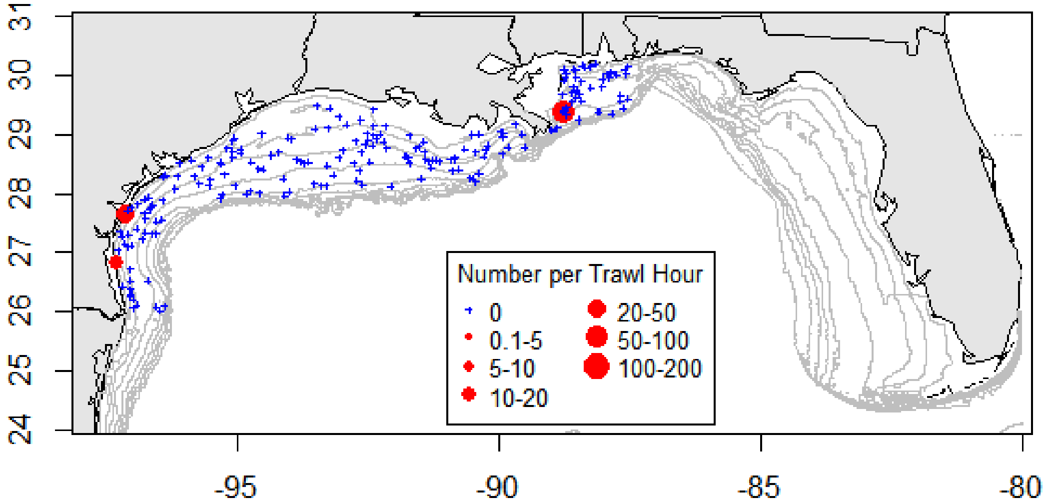
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2008	582	17	0.02921	0.23766
Year	2009	727	29	0.03989	0.24126
Year	2010	446	26	0.05830	0.20460
Year	2011	392	8	0.02041	0.04560
Year	2012	347	8	0.02305	0.13091
Region	ELA	4819	90	0.01868	0.17124
Region	MS	3613	70	0.01937	0.18914
Region	TX	5035	351	0.06971	0.48197
Region	WLA	2675	135	0.05047	0.31444
Season	Fall	9219	435	0.04719	0.23275
Season	Summer	6923	211	0.03048	0.38000
Time of Day	Day	7859	551	0.07011	0.54516
Time of Day	Night	8283	95	0.01147	0.05940

Appendix Figure 1. Annual survey effort and catch of king mackerel from the SEAMAP groundfish survey during the summer (1982-2012) and fall (1972-2012).

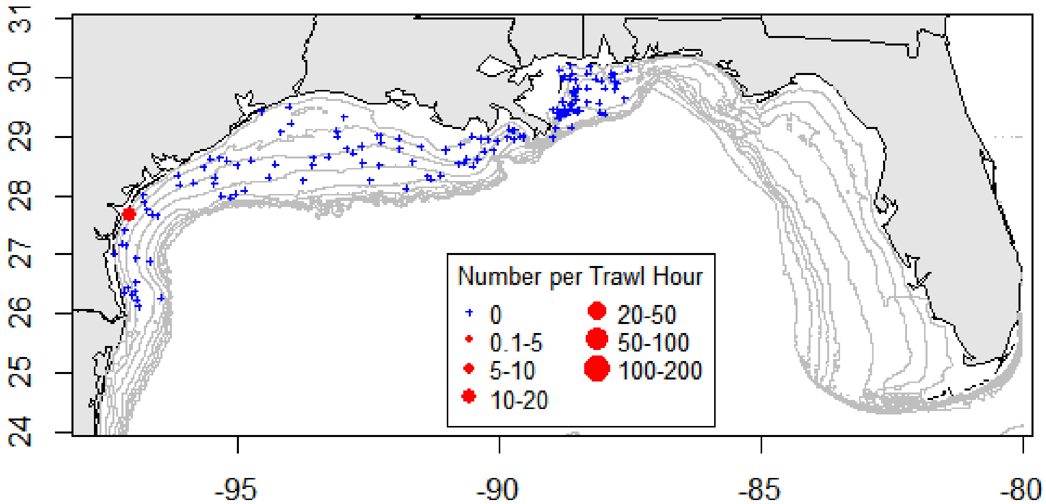




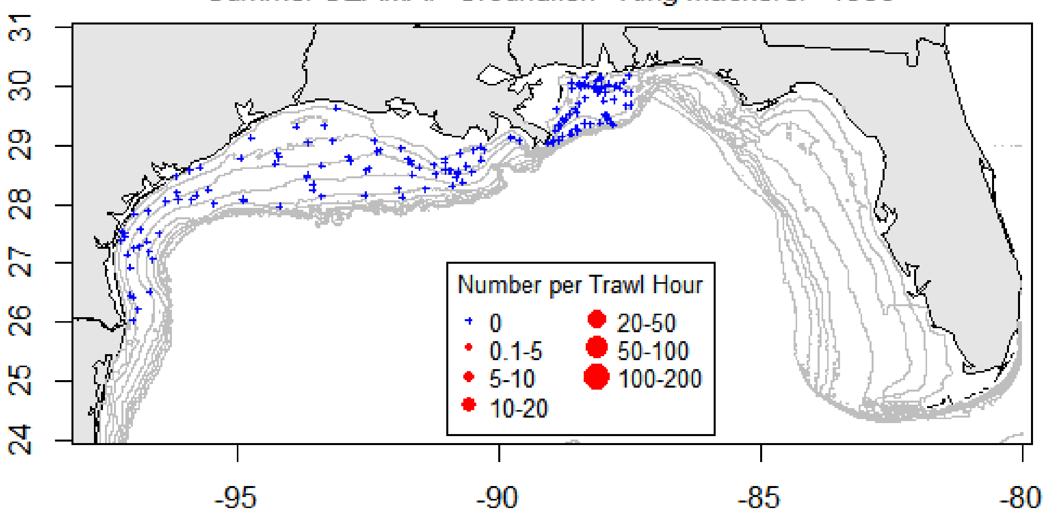
Summer SEAMAP Groundfish - King Mackerel - 1984

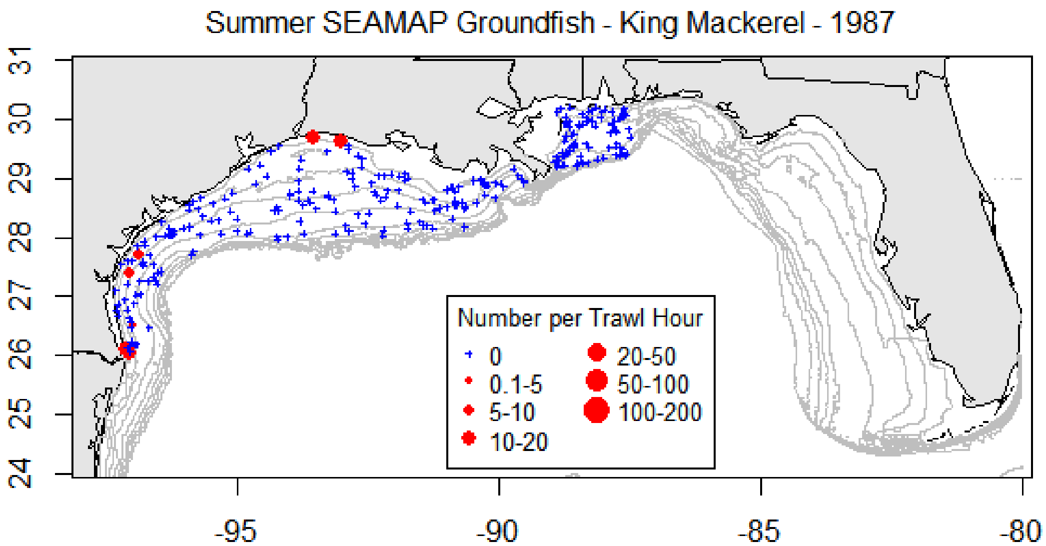


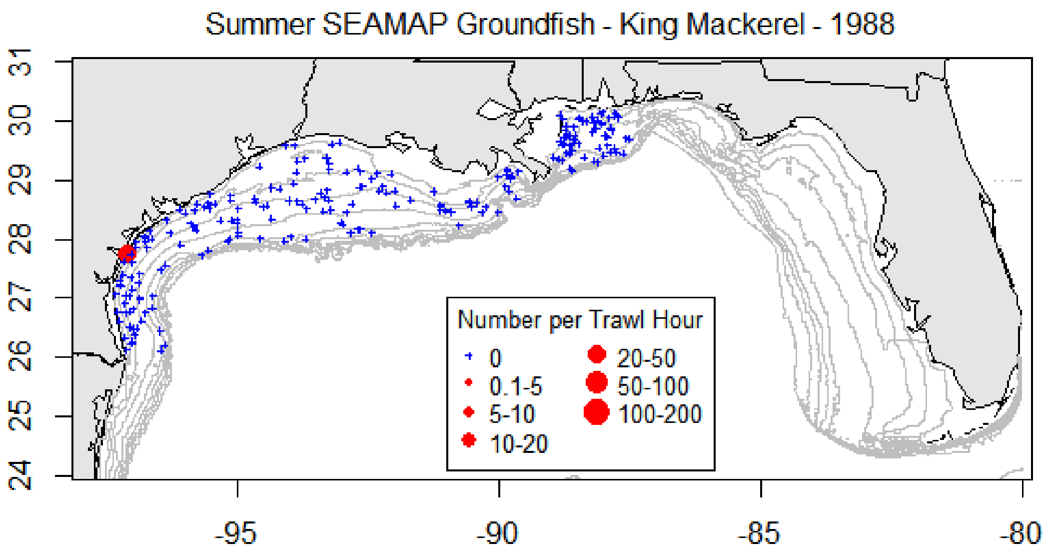
Summer SEAMAP Groundfish - King Mackerel - 1985

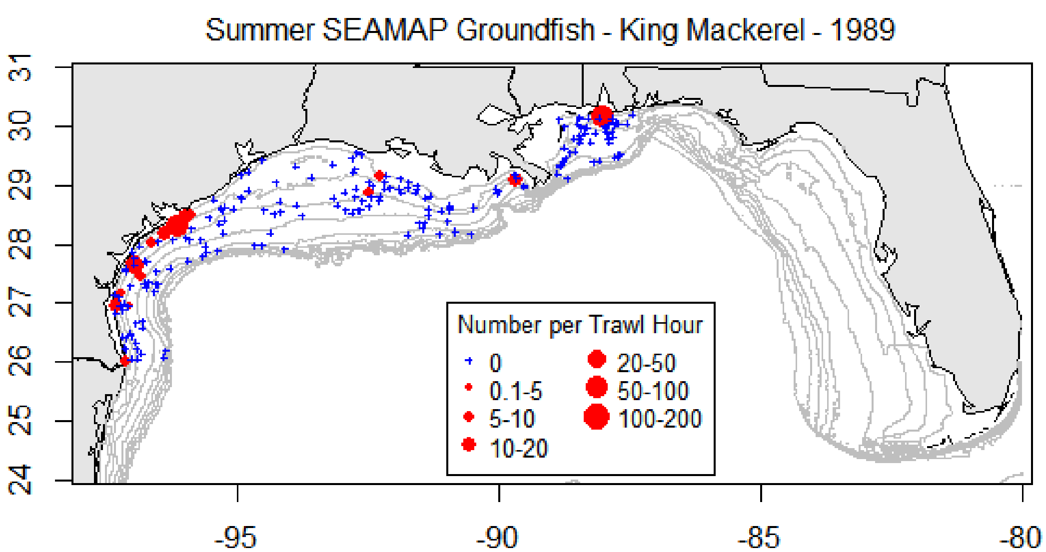


Summer SEAMAP Groundfish - King Mackerel - 1986

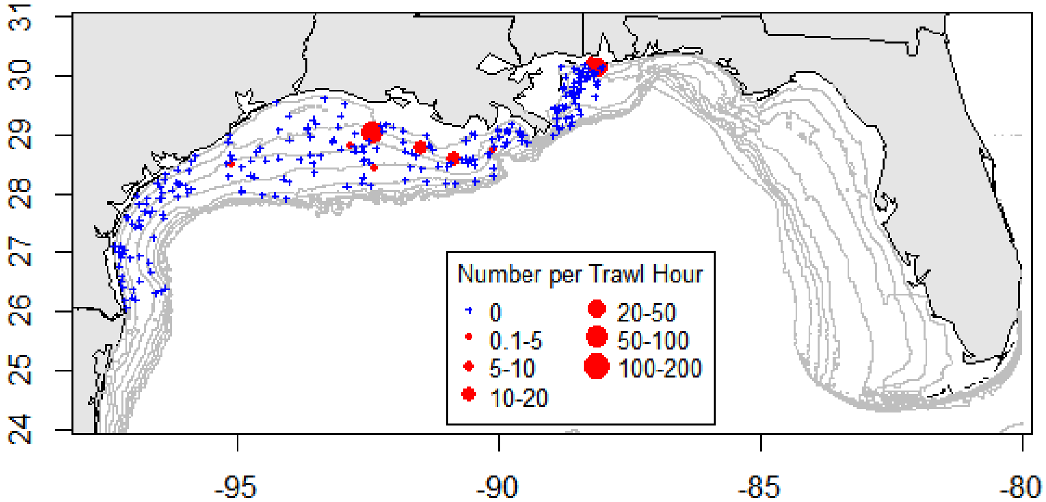



Summer SEAMAP Groundfish - King Mackerel - 1987
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

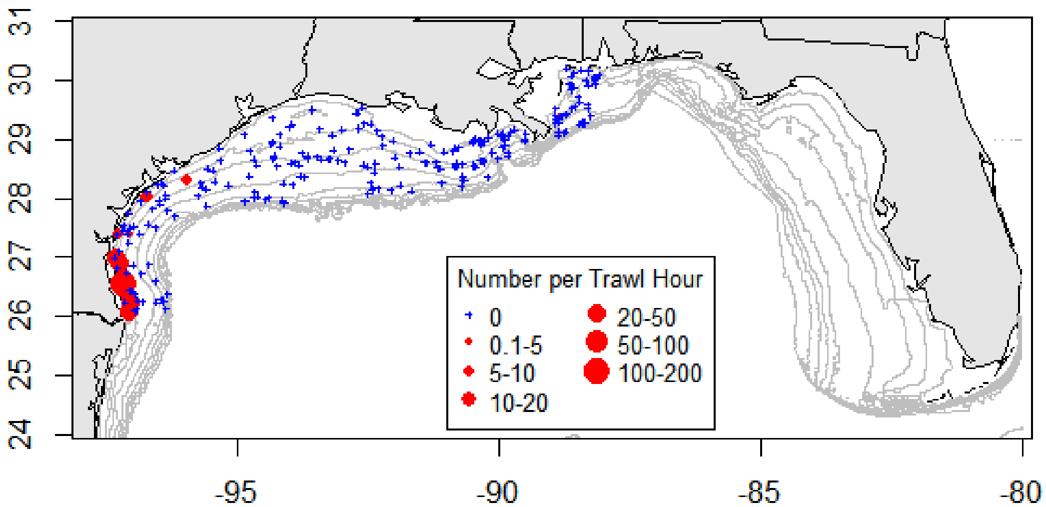

Summer SEAMAP Groundfish - King Mackerel - 1988
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Summer SEAMAP Groundfish - King Mackerel - 1989
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

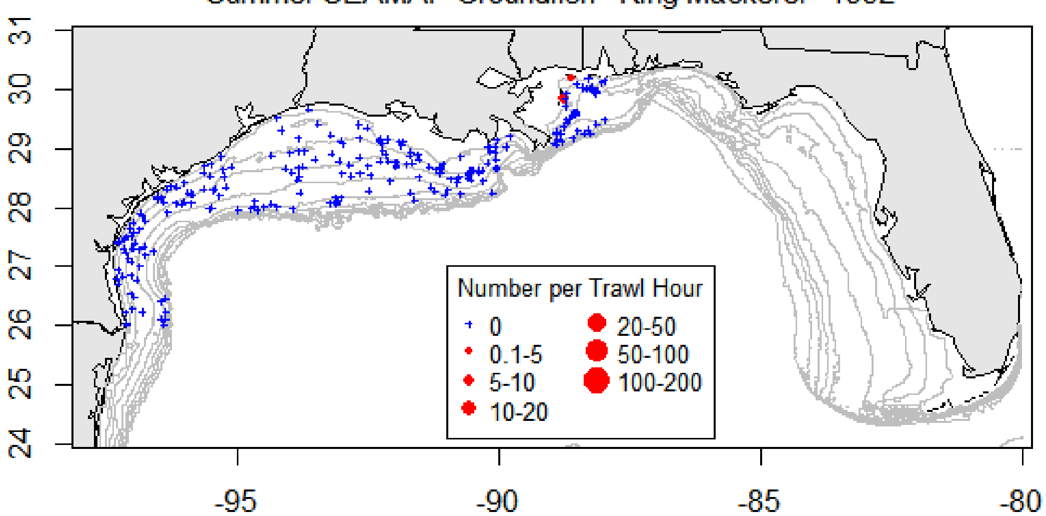
Summer SEAMAP Groundfish - King Mackerel - 1990



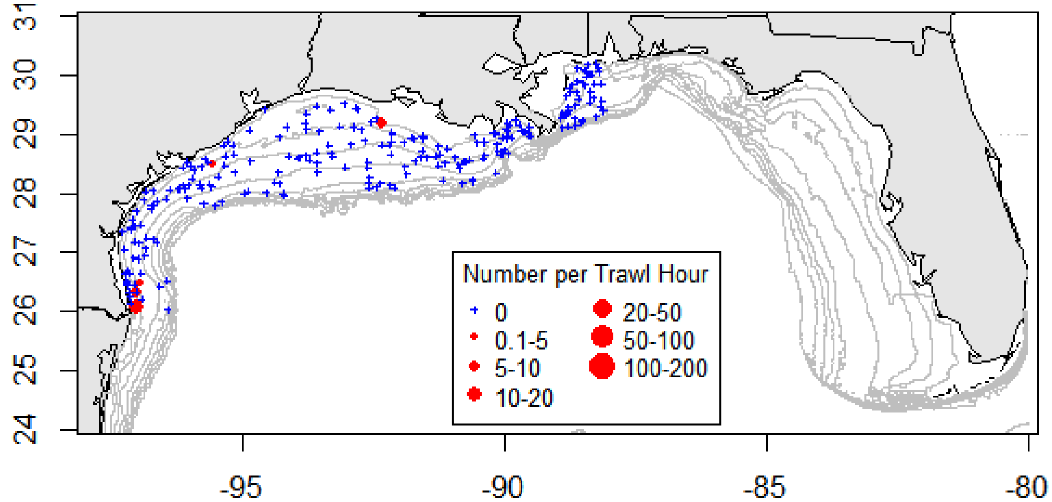
Summer SEAMAP Groundfish - King Mackerel - 1991



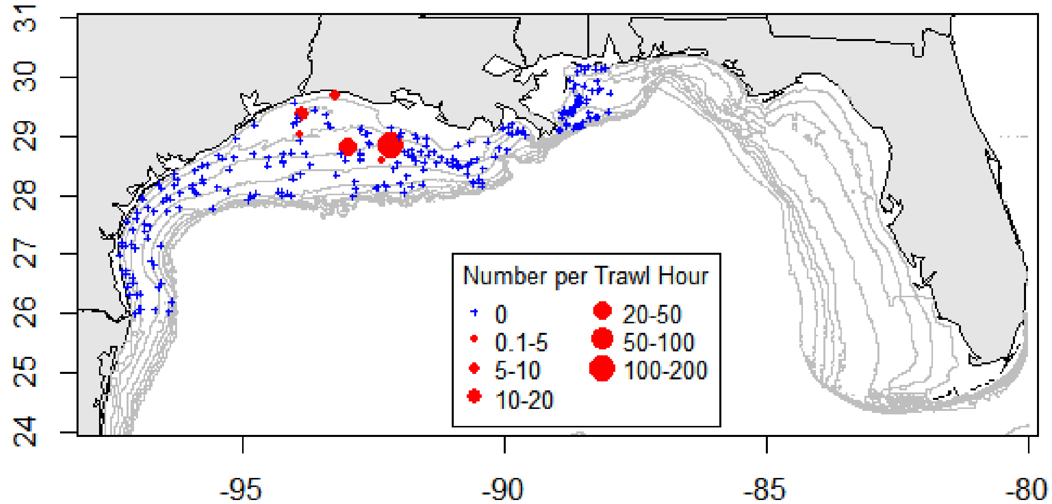
Summer SEAMAP Groundfish - King Mackerel - 1992



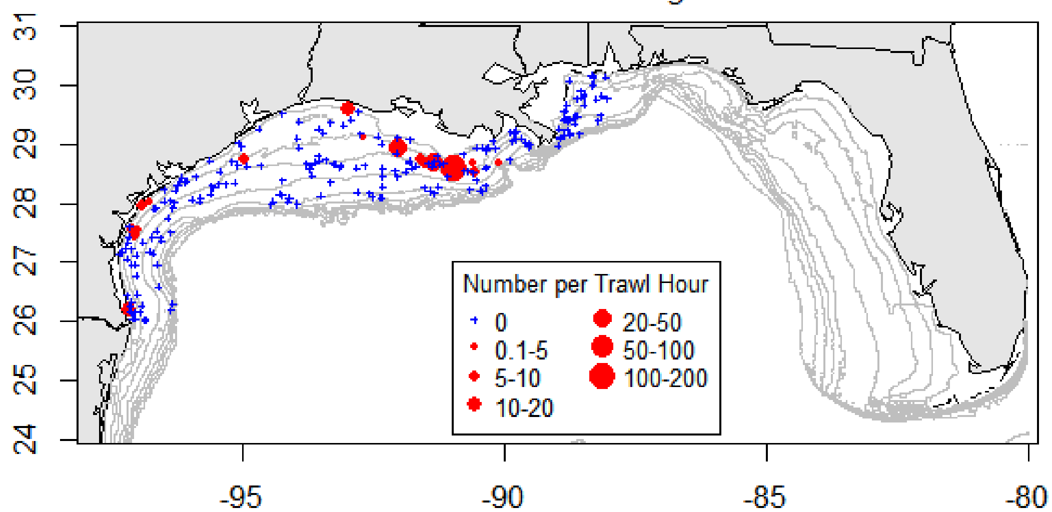
Summer SEAMAP Groundfish - King Mackerel - 1993

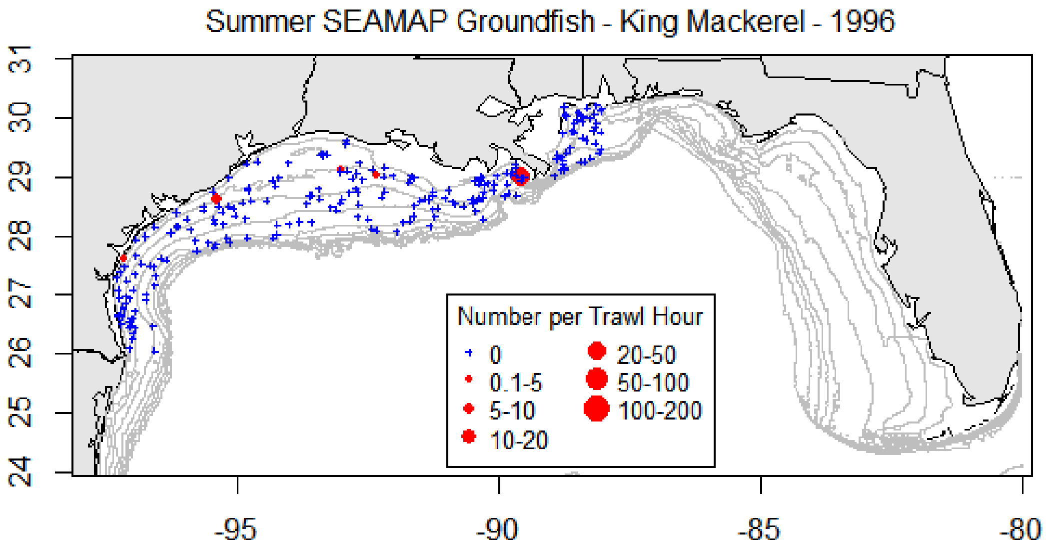


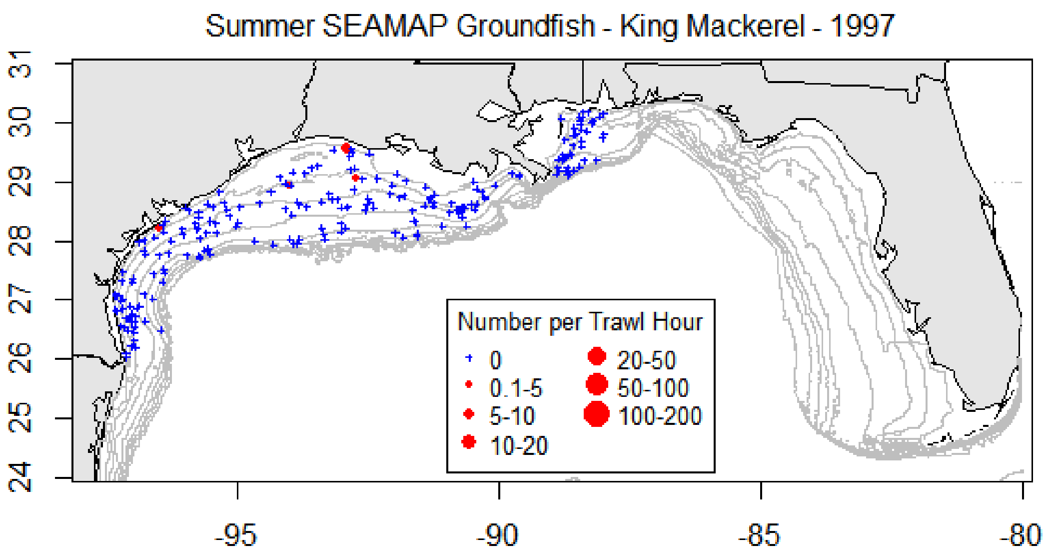
Summer SEAMAP Groundfish - King Mackerel - 1994

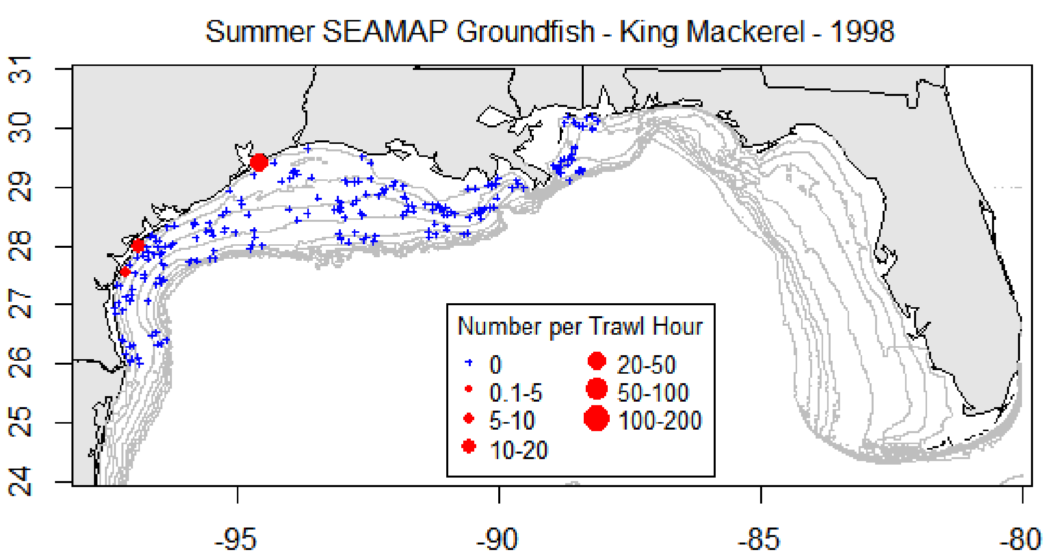


Summer SEAMAP Groundfish - King Mackerel - 1995

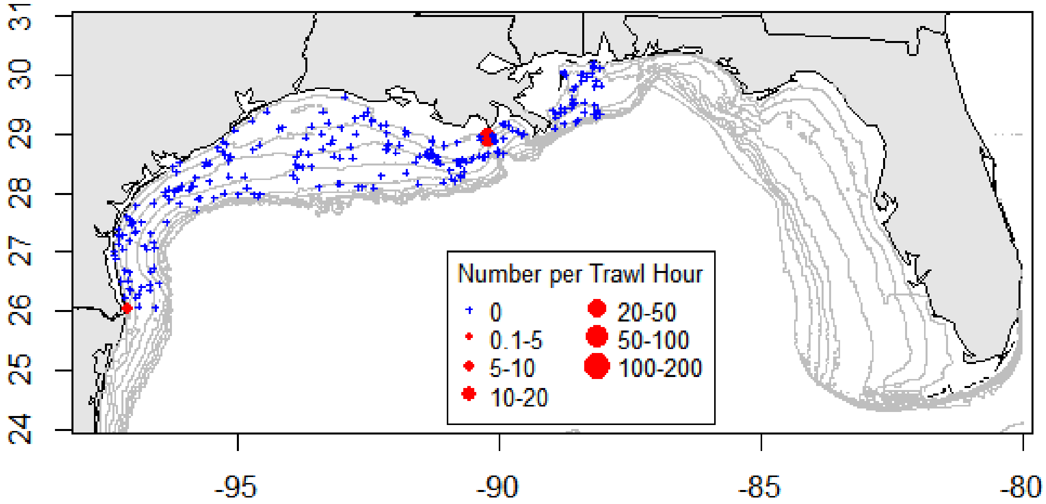



Summer SEAMAP Groundfish - King Mackerel - 1996
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
31
30
29
28
27
26
25
24
-95
-90
-85
-80

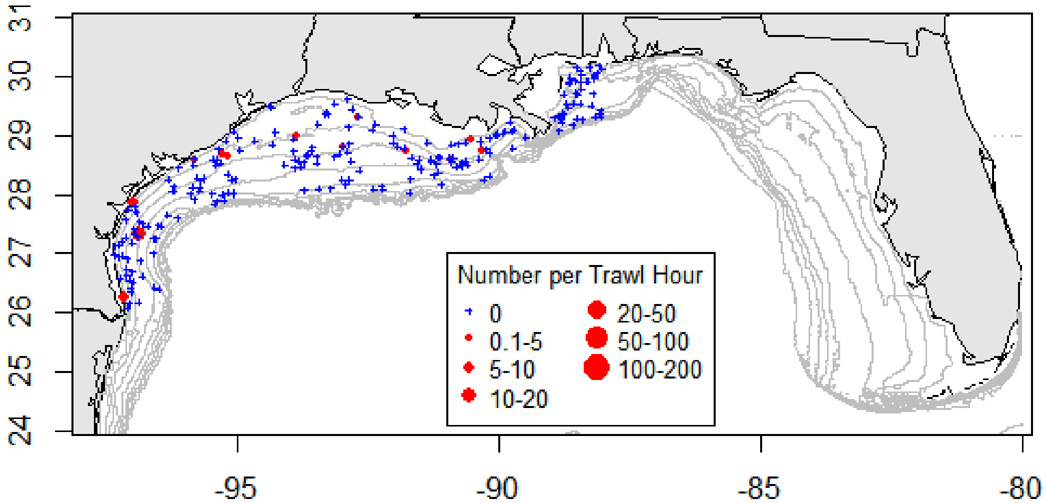

Summer SEAMAP Groundfish - King Mackerel - 1997
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
31
30
29
28
27
26
25
24
-95
-90
-85
-80


Summer SEAMAP Groundfish - King Mackerel - 1998
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
31
30
29
28
27
26
25
24
-95
-90
-85
-80

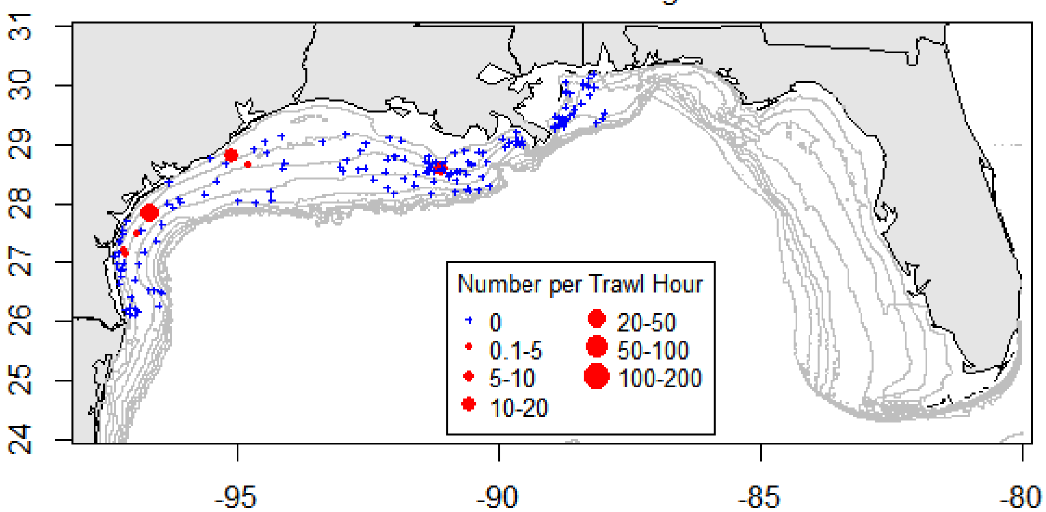
Summer SEAMAP Groundfish - King Mackerel - 1999

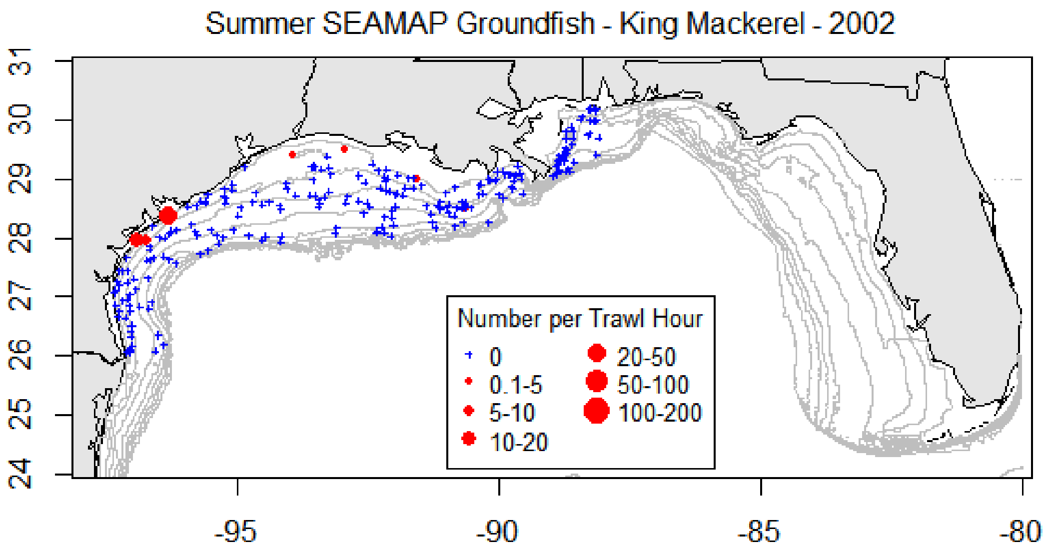


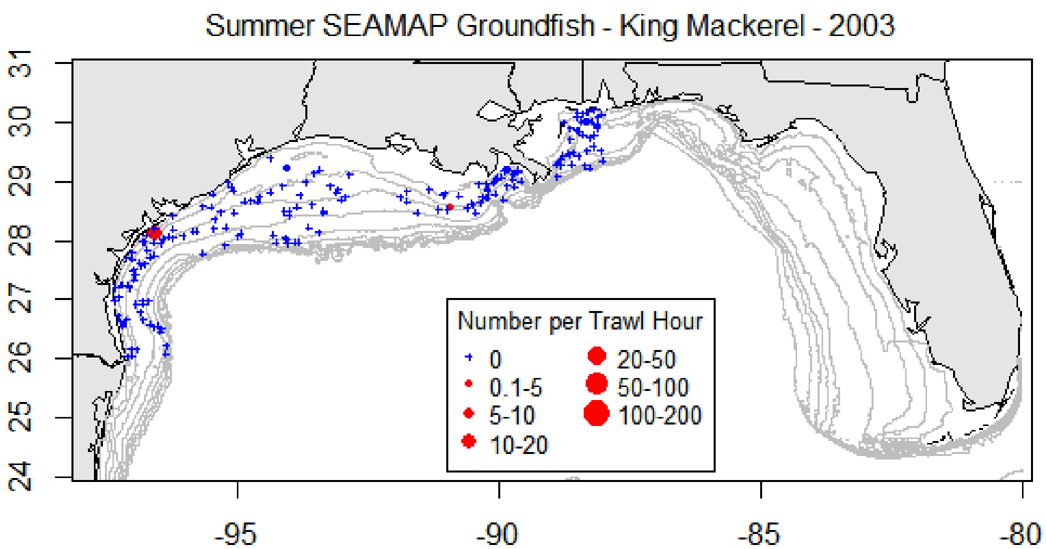
Summer SEAMAP Groundfish - King Mackerel - 2000

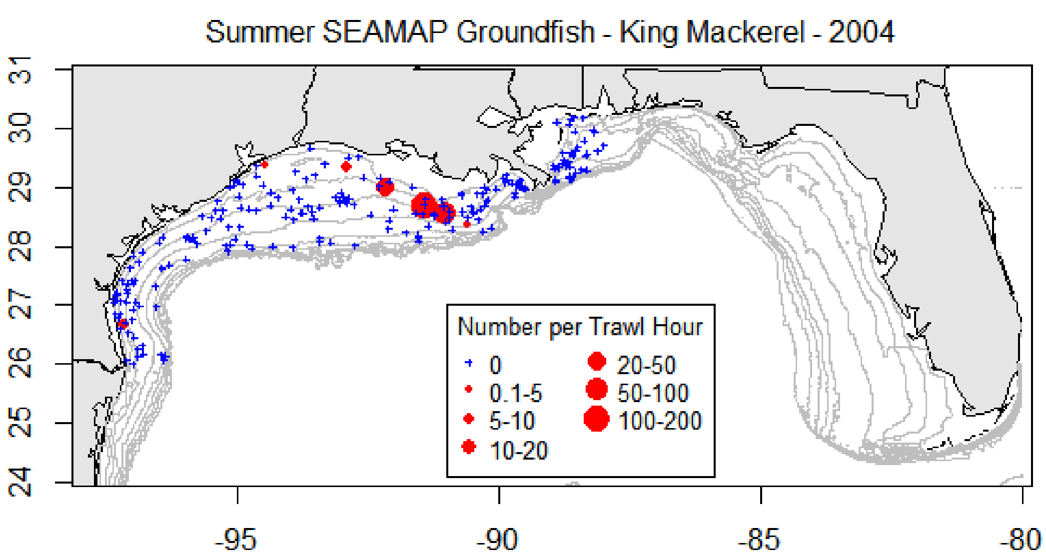


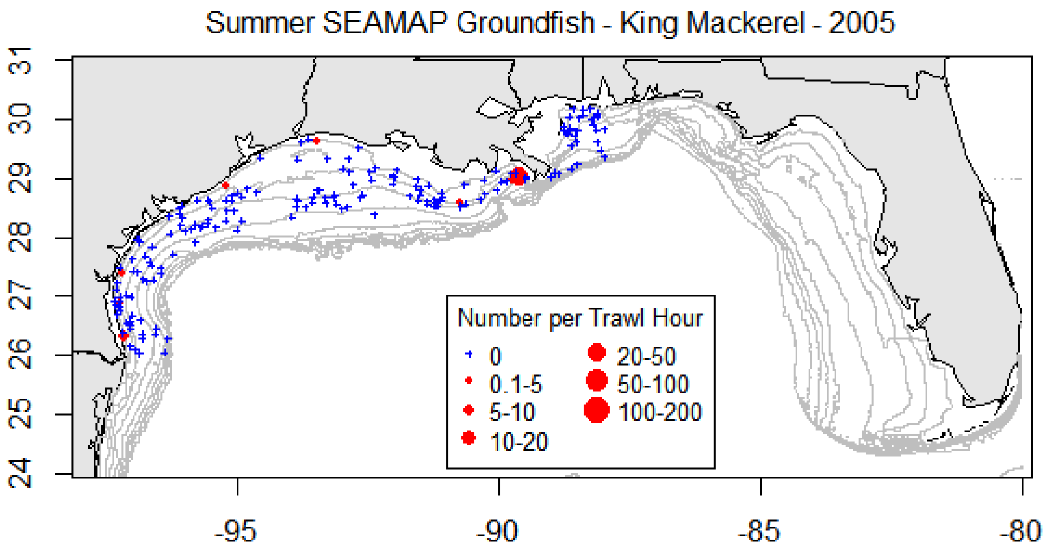
Summer SEAMAP Groundfish - King Mackerel - 2001

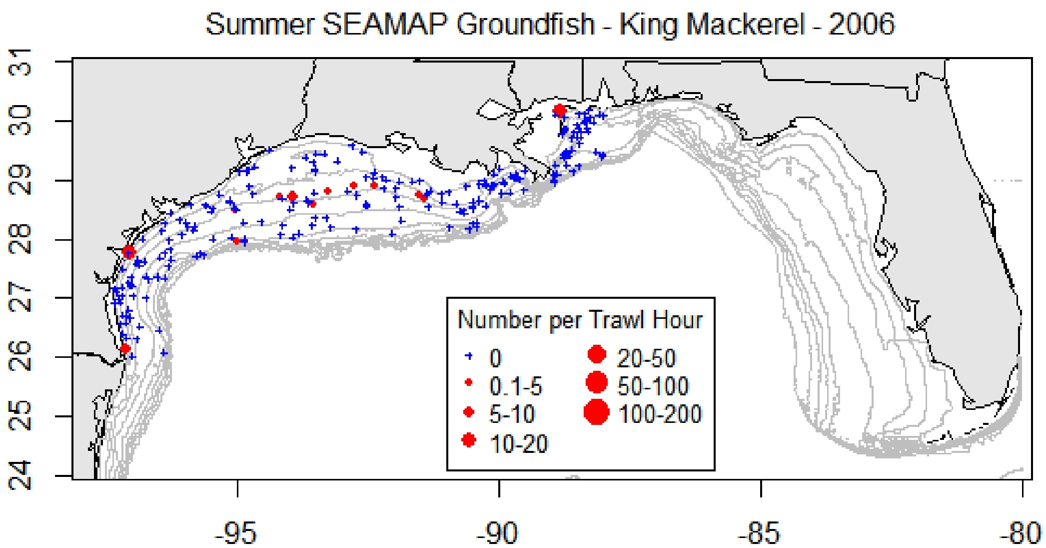


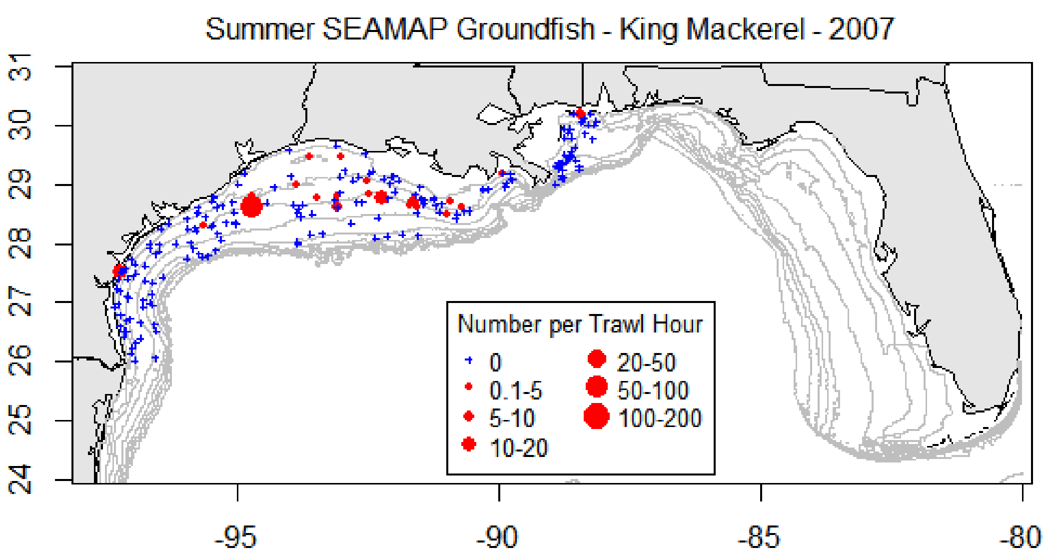

Summer SEAMAP Groundfish - King Mackerel - 2002
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Summer SEAMAP Groundfish - King Mackerel - 2003
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

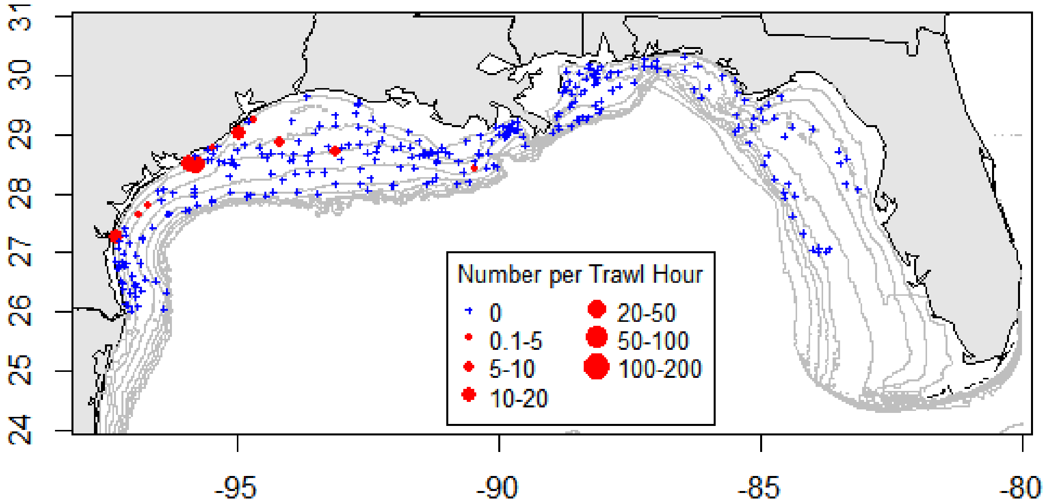

Summer SEAMAP Groundfish - King Mackerel - 2004
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Summer SEAMAP Groundfish - King Mackerel - 2005
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

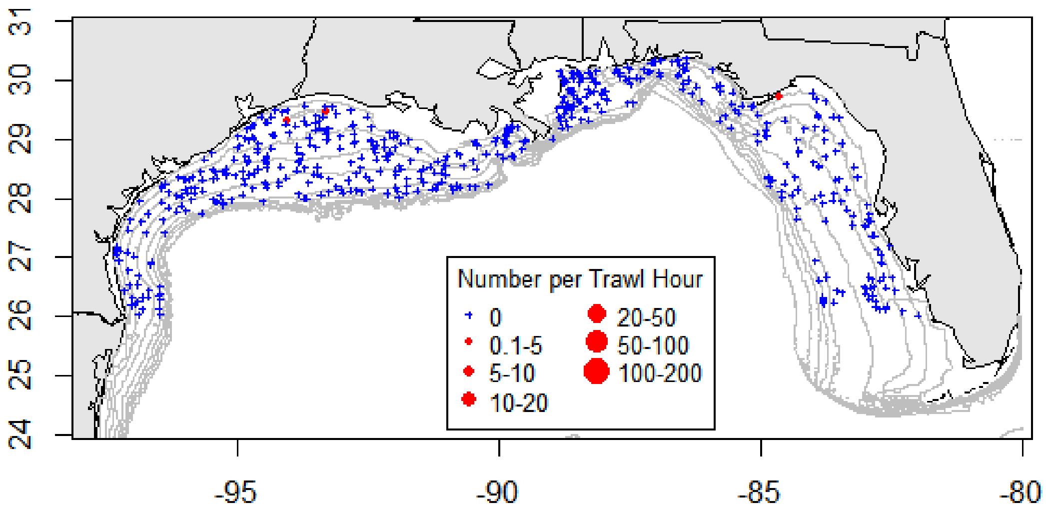

Summer SEAMAP Groundfish - King Mackerel - 2006
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Summer SEAMAP Groundfish - King Mackerel - 2007
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

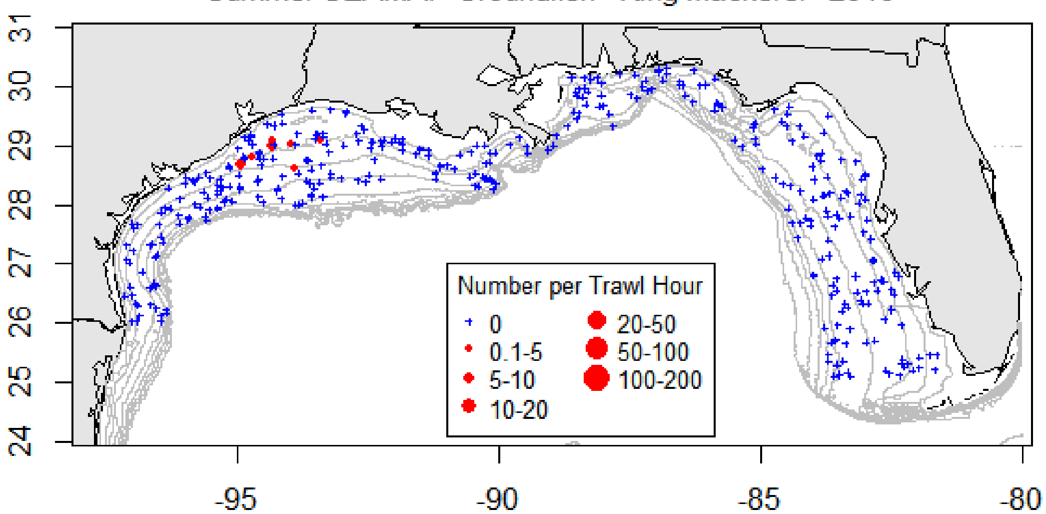
Summer SEAMAP Groundfish - King Mackerel - 2008



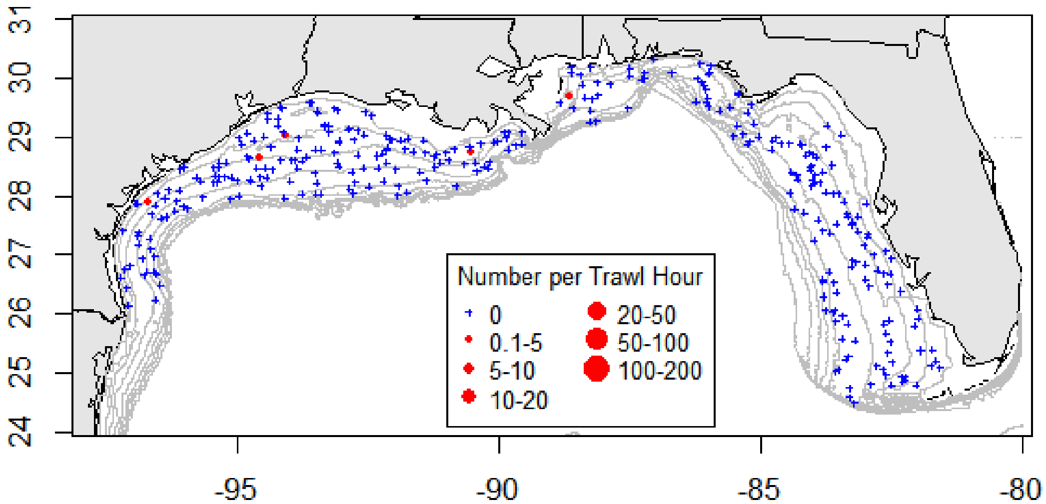
Summer SEAMAP Groundfish - King Mackerel - 2009



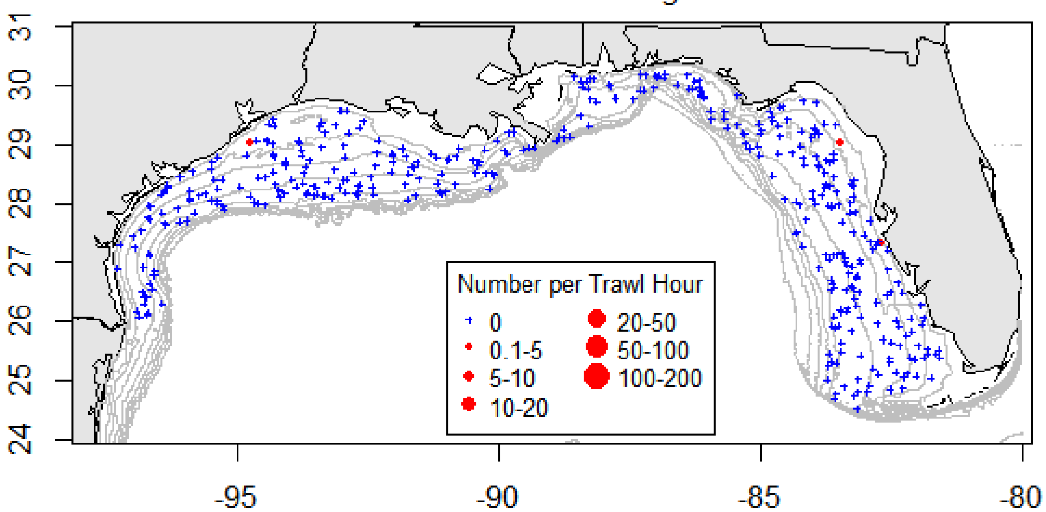
Summer SEAMAP Groundfish - King Mackerel - 2010



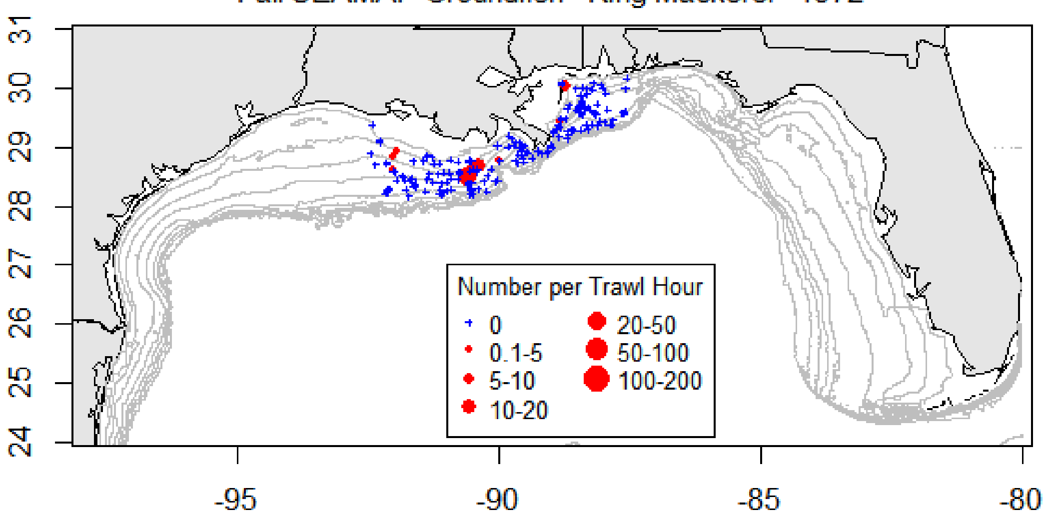
Summer SEAMAP Groundfish - King Mackerel - 2011



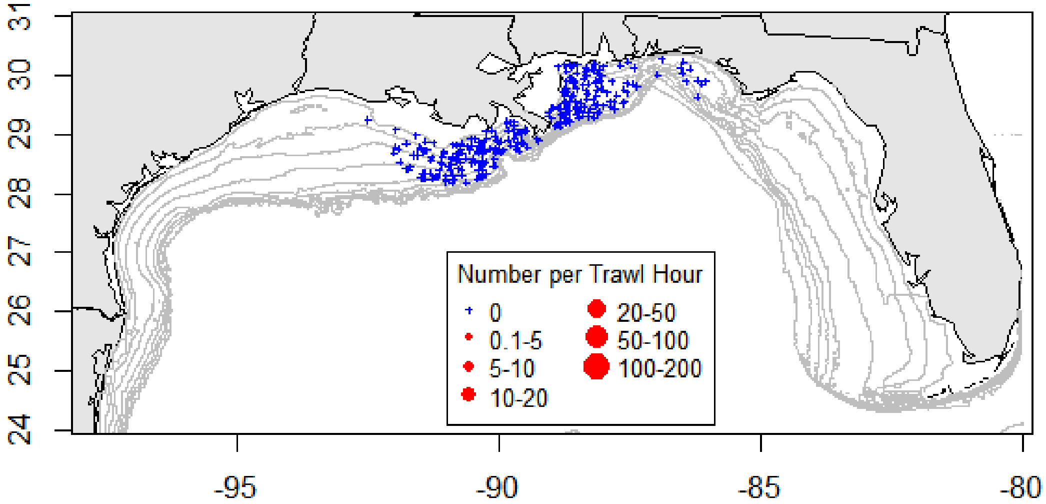
Summer SEAMAP Groundfish - King Mackerel - 2012



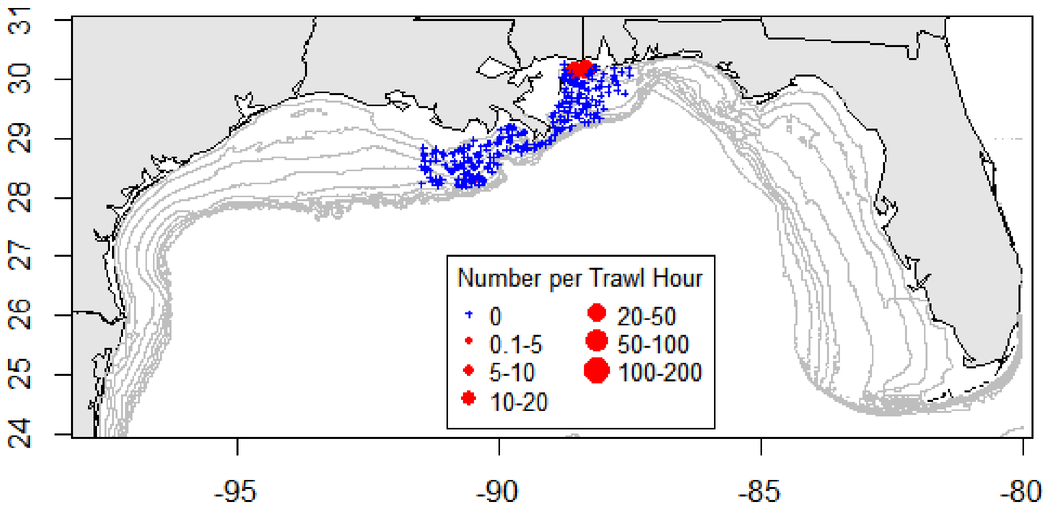
Fall SEAMAP Groundfish - King Mackerel - 1972



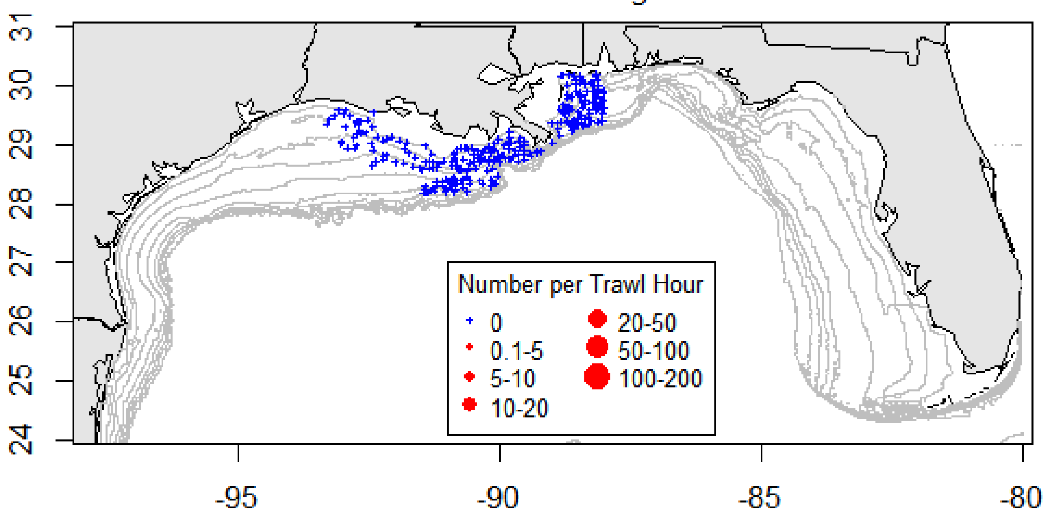
Fall SEAMAP Groundfish - King Mackerel - 1973



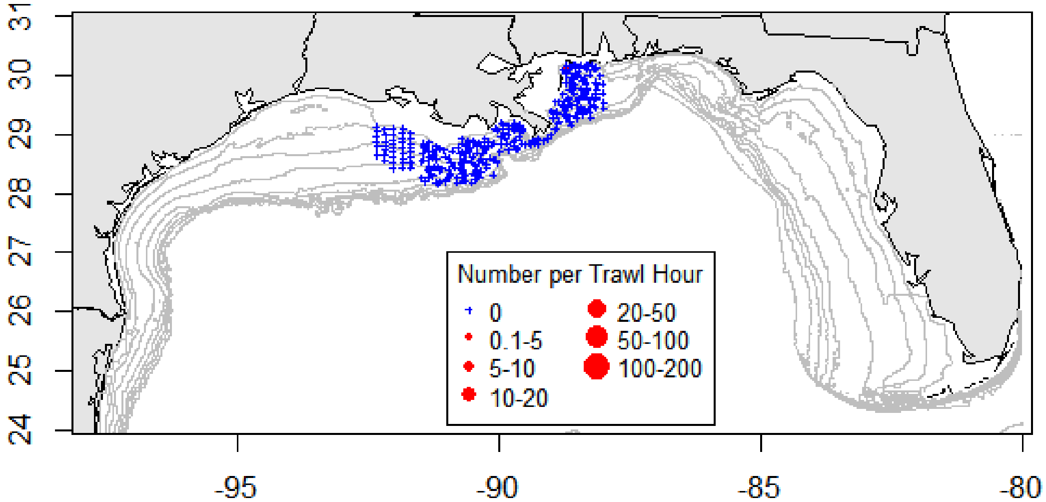
Fall SEAMAP Groundfish - King Mackerel - 1974



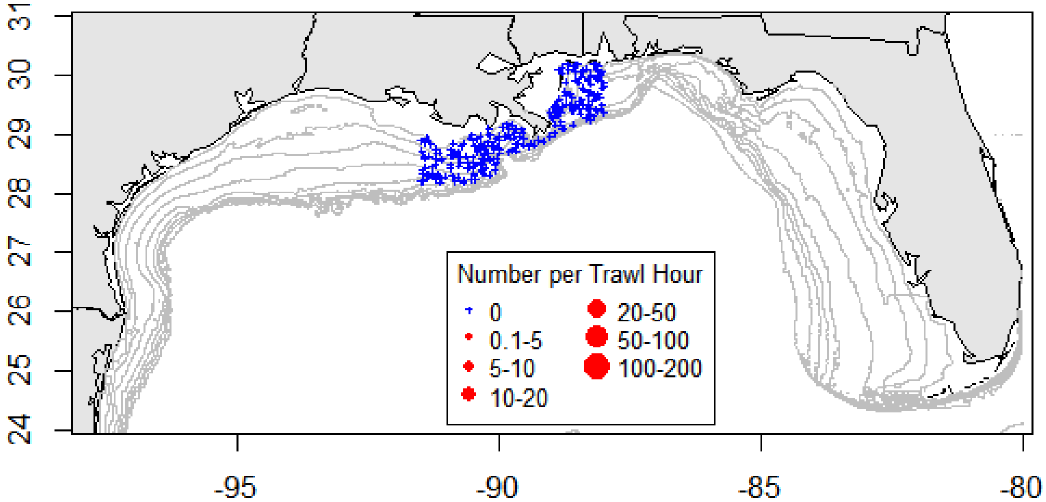
Fall SEAMAP Groundfish - King Mackerel - 1975



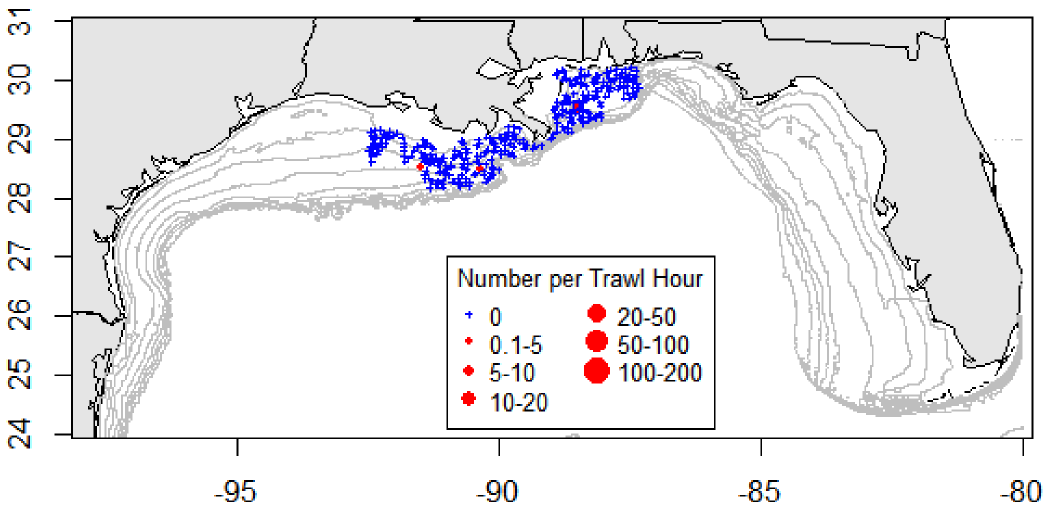
Fall SEAMAP Groundfish - King Mackerel - 1976

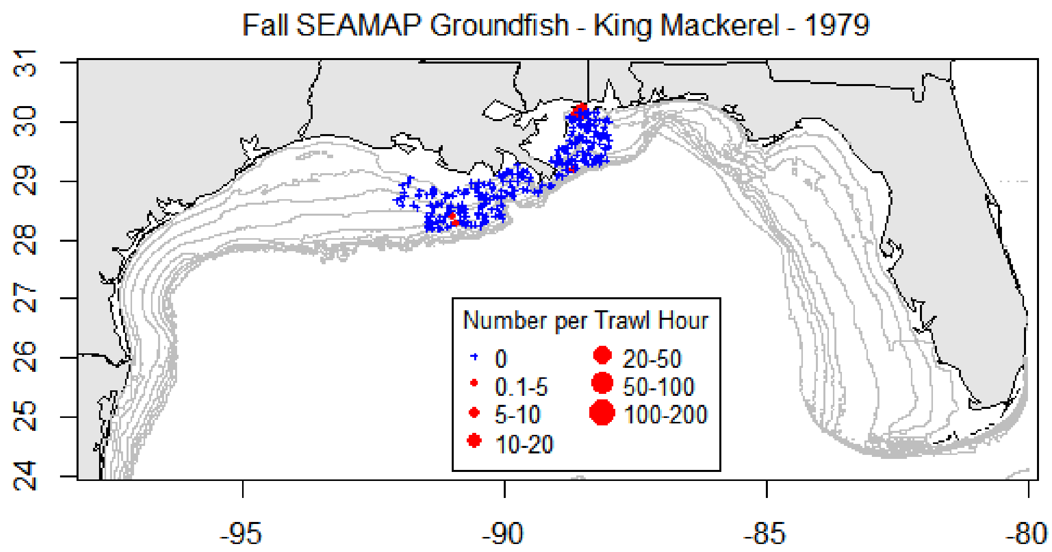


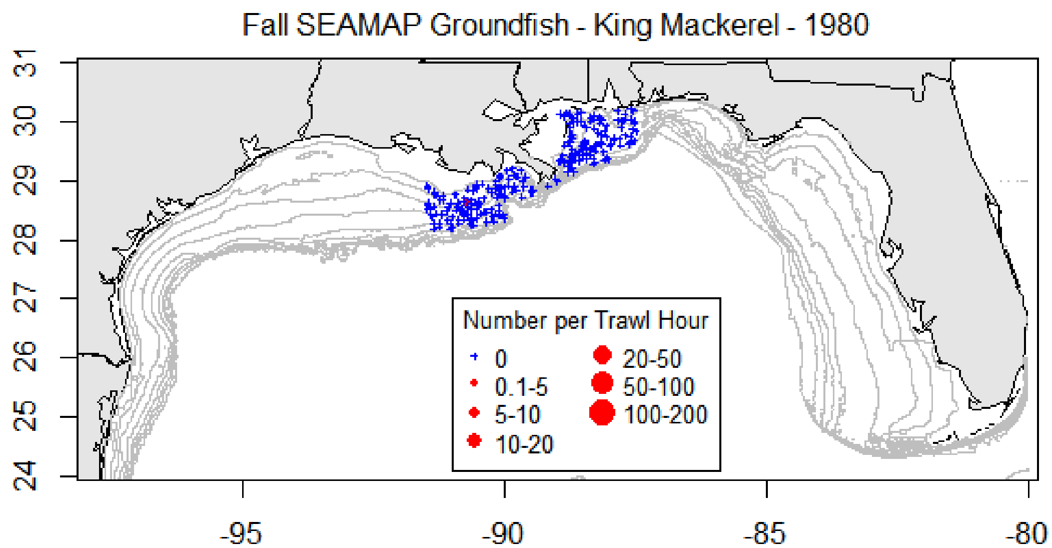
Fall SEAMAP Groundfish - King Mackerel - 1977

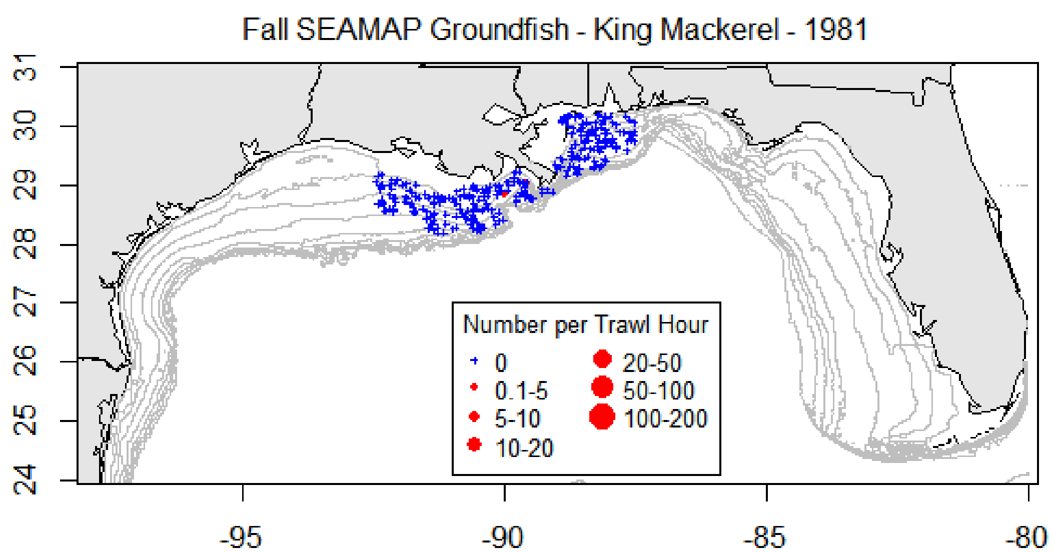


Fall SEAMAP Groundfish - King Mackerel - 1978

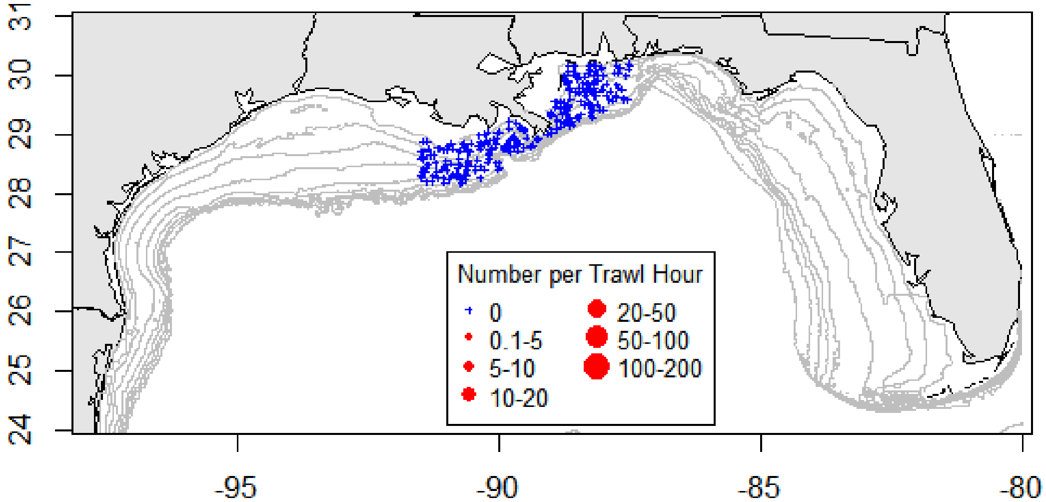



Fall SEAMAP Groundfish - King Mackerel - 1979
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

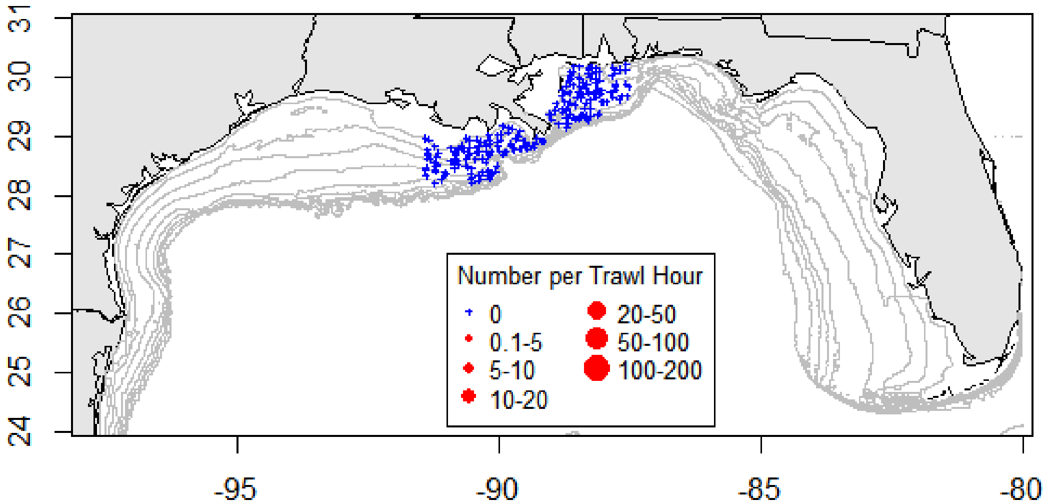

Fall SEAMAP Groundfish - King Mackerel - 1980
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Fall SEAMAP Groundfish - King Mackerel - 1981
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80

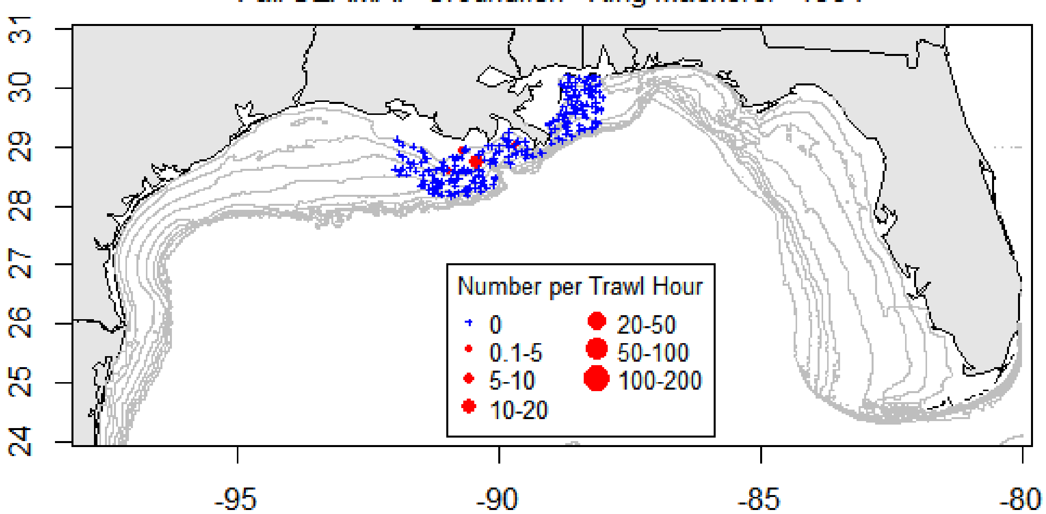
Fall SEAMAP Groundfish - King Mackerel - 1982

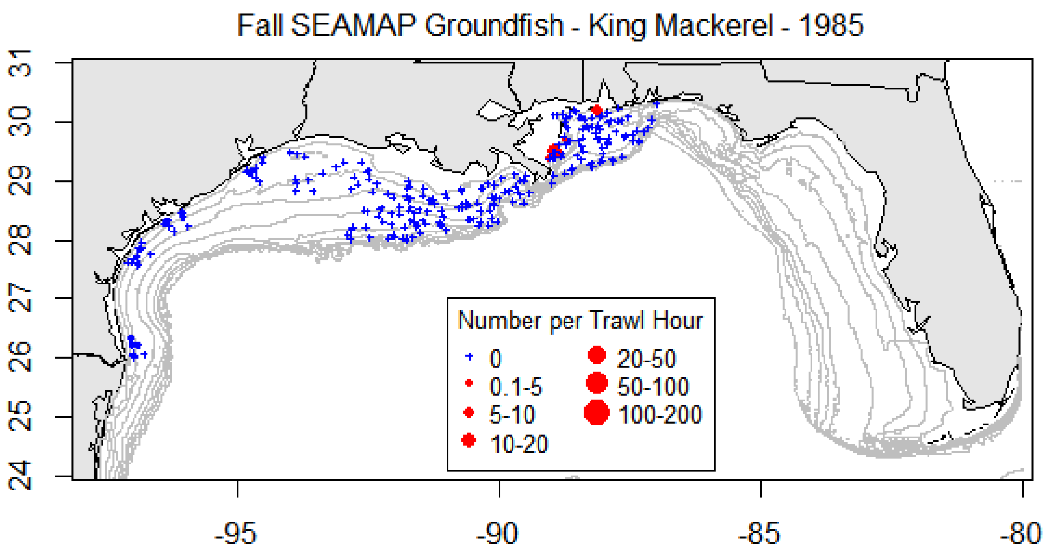


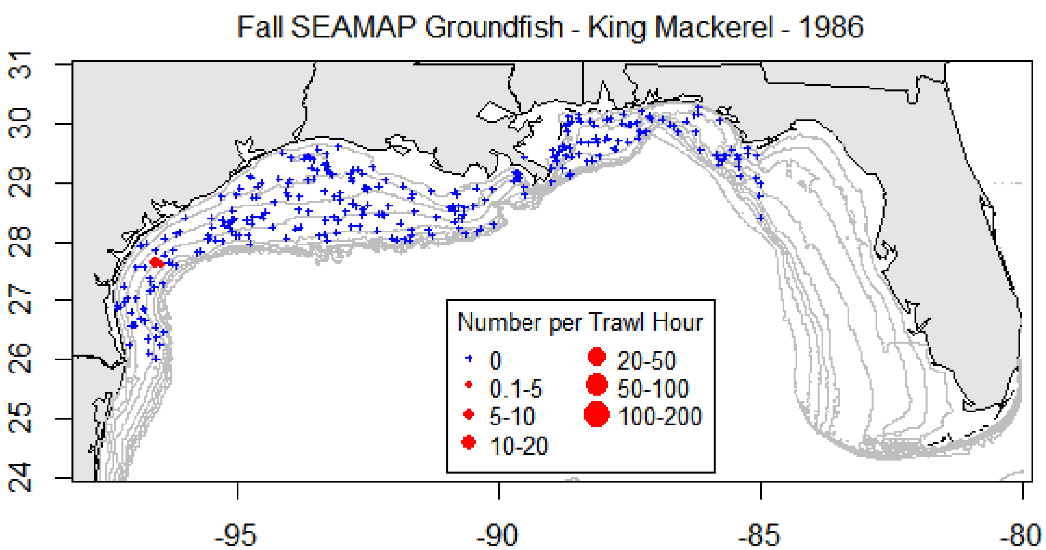
Fall SEAMAP Groundfish - King Mackerel - 1983

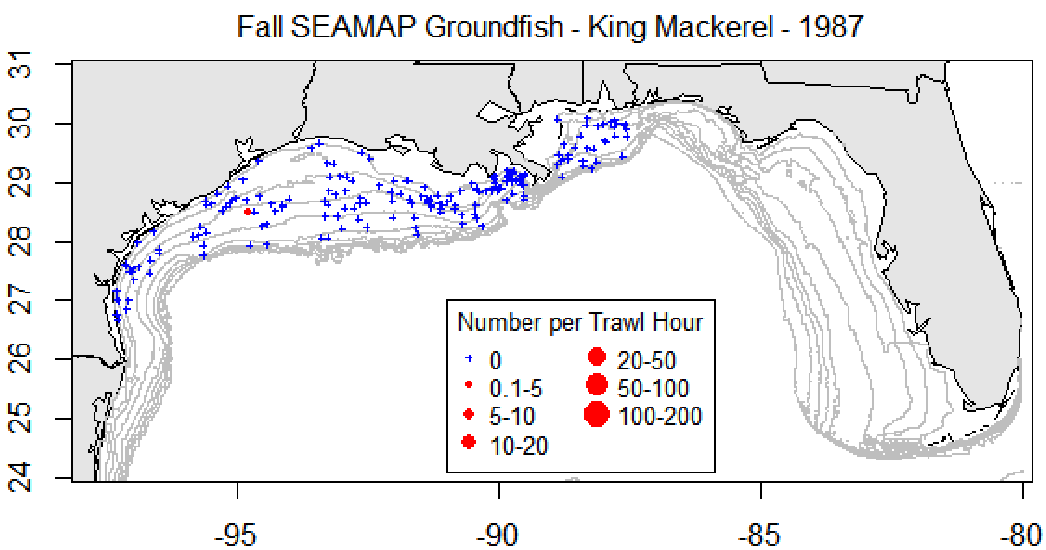


Fall SEAMAP Groundfish - King Mackerel - 1984

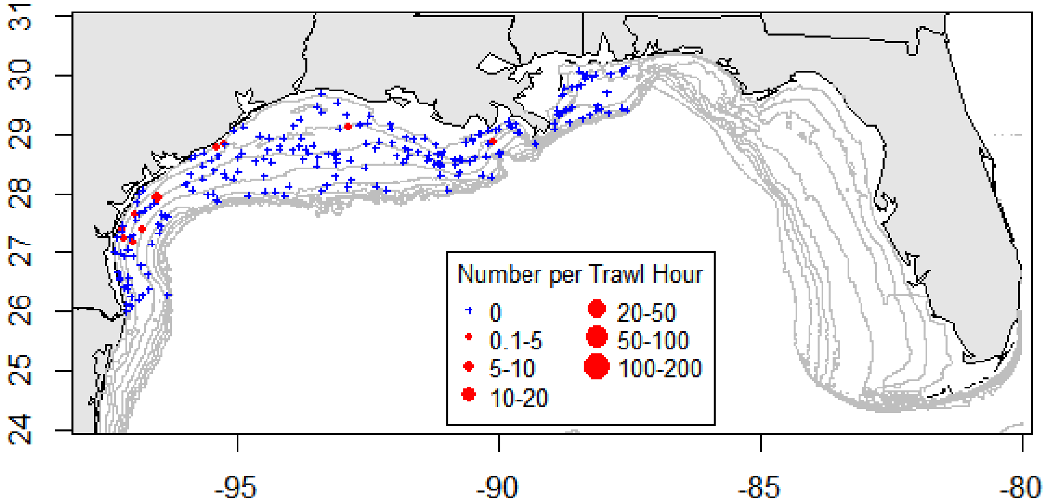



Fall SEAMAP Groundfish - King Mackerel - 1985
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200

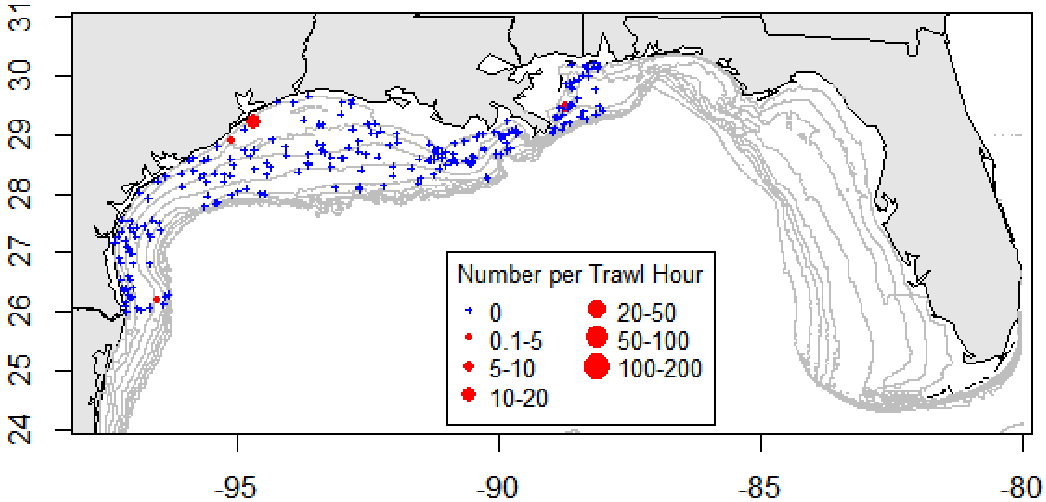

Fall SEAMAP Groundfish - King Mackerel - 1986
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200


Fall SEAMAP Groundfish - King Mackerel - 1987
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200

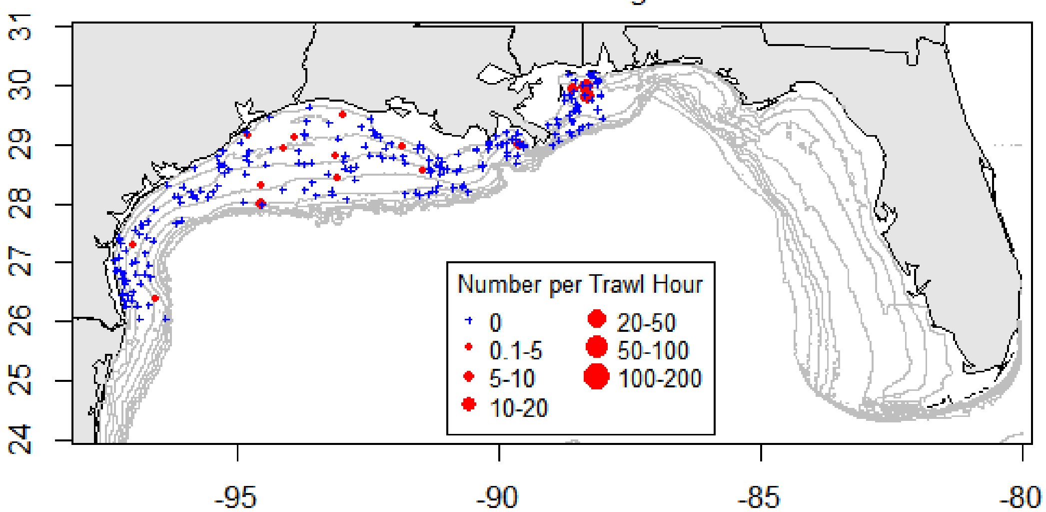
Fall SEAMAP Groundfish - King Mackerel - 1988



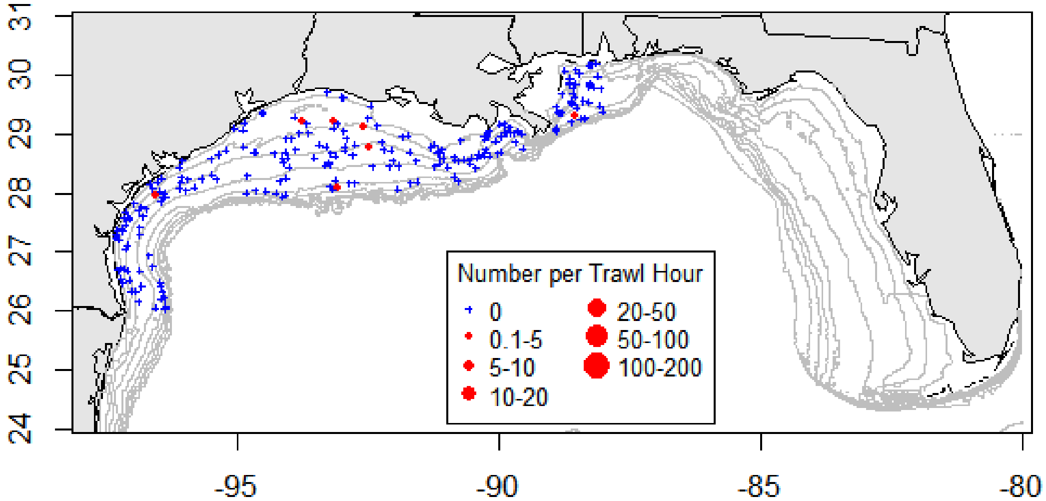
Fall SEAMAP Groundfish - King Mackerel - 1989



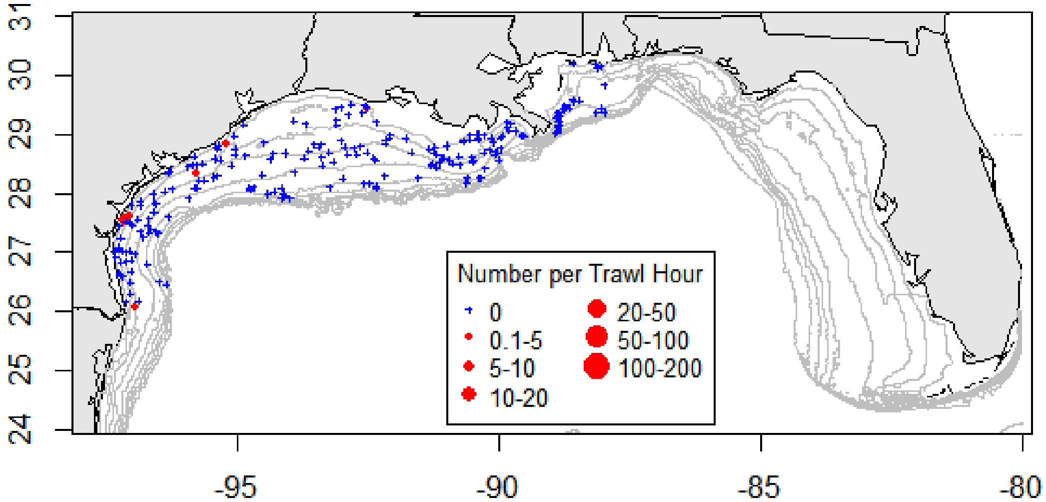
Fall SEAMAP Groundfish - King Mackerel - 1990



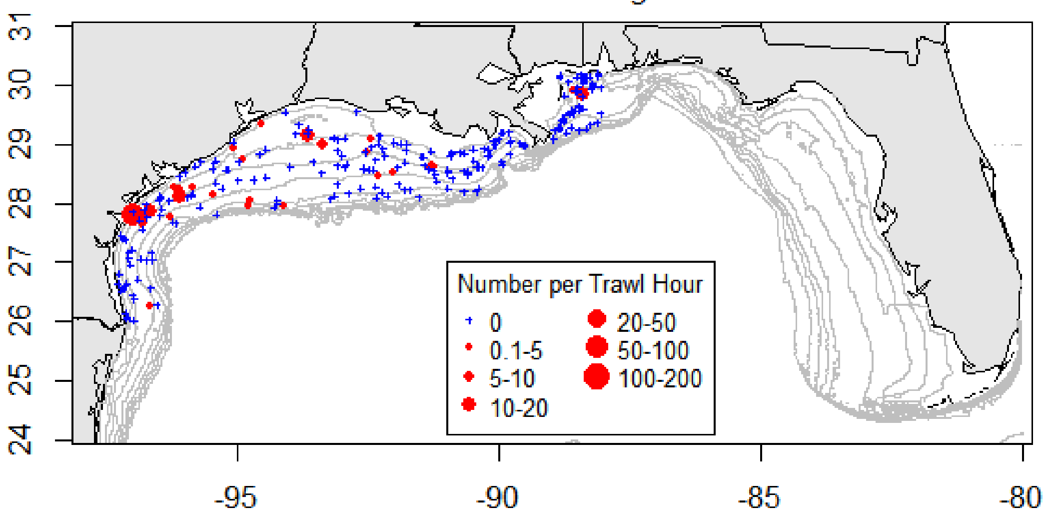
Fall SEAMAP Groundfish - King Mackerel - 1991



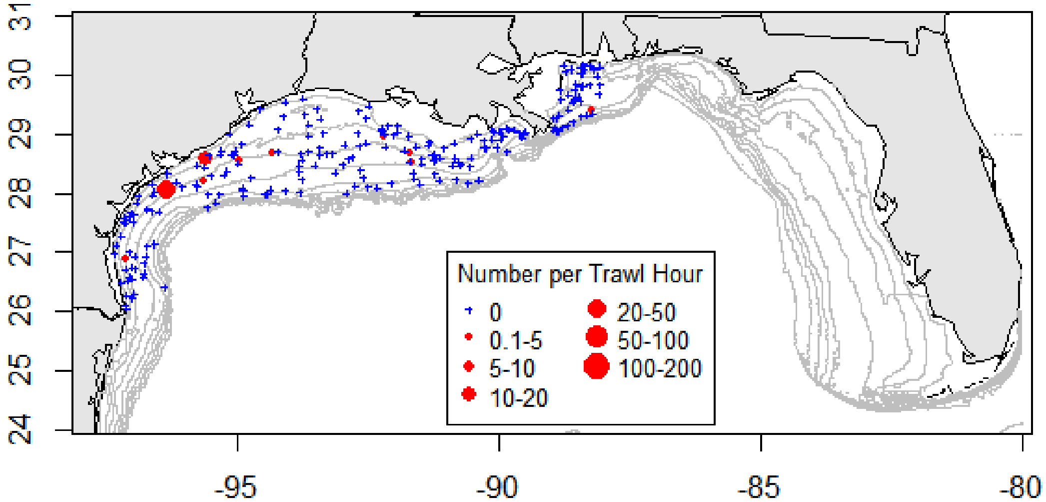
Fall SEAMAP Groundfish - King Mackerel - 1992



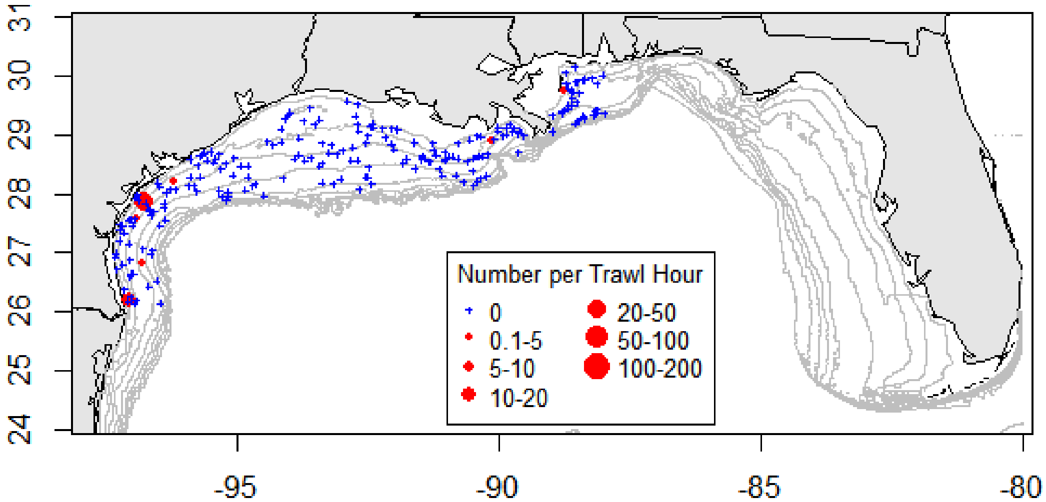
Fall SEAMAP Groundfish - King Mackerel - 1993



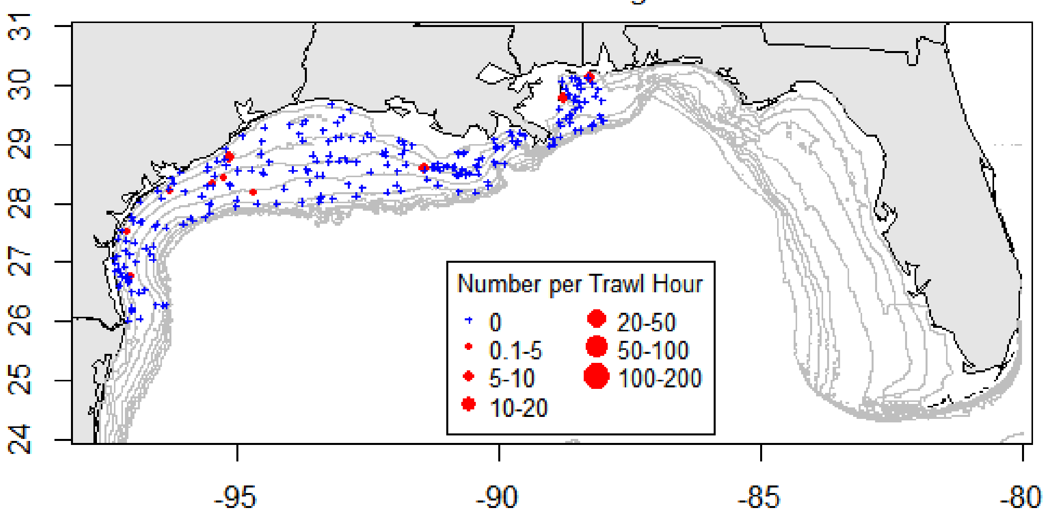
Fall SEAMAP Groundfish - King Mackerel - 1994



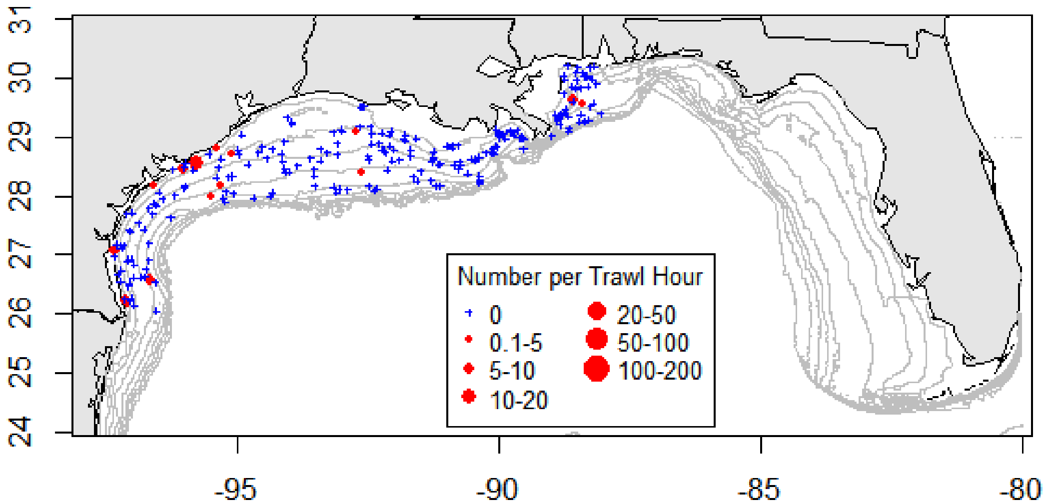
Fall SEAMAP Groundfish - King Mackerel - 1995



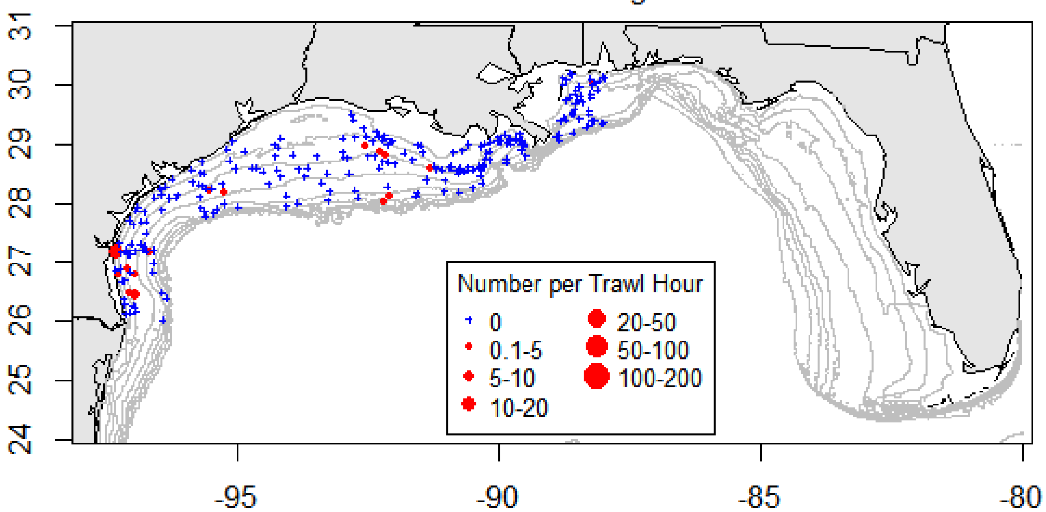
Fall SEAMAP Groundfish - King Mackerel - 1996



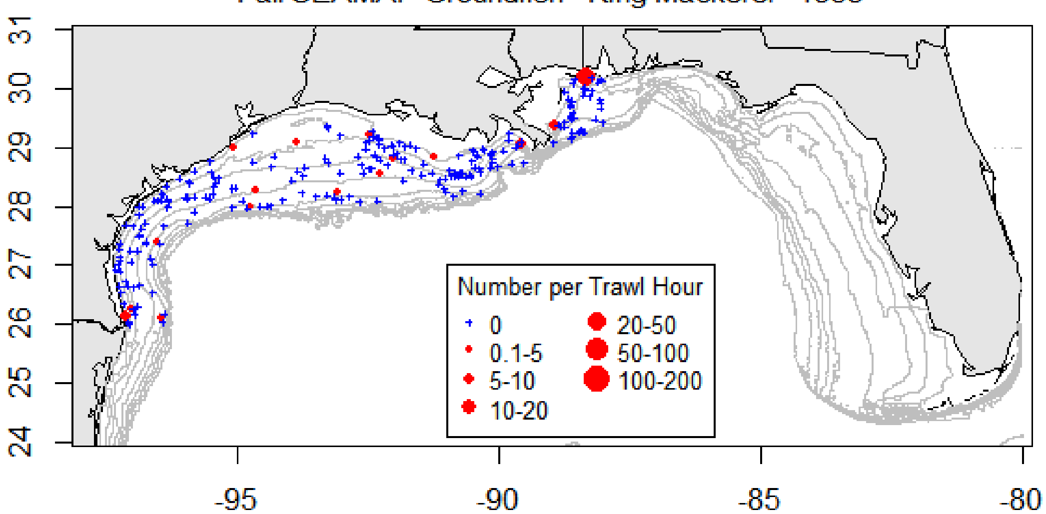
Fall SEAMAP Groundfish - King Mackerel - 1997



Fall SEAMAP Groundfish - King Mackerel - 1998



Fall SEAMAP Groundfish - King Mackerel - 1999



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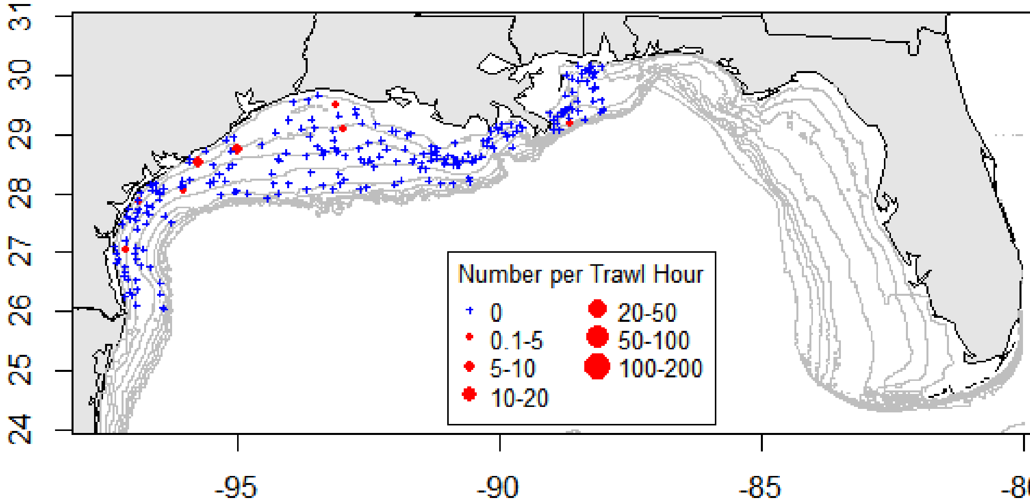
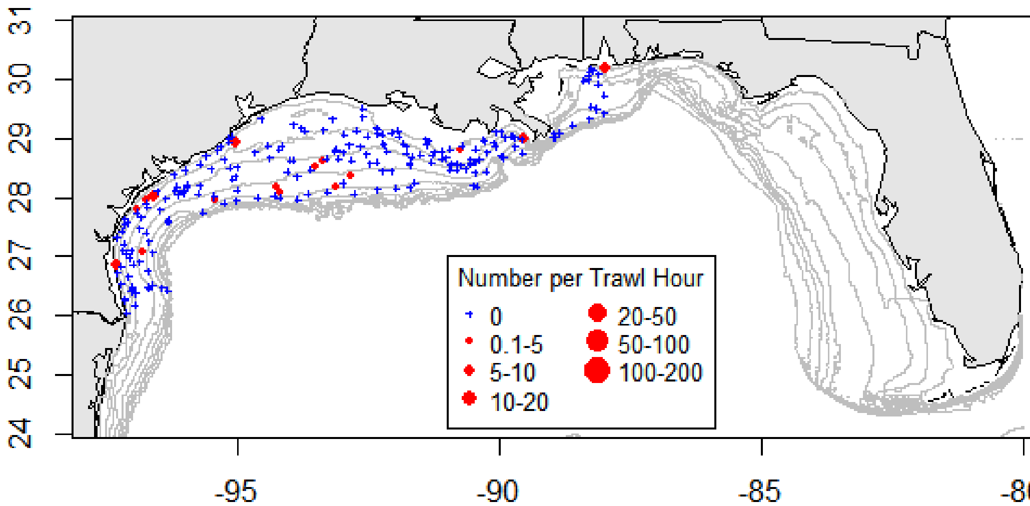
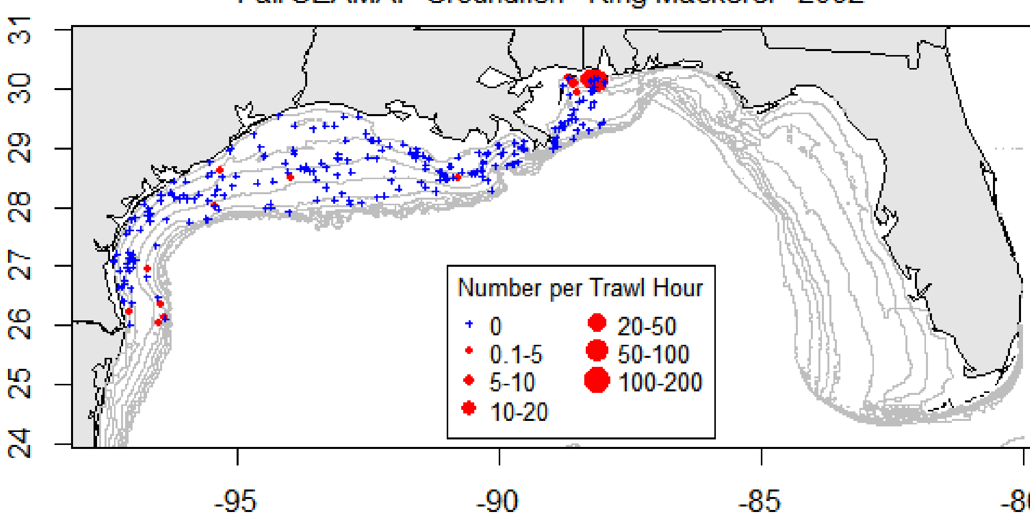


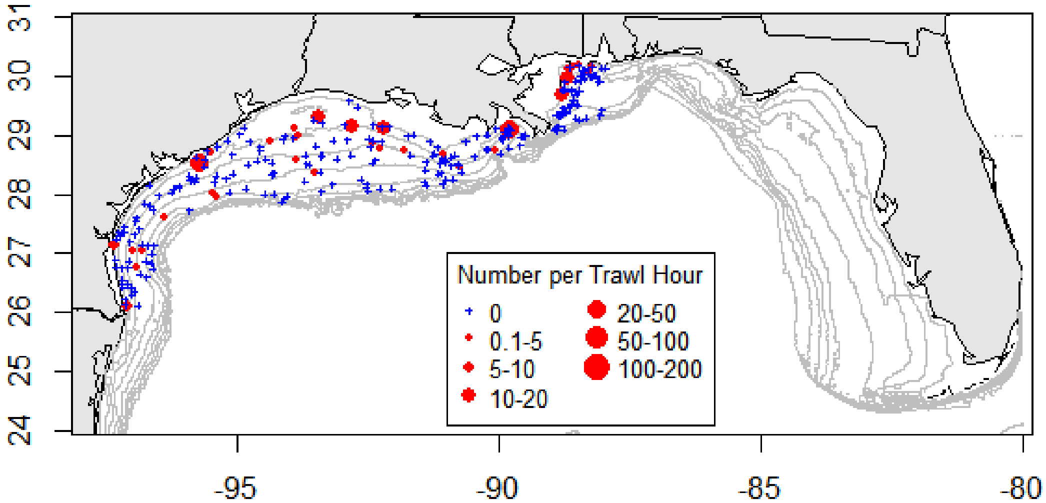
Fall SEAMAP Groundfish - King Mackerel - 2001



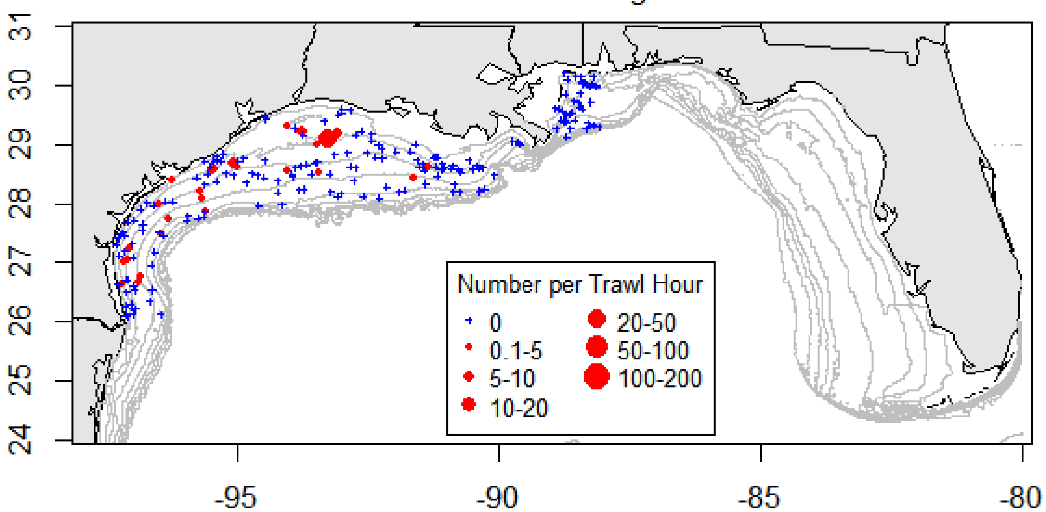
Fall SEAMAP Groundfish - King Mackerel - 2002



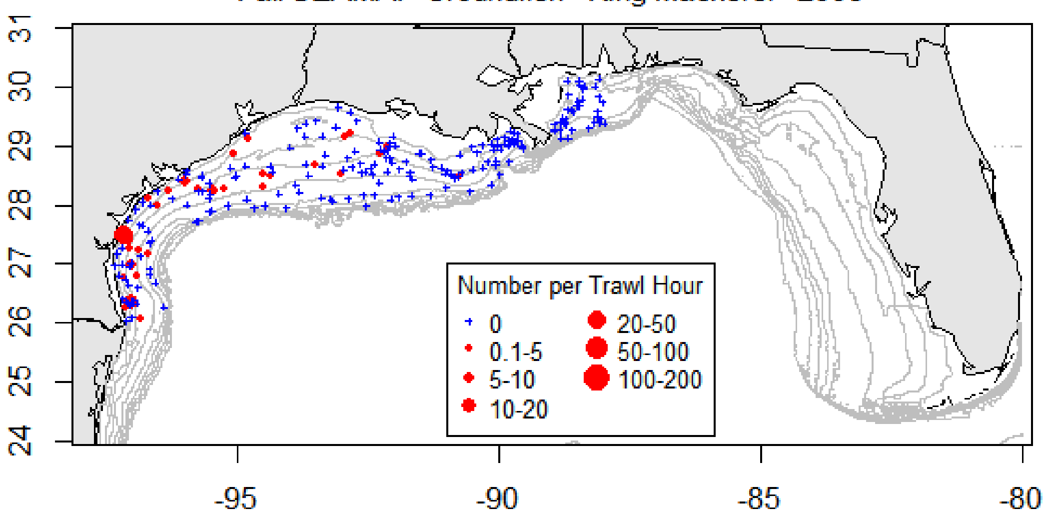
Fall SEAMAP Groundfish - King Mackerel - 2003



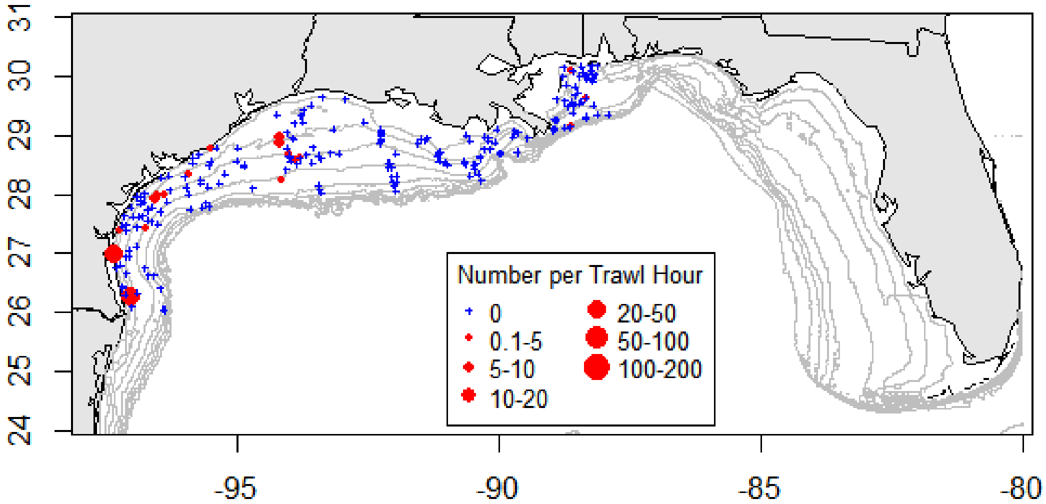
Fall SEAMAP Groundfish - King Mackerel - 2004



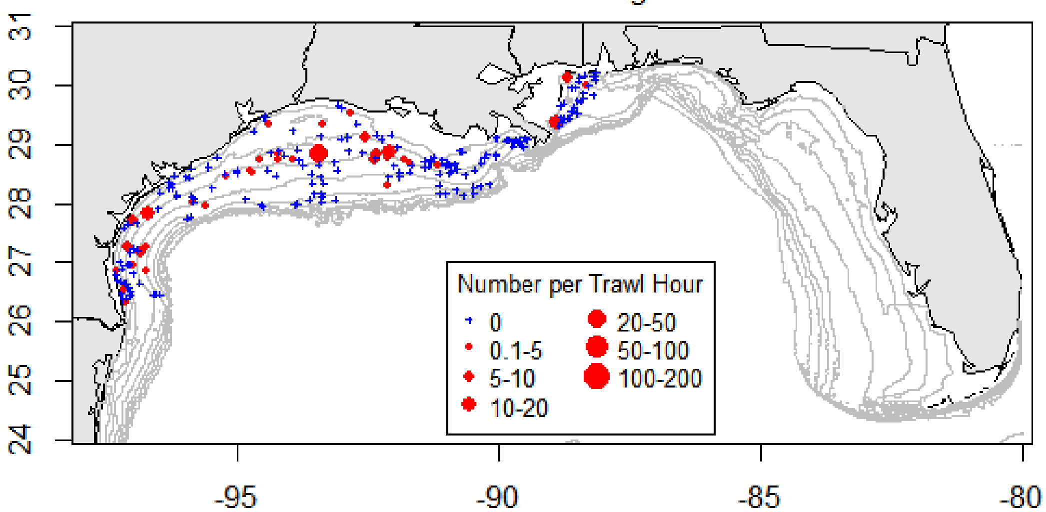
Fall SEAMAP Groundfish - King Mackerel - 2005



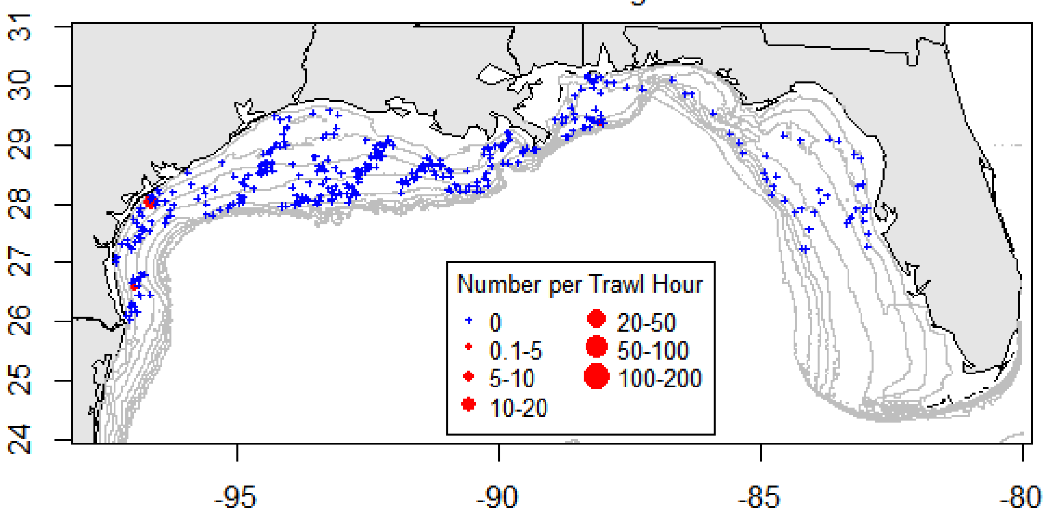
Fall SEAMAP Groundfish - King Mackerel - 2006

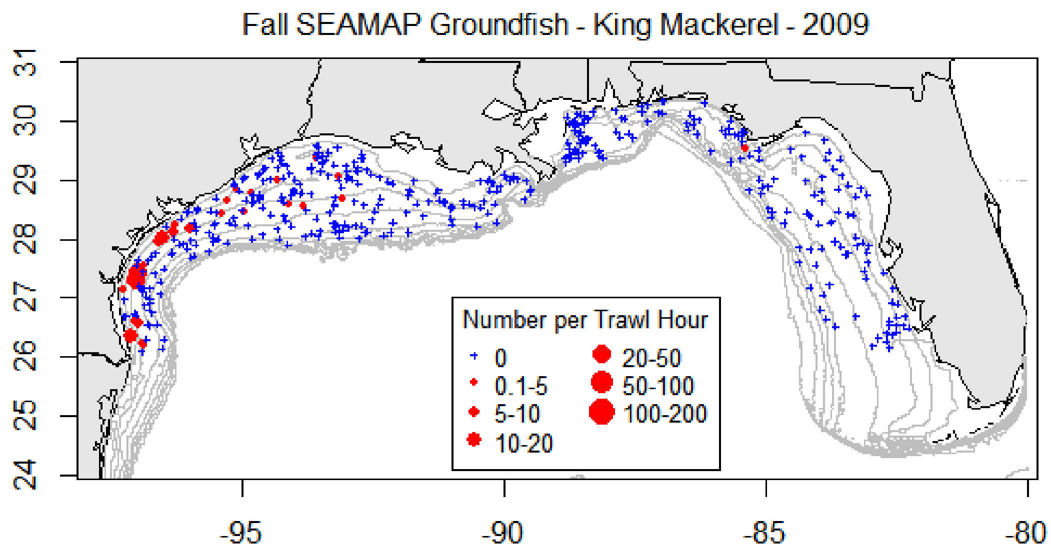


Fall SEAMAP Groundfish - King Mackerel - 2007

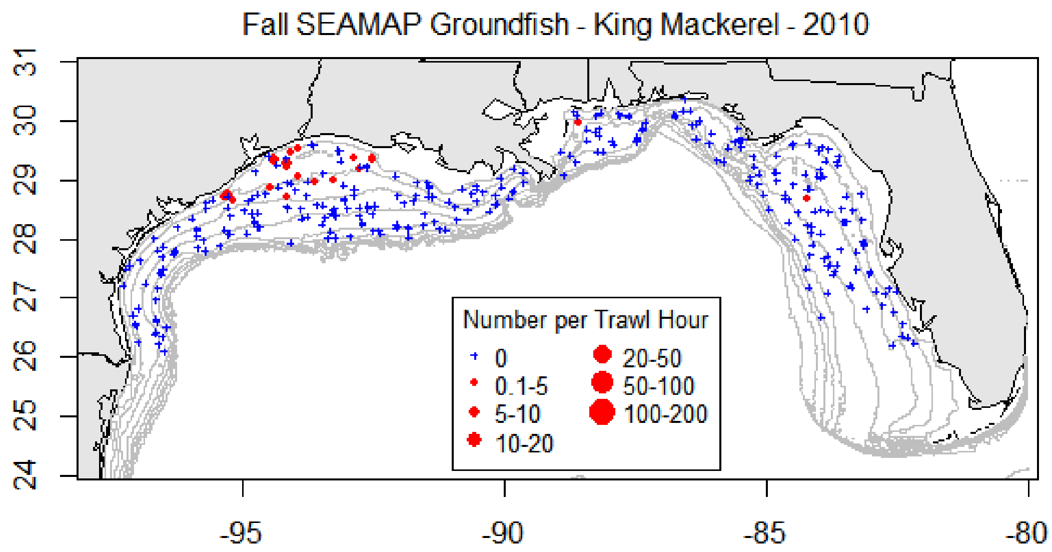


Fall SEAMAP Groundfish - King Mackerel - 2008

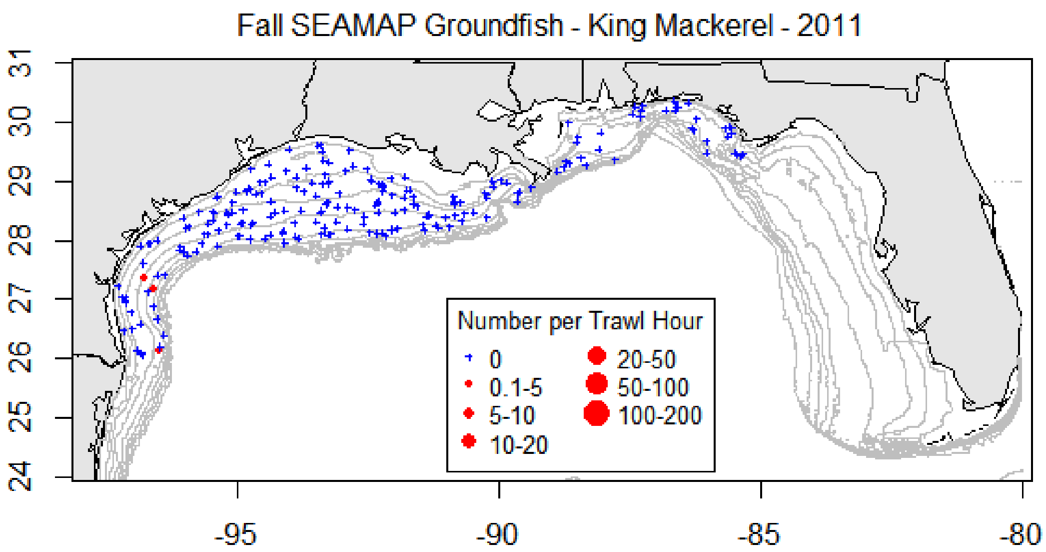


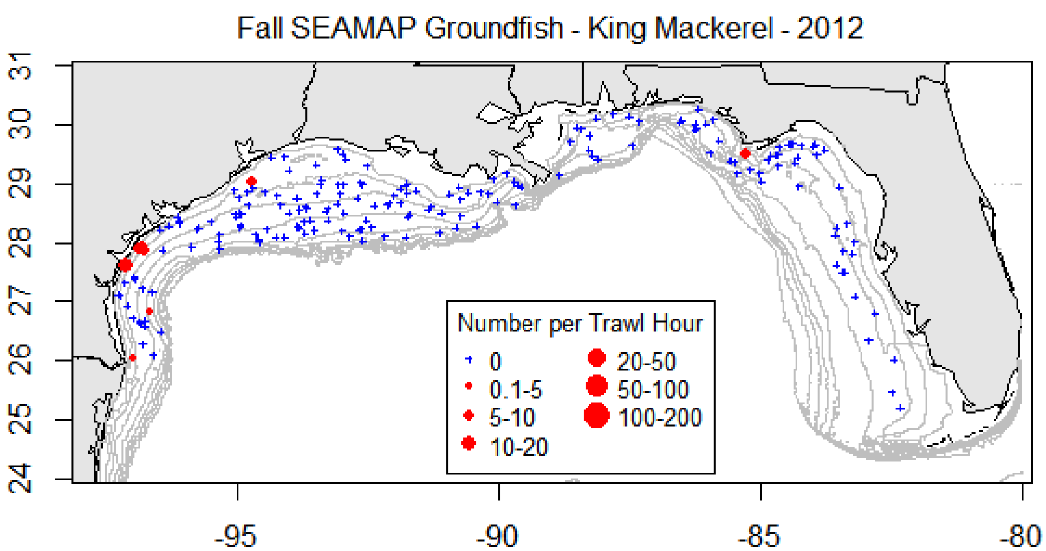


Fall SEAMAP Groundfish - King Mackerel - 2009
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80



Fall SEAMAP Groundfish - King Mackerel - 2010
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
24
25
26
27
28
29
30
31
-95
-90
-85
-80


Fall SEAMAP Groundfish - King Mackerel - 2011
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
31
30
29
28
27
26
25
24
-95
-90
-85
-80


Fall SEAMAP Groundfish - King Mackerel - 2012
Number per Trawl Hour
0
0.1-5
5-10
10-20
20-50
50-100
100-200
31
30
29
28
27
26
25
24
-95
-90
-85
-80

Addendum to SEDAR38-DW-02

During the SEDAR 38 Data Workshop, several concerns were raised regarding the relative abundance indices produced from the SEAMAP groundfish survey data. The main concern was whether the lack of coverage in the western gulf during the early years of the fall survey had an effect on the overall index. This may be warranted since occurrences and CPUE of king mackerel from this area seem to drive the overall frequency of occurrence and CPUE (Addendum Figure 1). The other concern was whether the summer survey data should be included in the index. After examining these issues, our recommendation is for a combined summer and fall index from 1987 to 2012.

The index was constructed following the methodology outlined in the main section of this document. The only difference in the methodology was the survey variable was added to the submodels.

Submodel Variables (Summer and Fall SEAMAP Groundfish Survey)

Year: 1972 – 2012
Region: Texas, West Louisiana, East Louisiana, Mississippi/Alabama
Depth: 5 – 60 (continuous)
Time of Day: Day, Night
Season: Summer, Fall
Survey: Old (1987 – 2008 (summer)), New (2008 (fall) – 2012)

For the combined (summer and fall) SEAMAP abundance index of king mackerel, the nominal CPUE and number of stations with a positive catch are presented in Addendum Figure 2. Year, region, season, survey, time of day and depth were retained in the binomial submodel. While year, region, season, time of day and depth were retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Addendum Table 1. Addendum Table 2 summarizes backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 83722.8 and 1672.2, respectively. There was a slight increase in the AIC between the two model runs for the lognormal submodel, however, since survey was not significant (P = 0.5827), this increase was deemed acceptable. The diagnostic plots for the binomial and lognormal submodels are shown in Addendum Figures 3-5, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Addendum Table 3 and Addendum Figure 6.

Addendum Table 1. Summary of the factors used in constructing the king mackerel abundance index from the Fall SEAMAP groundfish survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	1987	483	8	0.01656	0.15147
Year	1988	461	11	0.02386	0.14594
Year	1989	455	20	0.04396	0.69983
Year	1990	505	29	0.05743	0.40159
Year	1991	496	19	0.03831	0.71214
Year	1992	474	8	0.01688	0.05404
Year	1993	515	31	0.06019	0.38239
Year	1994	509	18	0.03536	0.59748
Year	1995	474	25	0.05274	0.73947
Year	1996	489	15	0.03067	0.17914
Year	1997	473	19	0.04017	0.15044
Year	1998	497	19	0.03823	0.23536
Year	1999	489	19	0.03885	0.20403
Year	2000	476	22	0.04622	0.16034
Year	2001	399	24	0.06015	0.31812
Year	2002	506	21	0.04150	0.41236
Year	2003	477	38	0.07966	0.43981
Year	2004	466	38	0.08155	0.75653
Year	2005	443	39	0.08804	0.33368
Year	2006	463	35	0.07559	0.37667
Year	2007	445	56	0.12584	0.69190
Year	2008	582	17	0.02921	0.23766
Year	2009	727	29	0.03989	0.24126
Year	2010	446	26	0.05830	0.20460
Year	2011	392	8	0.02041	0.04560
Year	2012	347	8	0.02305	0.13091
Region	ELA	3162	70	0.02214	0.22303
Region	MS	2295	53	0.02309	0.19178
Region	TX	4640	346	0.07457	0.50780
Region	WLA	2392	133	0.05560	0.35059

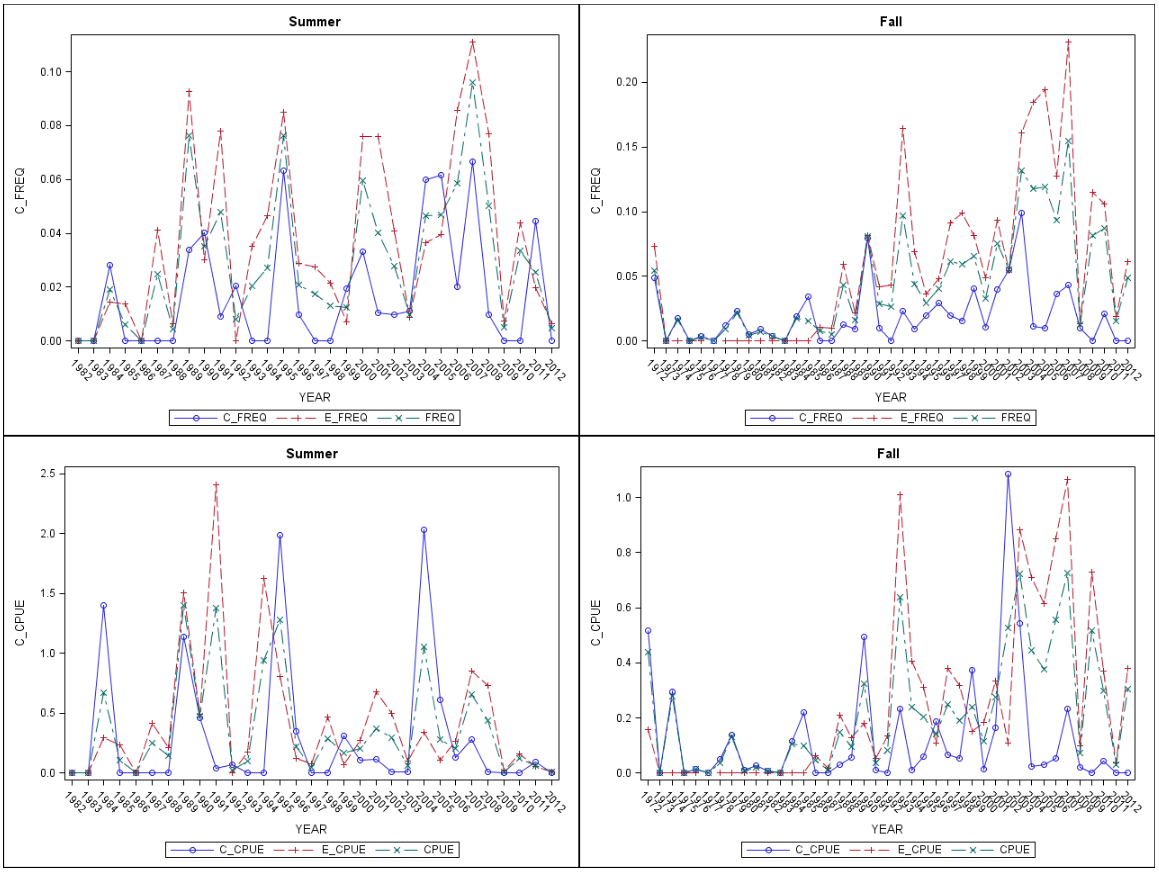
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Survey	New	2117	75	0.03543	0.16717
Survey	Old	10372	527	0.05081	0.38433
Season	Summer	6200	206	0.03323	0.39887
Season	Fall	6289	396	0.06297	0.29690
Time of Day	Day	6331	513	0.08103	0.61213
Time of Day	Night	6158	89	0.01445	0.07548

Addendum Table 2. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel combined (summer and fall) SEAMAP groundfish survey index of relative abundance from 1972 to 2012.

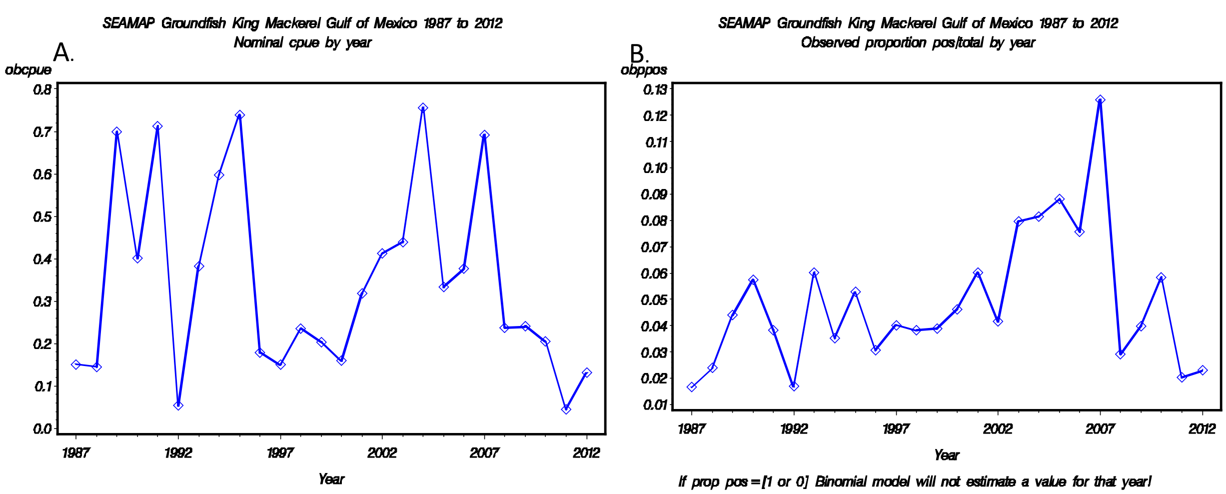
Model Run #1	*Binomial Submodel Type 3 Tests (AIC 83722.8)*						*Lognormal Submodel Type 3 Tests (AIC 1671.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	25	12456	125.35	5.01	<.0001	<.0001	25	569	1.83	0.0088
Region	3	12456	155.09	51.70	<.0001	<.0001	3	569	6.65	0.0002
Season	1	12456	64.74	64.74	<.0001	<.0001	1	569	19.11	<.0001
Survey	1	12456	4.71	4.71	0.0300	0.0300	1	569	0.30	0.5827
Time of Day	1	12456	247.15	247.15	<.0001	<.0001	1	569	4.71	0.0304
Depth	1	12456	59.18	59.18	<.0001	<.0001	1	569	89.18	<.0001
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 83722.8)*						*Lognormal Submodel Type 3 Tests (AIC 1672.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	25	12456	125.35	5.01	<.0001	<.0001	25	570	1.82	0.0094
Region	3	12456	155.09	51.70	<.0001	<.0001	3	570	6.69	0.0002
Season	1	12456	64.74	64.74	<.0001	<.0001	1	570	18.84	<.0001
Survey	1	12456	4.71	4.71	0.0300	0.0300		Dropped		
Time of Day	1	12456	247.15	247.15	<.0001	<.0001	1	570	4.84	0.0282
Depth	1	12456	59.18	59.18	<.0001	<.0001	1	570	88.99	<.0001

Addendum Table 3. Indices of king mackerel abundance developed using the delta-lognormal model for combined (summer and fall) SEAMAP groundfish survey 1972-2012. 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.

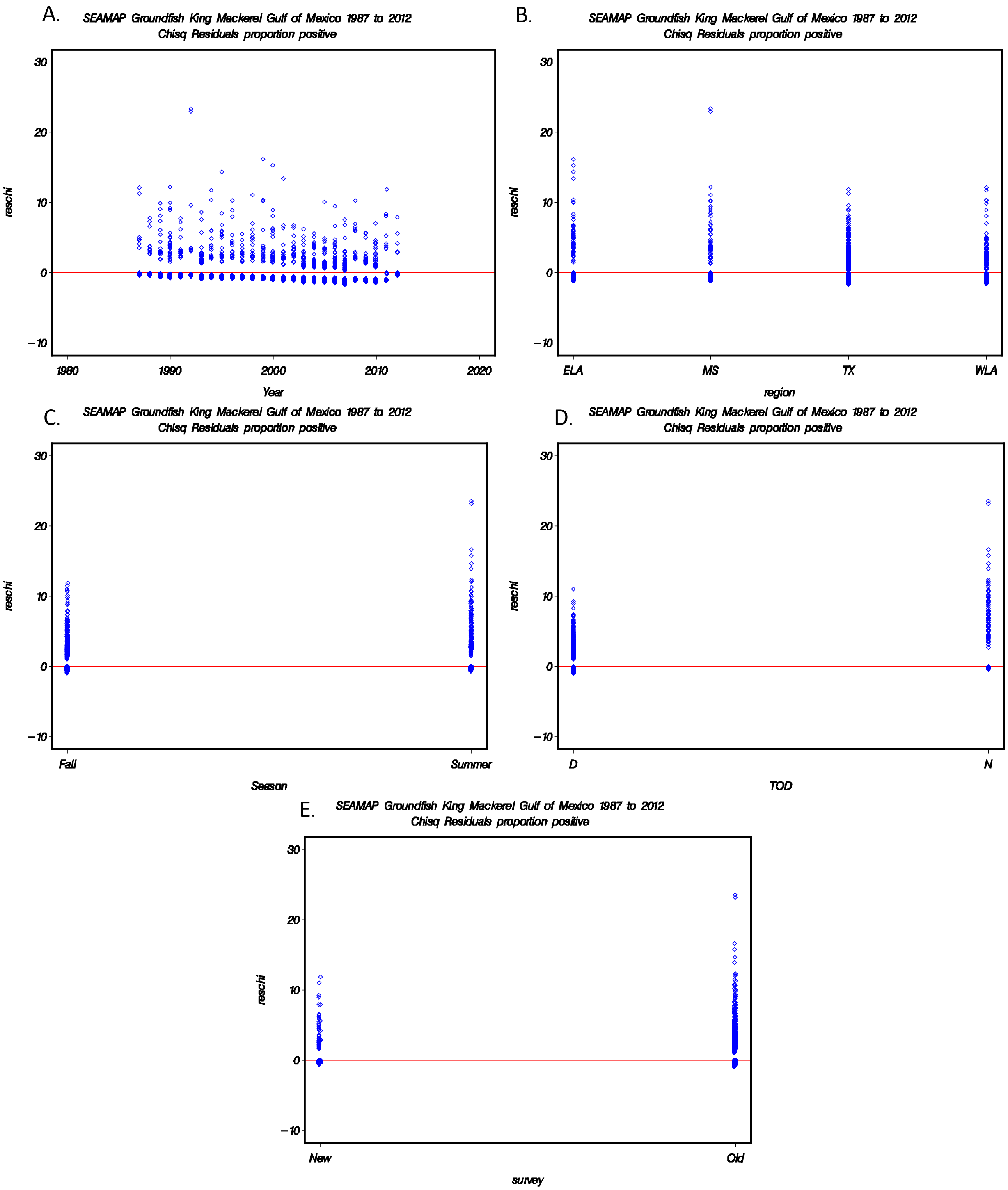
Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.01656	483	0.04673	0.48229	0.46478	0.19915	1.16800
1988	0.02386	461	0.03920	0.40458	0.41109	0.18356	0.89173
1989	0.04396	455	0.12707	1.31135	0.33307	0.68548	2.50866
1990	0.05743	505	0.10670	1.10113	0.29477	0.61819	1.96137
1991	0.03831	496	0.07400	0.76364	0.33736	0.39602	1.47250
1992	0.01688	474	0.01568	0.16177	0.46609	0.06665	0.39265
1993	0.06019	515	0.12042	1.24274	0.28791	0.70675	2.18521
1994	0.03536	509	0.08200	0.84621	0.34261	0.43462	1.64760
1995	0.05274	474	0.13597	1.40322	0.30984	0.76586	2.57102
1996	0.03067	489	0.04790	0.49432	0.36516	0.24362	1.00303
1997	0.04017	473	0.04807	0.49609	0.33684	0.25752	0.95567
1998	0.03823	497	0.07463	0.77016	0.33659	0.39997	1.48296
1999	0.03885	489	0.06541	0.67506	0.33692	0.35037	1.30064
2000	0.04622	476	0.04274	0.44107	0.32098	0.23578	0.82508
2001	0.06015	399	0.11955	1.23375	0.31366	0.66857	2.27670
2002	0.04150	506	0.07705	0.79513	0.32552	0.42149	1.50002
2003	0.07966	477	0.14296	1.47532	0.27345	0.86227	2.52425
2004	0.08155	466	0.15820	1.63262	0.27274	0.95549	2.78961
2005	0.08804	443	0.10099	1.04223	0.27150	0.61139	1.77666
2006	0.07559	463	0.09957	1.02754	0.27889	0.59440	1.77630
2007	0.12584	445	0.22714	2.34401	0.24590	1.44378	3.80556
2008	0.02921	582	0.08546	0.88188	0.30241	0.48805	1.59351
2009	0.03989	727	0.15832	1.63387	0.25861	0.98224	2.71780
2010	0.05830	446	0.17300	1.78536	0.29441	1.00300	3.17800
2011	0.02041	392	0.04408	0.45485	0.45941	0.18957	1.09134
2012	0.02305	347	0.10657	1.09981	0.45969	0.45816	2.64011



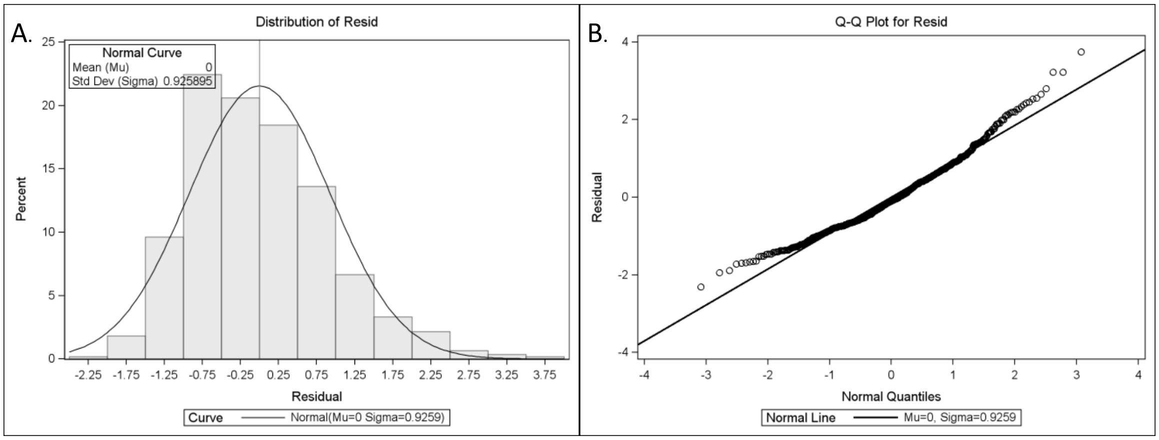
Addendum Figure 1. Frequency of occurrence (top) and CPUE (bottom) for king mackerel from the summer and fall SEAMAP groundfish survey for the core survey area (blue, 87 to 92 degrees west), expanded survey area (red, west of 92 degrees) and combined survey areas (green).



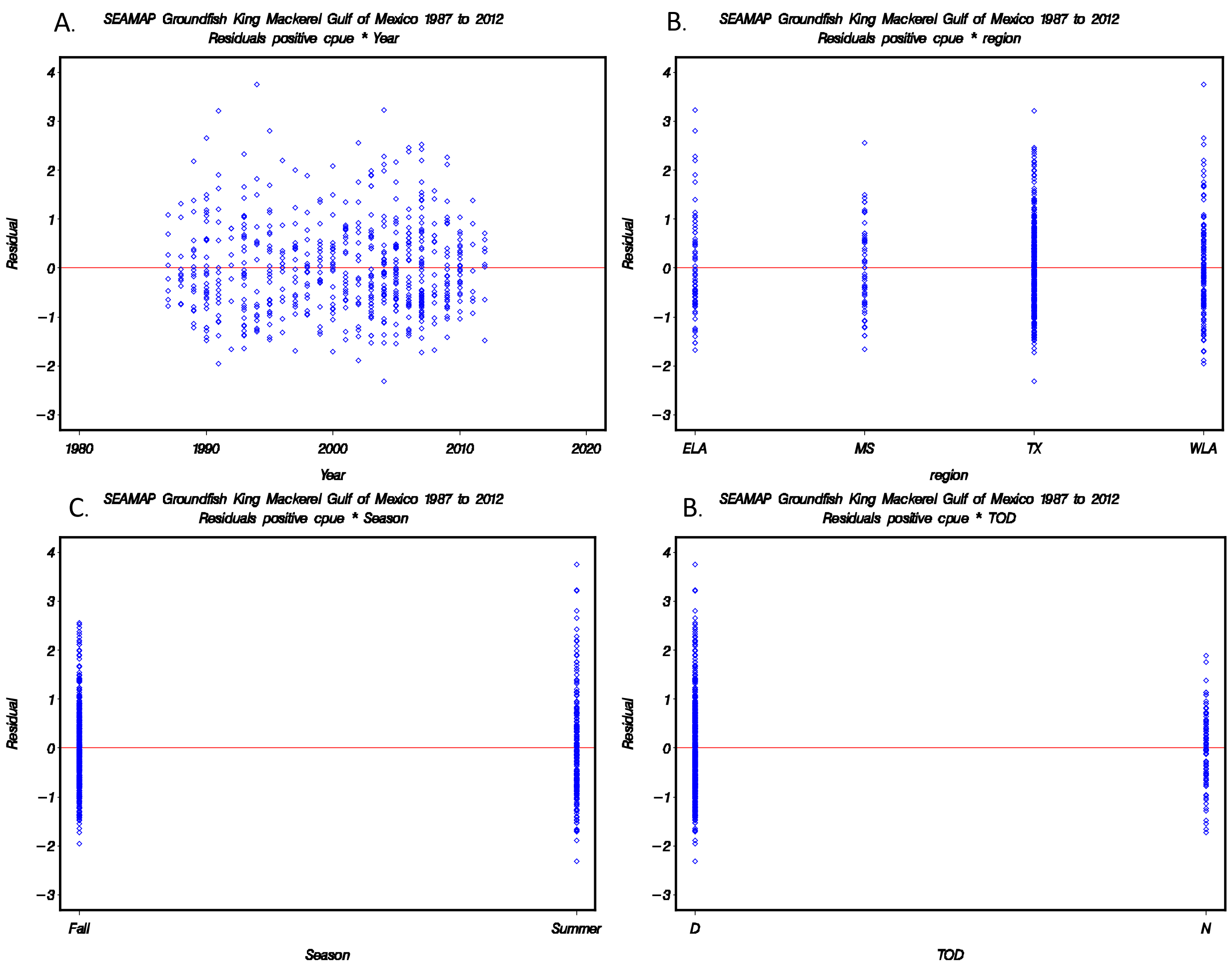
Addendum Figure 2. Annual trends for king mackerel captured during combined (summer and fall) SEAMAP Groundfish Surveys from 1987 to 2012 in **A.** nominal CPUE and **B.** proportion of positive stations.



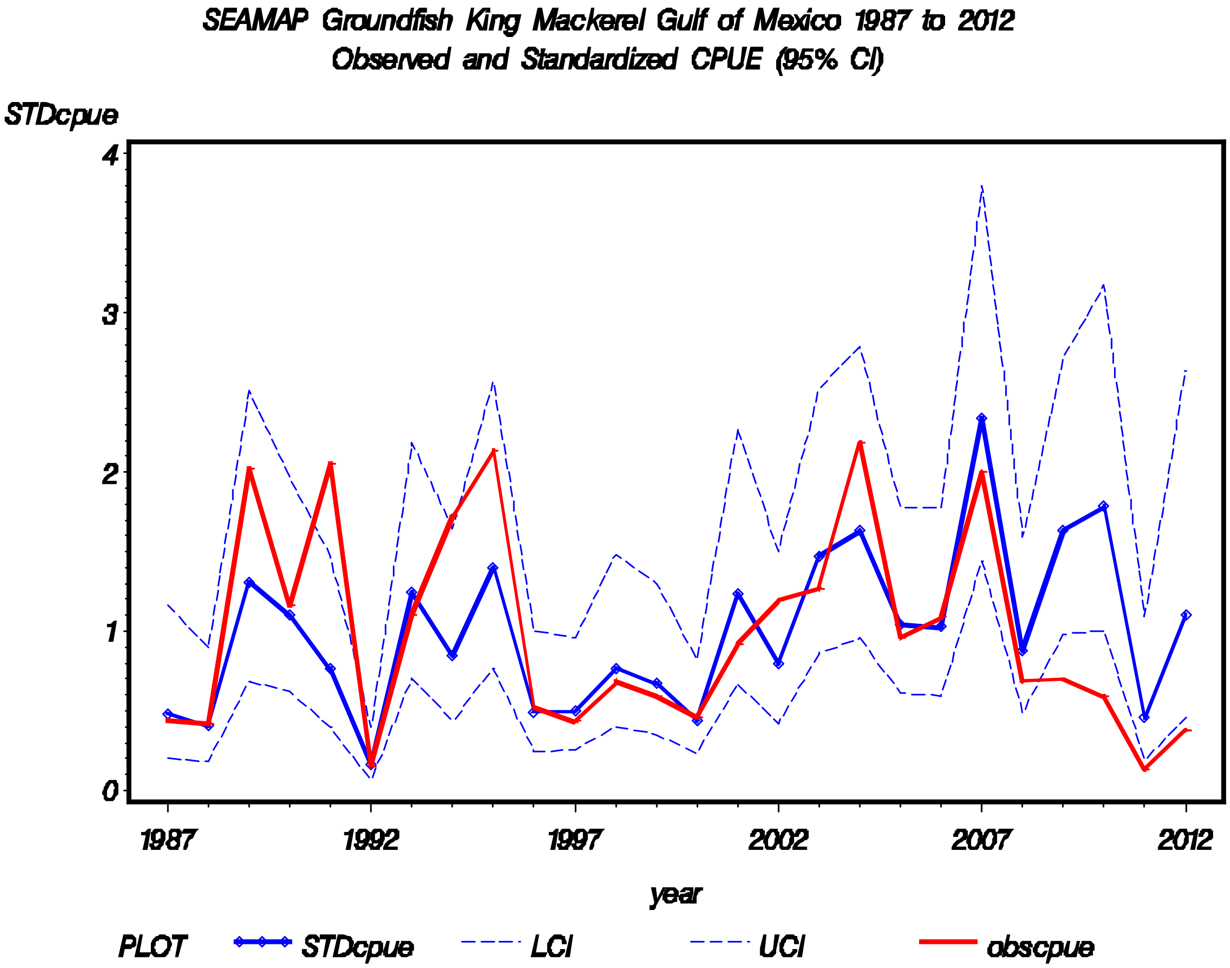
Addendum Figure 3. Diagnostic plots for binomial component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, **C.** the Chi-Square residuals by season, **D.** the Chi-Square residuals by time of day and **E.** the Chi-Square residuals by survey.



Addendum Figure 4. Diagnostic plots for lognormal component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).



Addendum Figure 5. Diagnostic plots for lognormal component of the king mackerel combined (summer and fall) SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, **C.** the Chi-Square residuals by season and **D.** the Chi-Square residuals by time of day.



Addendum Figure 6. Annual index of abundance for king mackerel from the combined (summer and fall) SEAMAP Groundfish Survey from 1987 – 2012.