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

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Abstract

The Southeast Fisheries Science Center Mississippi Laboratories 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 bonnethead (Sphyrna tiburo). Separate indices were produced using the summer and fall SEAMAP groundfish survey data. Annual abundance indices were more variable in the early years of the index; subsequently in more recent years they appear to show very little variation. Additionally, age 0 sharks were not able to be separated out due to the lack of lengths from the early years of the survey. With the low catches of bonnethead in the summer survey, caution should be exercised before using this index in the stock assessment.

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories has 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 bonnethead (*Sphyrna tiburo*).

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.

Data

A total of 17,919 stations were sampled from 1972- 2011, with 7437 and 10,482 stations sampled during the summer and fall survey, respectively (Tables 1 and 2). Data was limited to only those stations that did not indicate a problem with the tow. Additionally, any stations in shrimp statistical zone 12, or stations that were outside the range of 5 to 60 fathoms were excluded from analysis. Trawl data was obtained from the MSLABS trawl unit leader (Gilmore Pellegrin) and combined with data from the Gulf States Marine Fisheries Commission database, which contains data collected by state agencies/partners from Alabama, Florida, Louisiana and Mississippi. 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).

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for Bonnethead (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) $$\mathrm{Cov}(c, p) \approx \rho_{c,p}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

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 $\alpha = 0.05$. 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 for the summer and fall surveys were:

Submodel Variables (Summer SEAMAP Groundfish Survey)

Year: 1982 – 2011
Area: Texas, Louisiana, Mississippi/Alabama, Florida
Depth: 5 – 60 (continuous)
Time of Day: Day, Night

Submodel Variables (Fall SEAMAP Groundfish Survey)

Year: 1972 – 2011
Region: Texas, West Louisiana, East Louisiana, Mississippi/Alabama, West Florida, East Florida (Figure 1)
Depth: 5 – 60 (continuous)
Time of Day: Day, Night

The difference in the area variables between the summer and fall survey 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.

Results and Discussion

The distribution of bonnethead is presented in Figure 2, with seasonal/annual abundance and distribution presented in the Appendix Figure 1. The total number of bonnethead captured ranged from 0 to 9 in the summer (Table 3) and 0 to 66 in the fall (Table 4). Of the 75 bonnethead captured during the summer survey, a total of 69 were measured from 1988 – 2011 with an average total length of 761 mm. While during the fall survey 735 bonnethead were captured, with 383 measured, with an average total length of 522 mm. The length frequency distribution of bonnethead captured is shown in Figure 3.

For the Summer SEAMAP abundance index of bonnethead, the nominal CPUE and number of stations with a positive catch are presented in Figure 4. Year, time of day and depth were retained in the binomial submodel while year was retained in the lognormal submodel. Table 5 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 40,513.5 and 83.1, respectively. With the removal of the area variable the AIC increased substantially from 32,310.3 to 40,513.5. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 5-7, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 6 and Figure 8. With the low catches of bonnethead in the summer survey, caution should be exercised before using this index in the stock assessment.

For the Fall SEAMAP abundance index of bonnethead, the nominal CPUE and number of stations with a positive catch are presented in Figure 9. Year, area, time of day and depth were retained in both the binomial and lognormal submodels. Table 7 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 67,707.5 and 824.2, respectively. Even though the AIC increased from the third to fourth run in the lognormal submodel, it was acceptable since the region was not significant (p = 0.1488). The diagnostic plots for the binomial and lognormal submodels are shown in Figures 10-12, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 8 and Figure 13.

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Table 1. Number of stations sampled by shrimp statistical zone during the Summer SEAMAP groundfish survey from 1982-2011.

	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	38	24	26	8	1	11	30	10	3	23	*188*
1983							5	19	8	27		6	16	19	25	24	21	5	17	*192*
1984									13	40	10	16	16	22	17	15	23	28	14	*214*
1985									10	51	11	31	12	10	7	7	12	11	10	*172*
1986									18	49	6	21	14	8	11	8	11	14	6	*166*
1987									28	61	8	34	23	25	20	16	25	28	19	*287*
1988									18	48	10	16	9	19	24	14	25	28	23	*234*
1989									23	30	8	13	20	25	7	15	20	29	24	*214*
1990										68	18	32	17	23	16	20	23	24	20	*261*
1991										46	16	41	15	23	22	24	18	23	26	*254*
1992									1	45	2	36	30	20	25	12	31	26	20	*248*
1993										45	22	29	19	24	19	14	29	24	22	*247*
1994										61	14	27	28	25	17	20	22	26	22	*262*
1995										44	12	26	24	22	23	13	27	26	21	*238*
1996										46	14	34	21	22	18	17	21	26	25	*244*
1997										44	4	26	22	22	23	10	28	26	26	*231*
1998										35	6	28	27	25	18	14	22	36	17	*228*
1999										44	11	31	27	20	23	13	25	32	20	*246*
2000										45	13	27	19	19	27	8	29	31	21	*239*
2001										36	15	24	28	13	3	10	9	17	21	*176*
2002										44	15	34	21	27	19	15	25	29	22	*251*
2003										44	17	26	8	2	17	20	22	26	23	*205*
2004										39	19	28	23	20	25	21	19	25	21	*240*
2005										32	10	9	23	16	21	5	28	22	27	*193*
2006										45	17	29	16	20	23	17	23	31	18	*239*
2007										41	12	10	23	22	23	7	29	32	21	*220*
2008			1	8	11	6	11	8	11	43	24	19	27	23	22	17	24	21	29	*305*
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*
Total	*11*	*55*	*85*	*72*	*95*	*34*	*60*	*70*	*191*	*1296*	*375*	*733*	*605*	*601*	*614*	*522*	*679*	*726*	*613*	*7437*

Table 2. Number of stations sampled by shrimp statistical zone during the Fall SEAMAP groundfish survey from 1972-2011.

	Shrimp Statistical Zone																			
Year	2	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	76	23	39	53	32	10	20	20	19	19	*341*
1986							20	10	25	37	13	29	14	27	35	26	23	22	21	*302*
1987									13	23	30	29	30	17	15	15	15	18	3	*208*
1988									8	28	10	31	24	18	26	19	21	31	20	*236*
1989										43	18	31	23	22	20	17	22	25	26	*247*
1990										52	20	24	27	22	19	18	22	19	27	*250*
1991										46	16	32	18	20	25	24	19	25	22	*247*
1992										33	15	33	14	25	18	17	27	30	18	*230*
1993										72	14	35	21	26	18	16	25	28	18	*273*
1994										50	19	24	27	25	20	21	23	24	20	*253*
1995										40	14	29	26	24	19	14	26	30	19	*241*
1996										45	11	36	23	17	28	13	25	29	24	*251*
1997										44	18	31	22	26	19	18	23	22	24	*247*
1998										44	30	50	14	34	11	15	24	29	22	*273*
1999										42	10	40	18	29	18	12	28	29	22	*248*
2000										43	10	29	28	20	26	12	30	25	21	*244*
2001										21	14	31	23	26	20	14	27	28	23	*227*
2002									1	51	16	27	26	22	23	14	26	30	21	*257*
2003									1	76	20	20	21	24	22	20	23	25	23	*275*
2004										43	6	23	24	17	27	14	24	30	21	*229*
2005										44	21	32	18	33	18	14	23	24	27	*254*
2006									1	47	7	22	14	18	28	13	23	32	19	*224*
2007										31	15	29	26	18	28	17	20	18	26	*228*
2008				15	14	4	4	3	4	35	18	28	34	42	46	44	19	36	20	*366*
2009			20	21	25	11	21	13	12	48	12	23	23	30	49	47	31	36	22	*444*
2010			9	27	27	18	16	11	14	16	7	15	18	26	31	29	18	19	14	*315*
2011							9	11	6	14	6	15	17	27	31	28	21	19	15	*219*
Total	*0*	*0*	*29*	*63*	*66*	*33*	*70*	*59*	*273*	*2333*	*845*	*1681*	*1162*	*793*	*657*	*531*	*628*	*702*	*557*	*10482*

Table 3. Summary of the bonnethead length data collected during Summer SEAMAP groundfish surveys conducted between 1987 and 2011. (Note that prior to 1988, no length data for bonnethead is available.)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Total Length (mm)	Maximum Total Length (mm)	Mean Total Length (mm)	Standard Deviation
1982	188	0					
1983	192	1					
1984	214	0					
1985	172	1					
1986	166	0					
1987	287	1					
1988	234	0					
1989	214	0					
1990	261	2	2	585	595	590	7
1991	254	0					
1992	248	1	1	1040	1040	1040	
1993	247	3	2	900	1000	950	71
1994	262	0					
1995	238	7	6	570	770	631	73
1996	244	5	4	509	874	705	163
1997	231	3	3	575	835	664	148
1998	228	0					
1999	246	3	3	154	677	477	283
2000	239	0					
2001	176	1	1	675	675	675	
2002	251	0					
2003	205	1	1	568	568	568	
2004	240	4	4	565	999	873	207
2005	193	2	2	553	620	587	47
2006	239	5	5	580	915	783	148
2007	220	5	5	275	950	663	265
2008	305	9	9	567	1079	898	141
2009	534	8	8	785	1079	947	85
2010	379	9	9	508	915	723	165
2011	330	4	4	687	940	769	115

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Total Length (mm)	
30	7437	75	69			761	

Table 4. Summary of the bonnethead length data collected during and Fall SEAMAP groundfish surveys conducted between 1987 and 2011. (Note that prior to 1988, no length data for bonnethead is available.)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Total Length (mm)	Maximum Total Length (mm)	Mean Total Length (mm)	Standard Deviation
1972	184	21					
1973	272	66					
1974	243	35					
1975	280	21					
1976	307	45					
1977	242	24					
1978	319	15					
1979	273	25					
1980	233	9					
1981	279	7					
1982	273	6					
1983	222	4					
1984	226	0					
1985	341	2					
1986	302	13					
1987	208	6					
1988	236	11	5	338	968	693	293
1989	247	3	3	410	425	416	8
1990	250	15	12	390	1014	687	240
1991	247	15	13	408	1005	488	157
1992	230	10	9	314	1064	484	223
1993	273	13	13	357	1075	541	242
1994	253	7	7	332	1040	500	241
1995	241	6	5	394	988	654	253
1996	251	13	13	364	1062	604	284
1997	247	11	11	418	833	553	160
1998	273	7	6	382	438	415	21
1999	248	12	12	401	500	445	30
2000	244	10	9	395	996	538	209
2001	227	14	14	365	1220	571	278
2002	257	19	10	400	1040	554	231
2003	275	19	16	333	900	415	135
2004	229	27	27	333	793	496	148
2005	254	41	26	318	1100	497	232
2006	224	19	19	360	1177	509	213
2007	228	34	31	305	1125	581	272
2008	366	33	33	274	1041	551	248
2009	444	56	56	313	987	510	206
2010	315	19	16	333	1010	489	224
2011	219	22	17	357	912	416	129
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Total Length (mm)	
40	10,482	735	383			522	

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for bonnethead Summer SEAMAP groundfish survey index of relative abundance from 1982 to 2011.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 32310.3)*						*Lognormal Submodel Type 3 Tests (AIC 86.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	4197	12.67	0.67	0.8549	0.8546	19	27	0.71	0.7815
Time of Day	1	4197	17.95	17.95	<.0001	<.0001	1	27	0.27	0.6080
Area	2	4197	5.68	2.84	0.0584	0.0586	2	27	0.09	0.9149
Depth	1	4197	18.55	18.55	<.0001	<.0001	1	27	1.84	0.1862
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 40513.5)*						*Lognormal Submodel Type 3 Tests (AIC 86.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	5165	14.17	0.75	0.7734	0.7732	19	29	0.75	0.7411
Time of Day	1	5165	17.79	17.79	<.0001	<.0001	1	29	0.27	0.6054
Area				Dropped				Dropped		
Depth	1	5165	17.52	17.52	<.0001	<.0001	1	29	2.16	0.1526
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 40513.5)*						*Lognormal Submodel Type 3 Tests (AIC 86.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	5165	14.17	0.75	0.7734	0.7732	19	30	0.78	0.7150
Time of Day	1	5165	17.79	17.79	<.0001	<.0001		Dropped		
Area				Dropped				Dropped		
Depth	1	5165	17.52	17.52	<.0001	<.0001	1	30	2.94	0.0967
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 40513.5)*						*Lognormal Submodel Type 3 Tests (AIC 83.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	5165	14.17	0.75	0.7734	0.7732	19	31	0.82	0.6734
Time of Day	1	5165	17.79	17.79	<.0001	<.0001		Dropped		
Area				Dropped				Dropped		
Depth	1	5165	17.52	17.52	<.0001	<.0001		Dropped		

Table 6. Indices of Bonnethead abundance developed using the delta-lognormal model for Summer SEAMAP groundfish survey from 1982-2011. 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
1982	0	188					
1983	0.005208	192	0.014950	0.81755	0.85708	0.18531	3.60684
1984	0	214					
1985	0.005814	172	0.023383	1.27870	0.85860	0.28925	5.65278
1986	0	166					
1987	0.003484	287	0.012535	0.68545	0.86000	0.15477	3.03585
1988	0	234					
1989	0	214					
1990	0.003831	261	0.004462	0.24403	0.86014	0.05509	1.08100
1991	0	254					
1992	0.004032	248	0.004834	0.26437	0.85943	0.05974	1.16998
1993	0.008097	247	0.011902	0.65088	.	.	.
1994	0	262					
1995	0.012605	238	0.025976	1.42047	0.51486	0.53857	3.74646
1996	0.012295	244	0.013167	0.72002	0.51456	0.27313	1.89807
1997	0.008658	231	0.018893	1.03316	0.62096	0.32971	3.23744
1998	0	228					
1999	0.012195	246	0.021862	1.19550	0.51445	0.45359	3.15091
2000	0	239					
2001	0.005682	176	.	.	.	.	.
2002	0	251					
2003	0.004878	205	.	.	.	.	.
2004	0.008333	240	0.018563	1.01513	0.62152	0.32368	3.18369
2005	0.010363	193	0.008680	0.47467	0.62314	0.15097	1.49248
2006	0.016736	239	0.024031	1.31413	0.45098	0.55579	3.10719
2007	0.022727	220	0.019021	1.04014	0.40772	0.47476	2.27882
2008	0.016393	305	0.040036	2.18934	0.40660	1.00129	4.78703
2009	0.007491	534	0.016553	0.90521	0.45119	0.38270	2.14111
2010	0.013193	379	0.031587	1.72735	0.40460	0.79283	3.76341
2011	0.012121	330	0.018724	1.02389	0.44956	0.43411	2.41499

Table 7. Summary of backward selection procedure for building delta-lognormal submodels for Bonnethead Fall SEAMAP groundfish survey index of relative abundance from 1972 to 2011.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 67707.5)*						*Lognormal Submodel Type 3 Tests (AIC 824.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	38	1E4	194.07	5.11	<.0001	<.0001	38	352	2.08	0.0003
Time of Day	1	1E4	72.88	72.88	<.0001	<.0001	1	352	1.72	0.1899
Region	5	1E4	143.36	28.67	<.0001	<.0001	5	352	1.65	0.1463
Depth	1	1E4	102.31	102.31	<.0001	<.0001	1	352	6.56	0.0109
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 67707.5)*						*Lognormal Submodel Type 3 Tests (AIC 823.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	38	1E4	194.07	5.11	<.0001	<.0001	38	353	2.15	0.0002
Time of Day	1	1E4	72.88	72.88	<.0001	<.0001	Dropped			
Region	5	1E4	143.36	28.67	<.0001	<.0001	5	353	1.64	0.1488
Depth	1	1E4	102.31	102.31	<.0001	<.0001	1	353	5.78	0.0167
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 67707.5)*						*Lognormal Submodel Type 3 Tests (AIC 824.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	38	1E4	194.07	5.11	<.0001	<.0001	38	358	2.99	<.0001
Time of Day	1	1E4	72.88	72.88	<.0001	<.0001	Dropped			
Region	5	1E4	143.36	28.67	<.0001	<.0001	Dropped			
Depth	1	1E4	102.31	102.31	<.0001	<.0001	1	358	7.79	0.0055

Table 8. Indices of Bonnethead abundance developed using the delta-lognormal model for Fall SEAMAP groundfish survey 1972-2011. 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	0.06522	184	0.20677	2.14642	0.39578	1.00086	4.6031
1973	0.09191	272	0.56700	5.88583	0.28902	3.34028	10.3713
1974	0.06996	243	0.42633	4.42556	0.34423	2.26623	8.6423
1975	0.04286	280	0.11745	1.21922	0.40455	0.55966	2.6561
1976	0.07166	307	0.35887	3.72532	0.31405	2.01730	6.8795
1977	0.04545	242	0.21262	2.20714	0.41479	0.99483	4.8968
1978	0.03448	319	0.11821	1.22707	0.41564	0.55224	2.7265
1979	0.02564	273	0.17781	1.84577	0.50558	0.71084	4.7927
1980	0.02146	233	0.09410	0.97677	0.58524	0.32991	2.8919
1981	0.02509	279	0.08084	0.83921	0.50638	0.32276	2.1820
1982	0.02198	273	0.06170	0.64044	0.54016	0.23281	1.7618
1983	0.01802	222	0.06599	0.68498	0.64936	0.20916	2.2433
1984	0.00000	226	.	.	.	.	.
1985	0.00587	341	0.01117	0.11598	0.89481	0.02502	0.5377
1986	0.02980	302	0.09418	0.97765	0.45022	0.41402	2.3086
1987	0.02404	208	0.02187	0.22698	0.58908	0.07619	0.6762
1988	0.02542	236	0.03992	0.41436	0.54469	0.14950	1.1484
1989	0.01215	247	0.01283	0.13321	0.74368	0.03534	0.5022
1990	0.02400	250	0.03412	0.35415	0.54415	0.12789	0.9807
1991	0.03239	247	0.02359	0.24490	0.48104	0.09834	0.6099
1992	0.02609	230	0.02360	0.24496	0.54491	0.08835	0.6792
1993	0.02930	273	0.03113	0.32315	0.47966	0.13006	0.8029
1994	0.01976	253	0.02864	0.29729	0.59007	0.09964	0.8870
1995	0.01660	241	0.02065	0.21439	0.65275	0.06512	0.7058
1996	0.04382	251	0.04754	0.49350	0.42052	0.22019	1.1061
1997	0.03239	247	0.03171	0.32915	0.48103	0.13216	0.8197
1998	0.02564	273	0.01870	0.19416	0.50848	0.07441	0.5066
1999	0.03226	248	0.02803	0.29094	0.48061	0.11691	0.7240
2000	0.03689	244	0.02512	0.26073	0.45702	0.10912	0.6230
2001	0.03524	227	0.03063	0.31797	0.48184	0.12750	0.7930
2002	0.03502	257	0.05636	0.58507	0.45691	0.24491	1.3977
2003	0.03273	275	0.05821	0.60430	0.45606	0.25333	1.4415
2004	0.03057	229	0.06763	0.70208	0.50975	0.26849	1.8359
2005	0.07087	254	0.05384	0.55884	0.34622	0.28512	1.0953

2006	0.04911	224	0.04223	0.43837	0.42124	0.19534	0.9838
2007	0.10088	228	0.10683	1.10896	0.31600	0.59834	2.0553
2008	0.06557	366	0.10954	1.13711	0.30163	0.63022	2.0517
2009	0.04730	444	0.10319	1.07119	0.30912	0.58543	1.9600
2010	0.03810	315	0.06680	0.69345	0.38886	0.32739	1.4688
2011	0.05479	219	0.08125	0.84340	0.39761	0.39198	1.8147

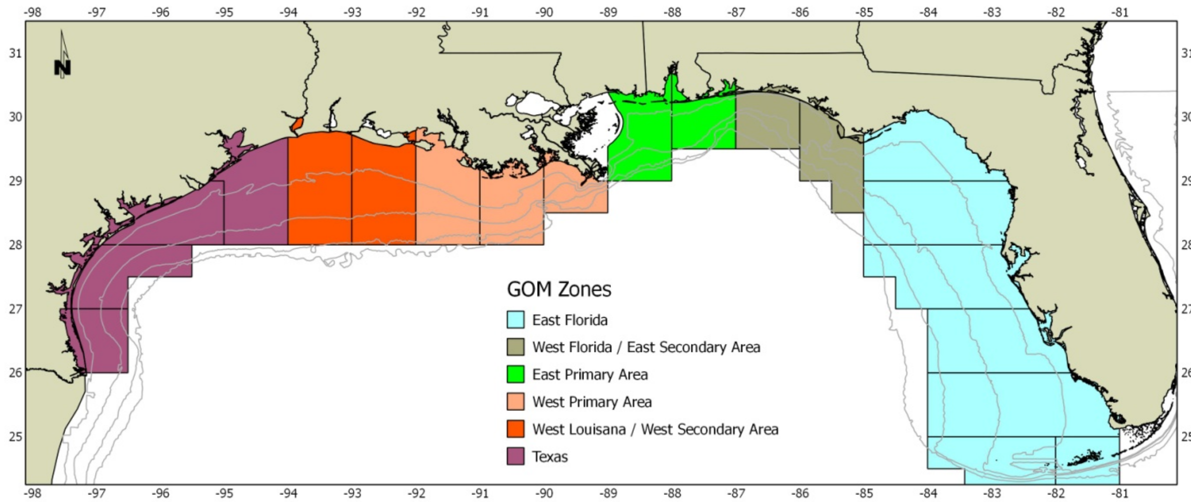


Figure 1. Combined areas for the Fall SEAMAP groundfish survey.

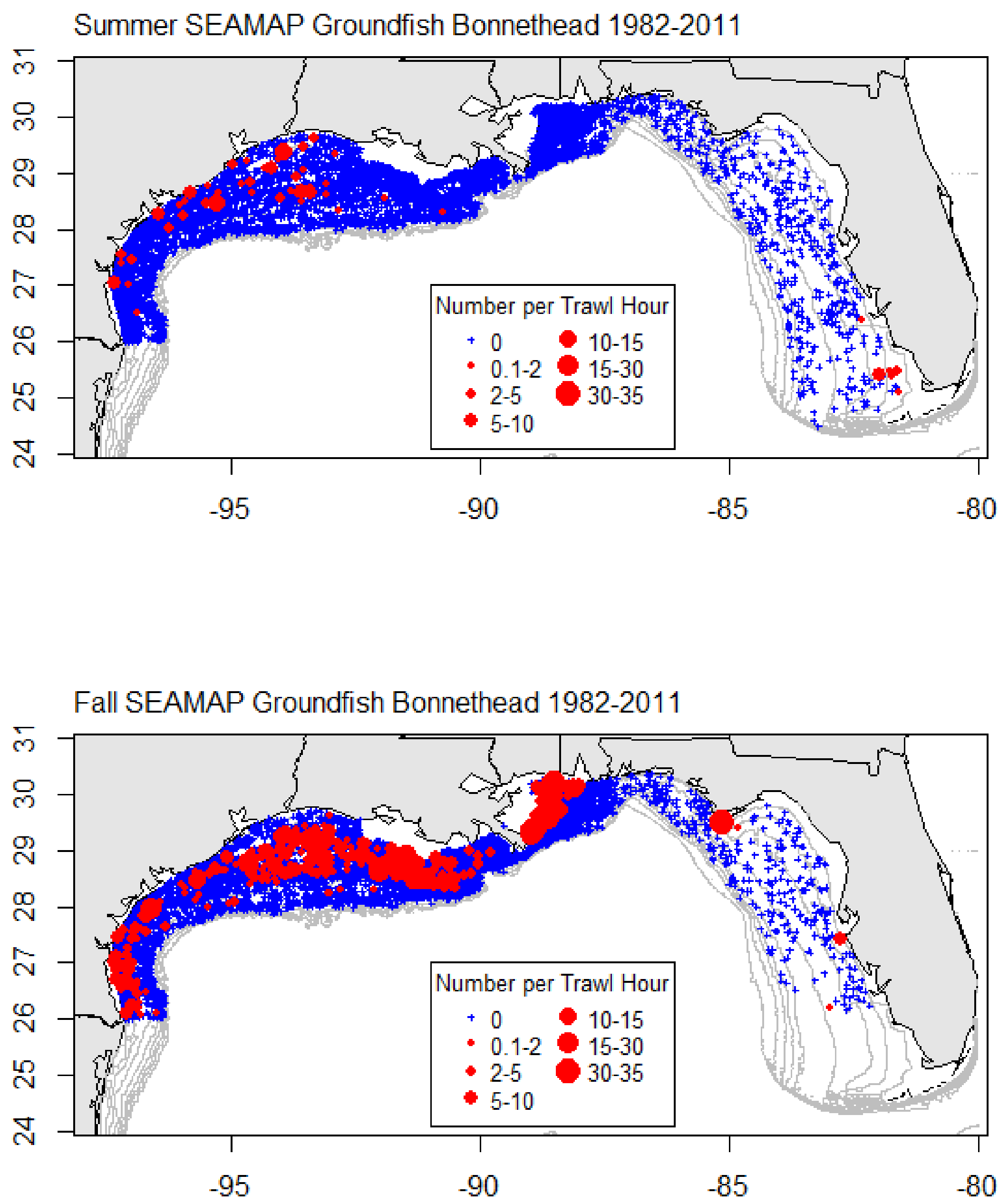
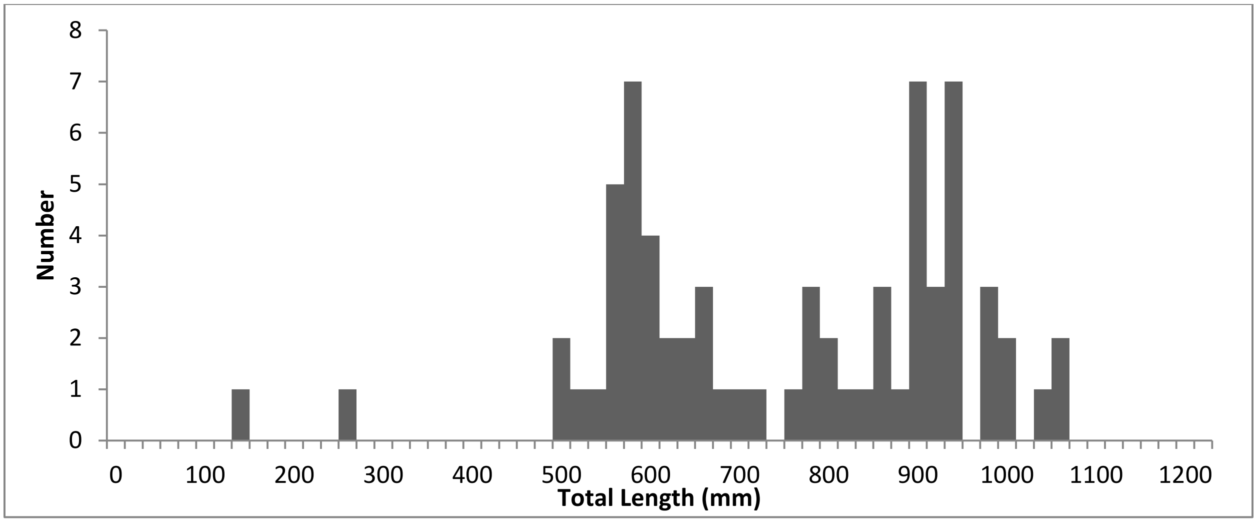


Figure 2. Stations sampled from 1987 to 2011 during the Summer (top), Fall (middle) and overall (bottom) SEAMAP Groundfish Survey with the CPUE for Bonnethead.



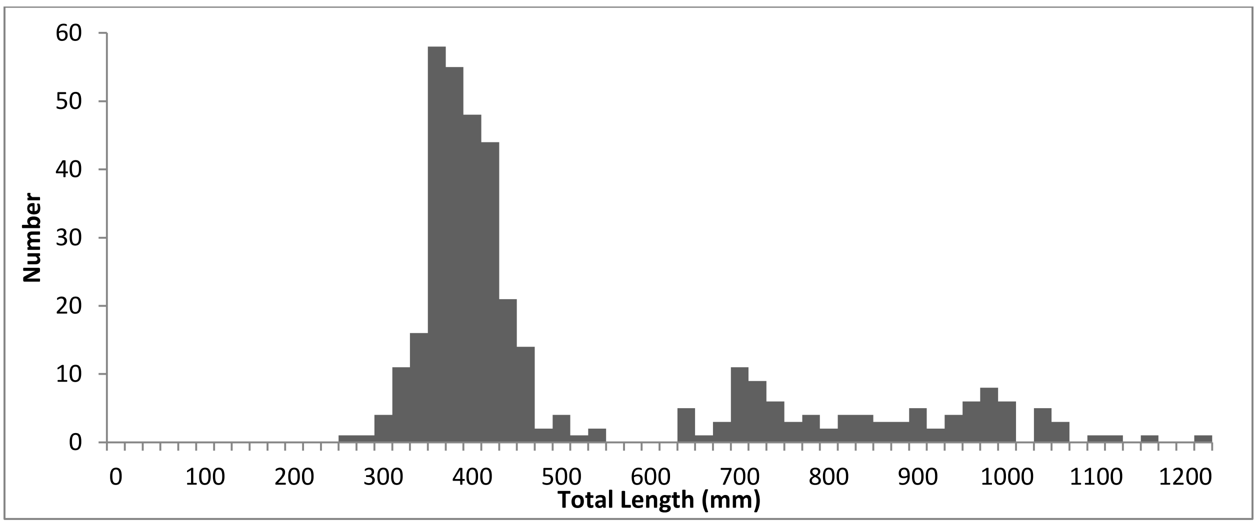


Figure 3. Length frequency histograms for Bonnethead captured in the Gulf of Mexico during the Summer (top) and Fall (bottom) SEAMAP Groundfish surveys from 1988-2010.

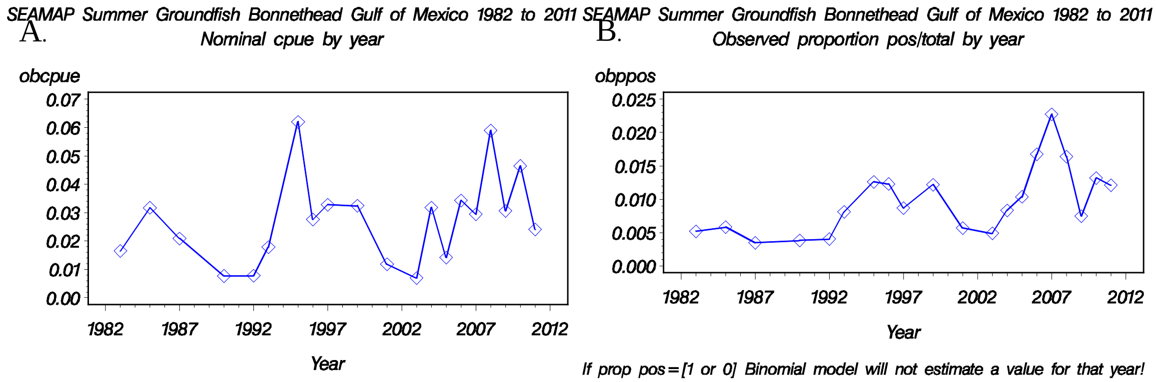


Figure 4. Annual trends for bonnethead captured during Summer SEAMAP Groundfish Surveys from 1982 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

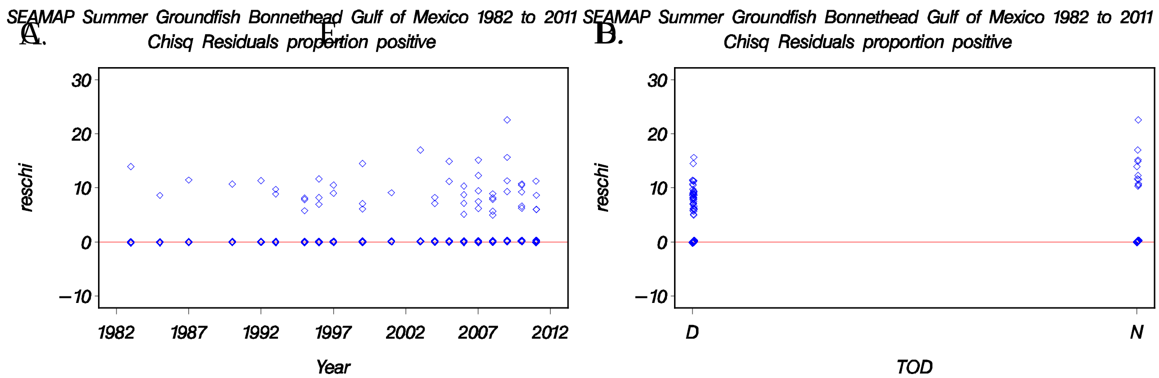


Figure 5. Diagnostic plots for binomial component of the bonnethead Summer SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year and **B.** the Chi-Square residuals by time of day.

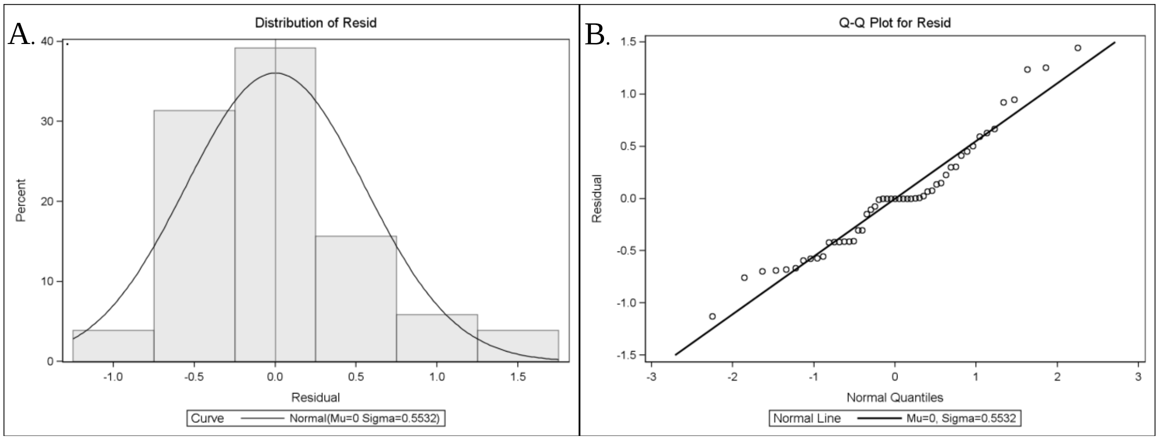


Figure 6. Diagnostic plots for lognormal component of the bonnethead Summer SEAMAP Groundfish Survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

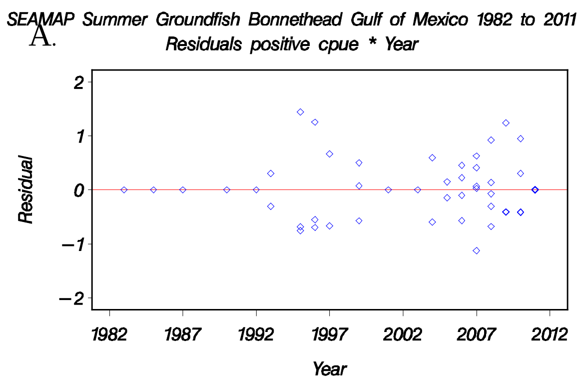


Figure 7. Diagnostic plots for lognormal component of the Bonnethead SEAMAP Groundfish Survey (GOM / all ages) model: **A.** the Chi-Square residuals by year.

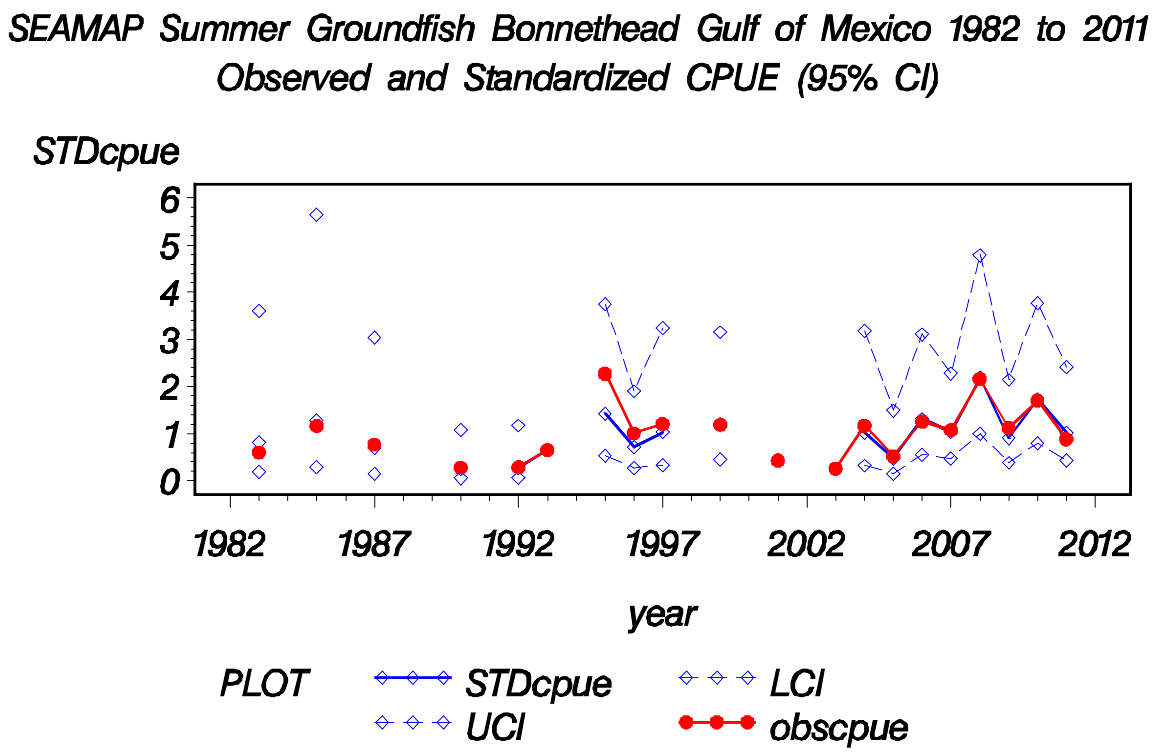


Figure 8. Annual index of abundance for bonnethead from the Summer SEAMAP Groundfish Survey from 1982 – 2011.

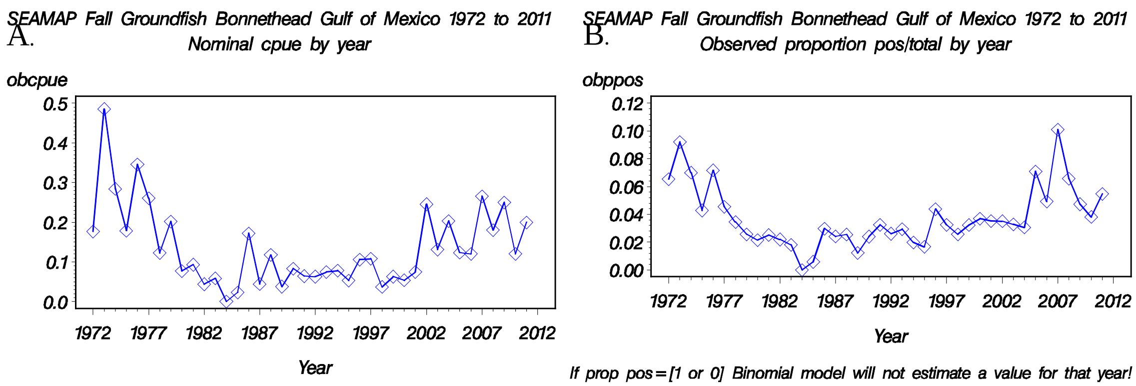


Figure 9. Annual trends for bonnethead captured during Fall SEAMAP Groundfish Surveys from 1972 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

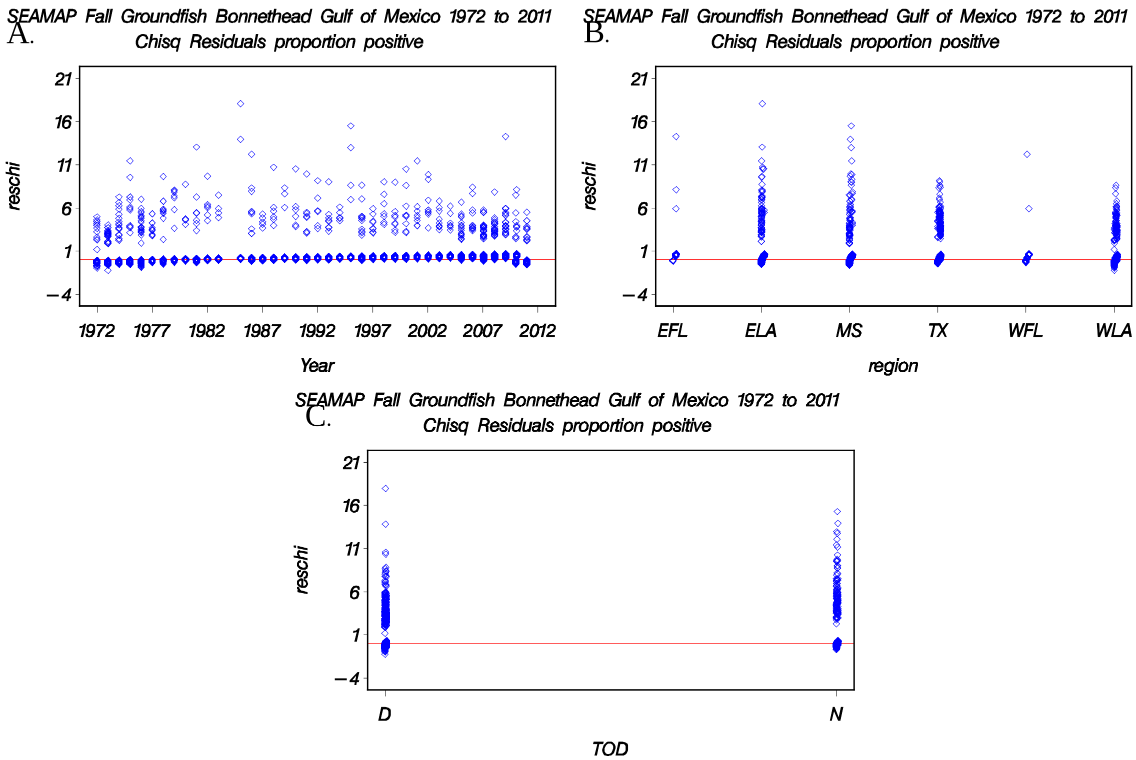


Figure 10. Diagnostic plots for binomial component of the Bonnethead SEAMAP Groundfish Survey (GOM / all ages) model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, and **C.** the Chi-Square residuals by time of day.

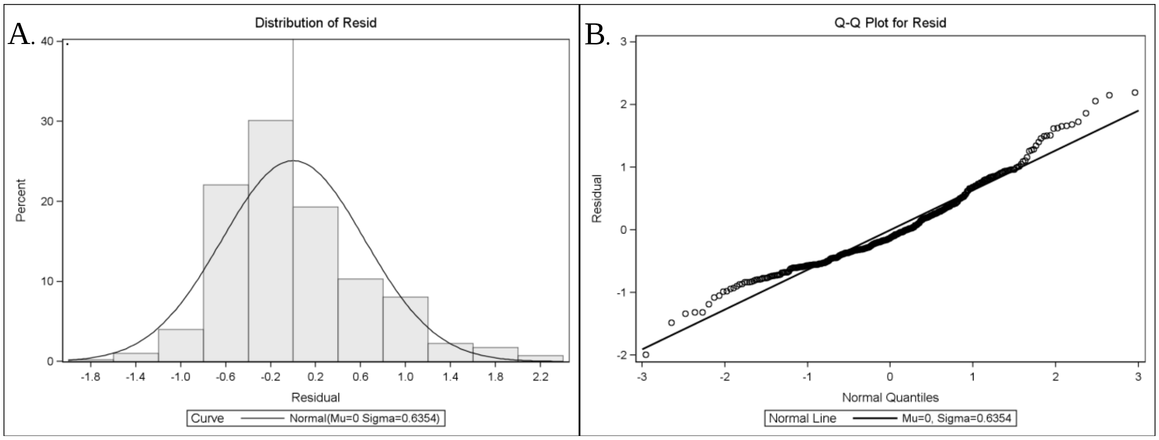


Figure 11. Diagnostic plots for lognormal component of the bonnethead Fall SEAMAP Groundfish Survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

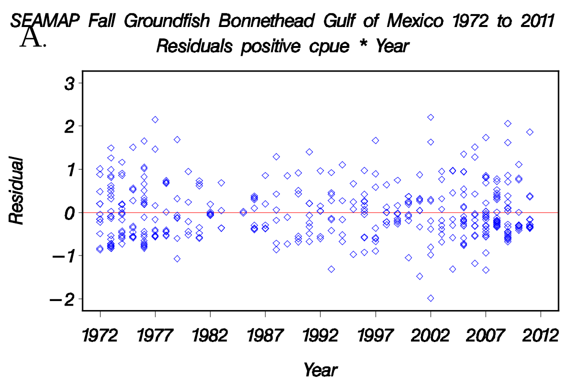


Figure 12. Diagnostic plots for lognormal component of the Bonnethead SEAMAP Groundfish Survey (GOM / all ages) model: **A.** the Chi-Square residuals by year.

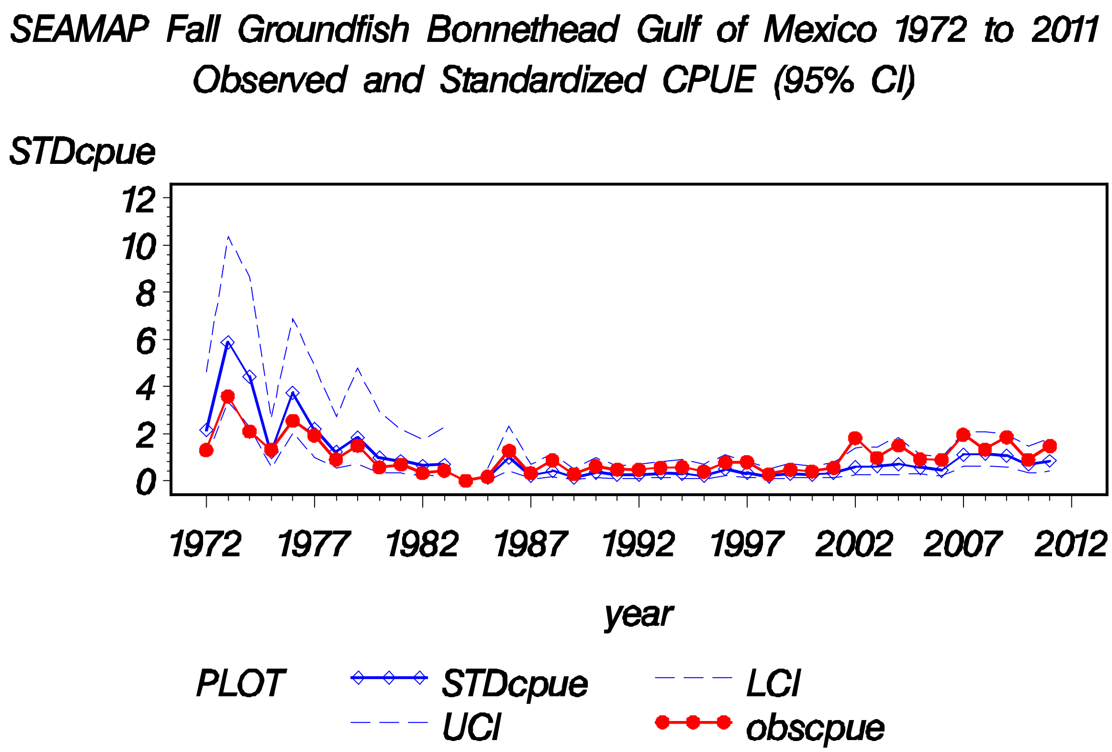
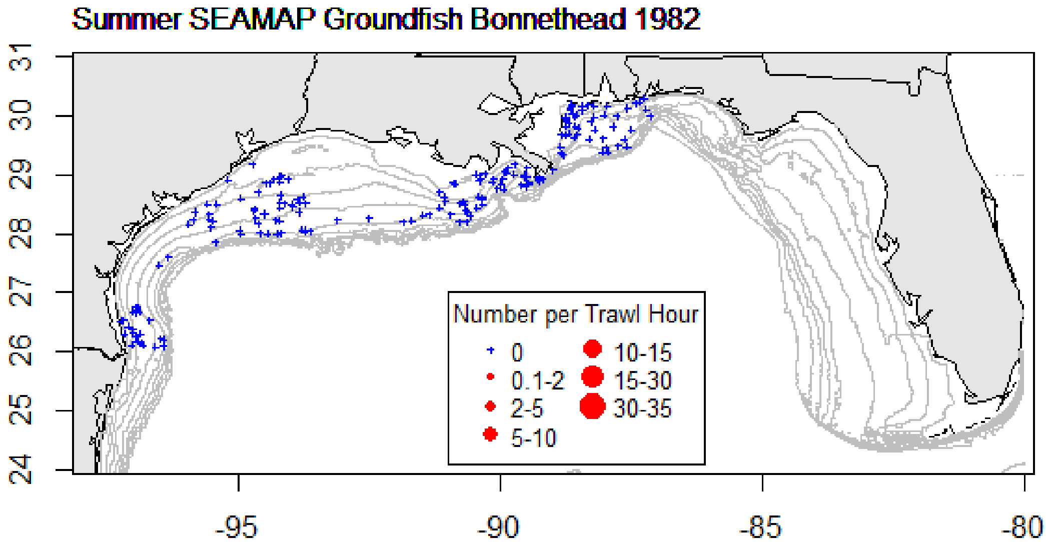
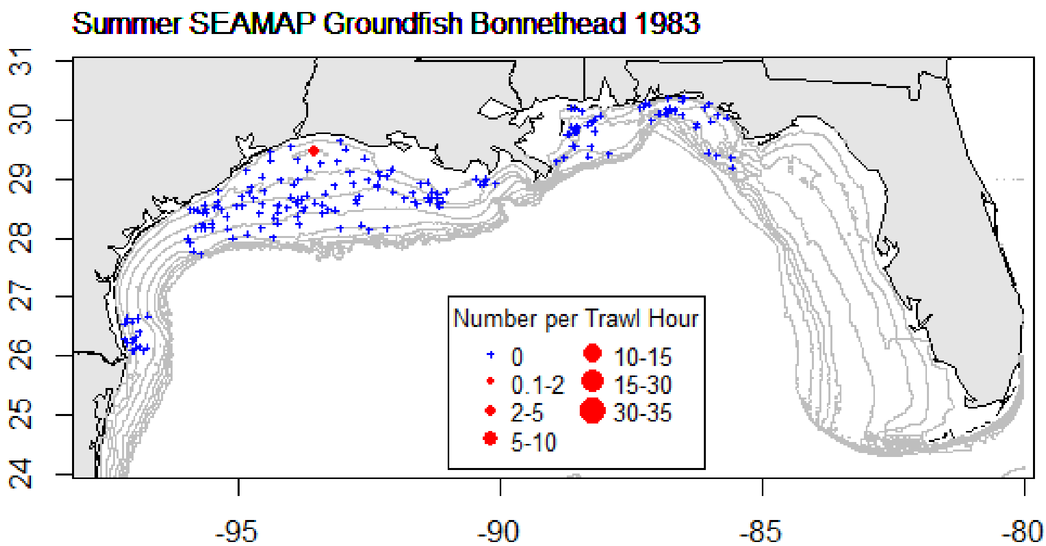


Figure 13. Annual index of abundance for bonnethead from the Fall SEAMAP Groundfish Survey from 1987 – 2011.

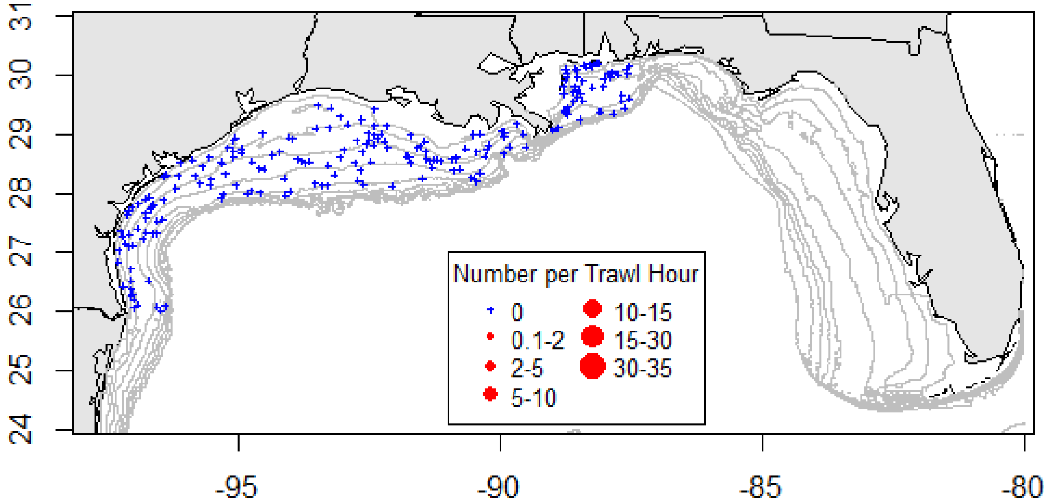
Appendix

Appendix Figure 1. Annual survey effort and catch of bonnethead from the SEAMAP groundfish survey during the summer (1982-2011) and fall (1972-2011)

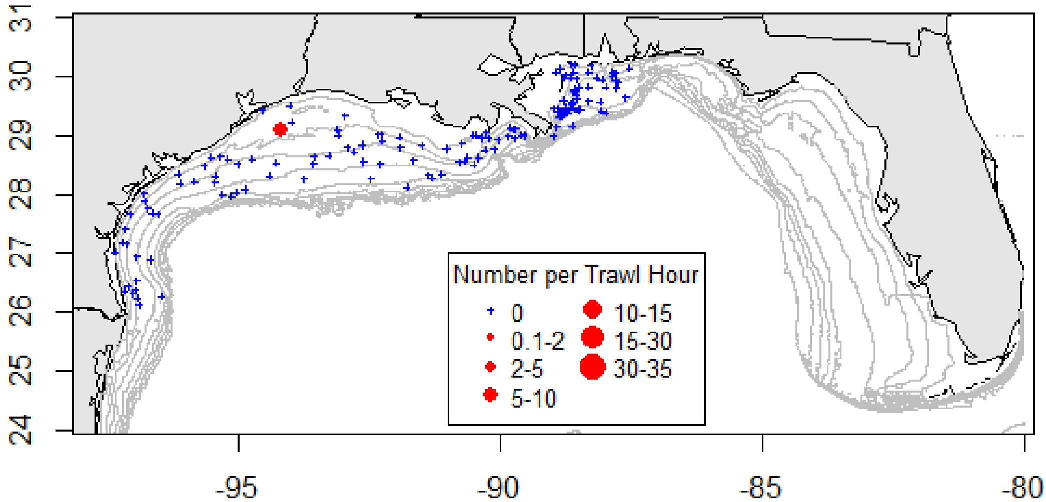




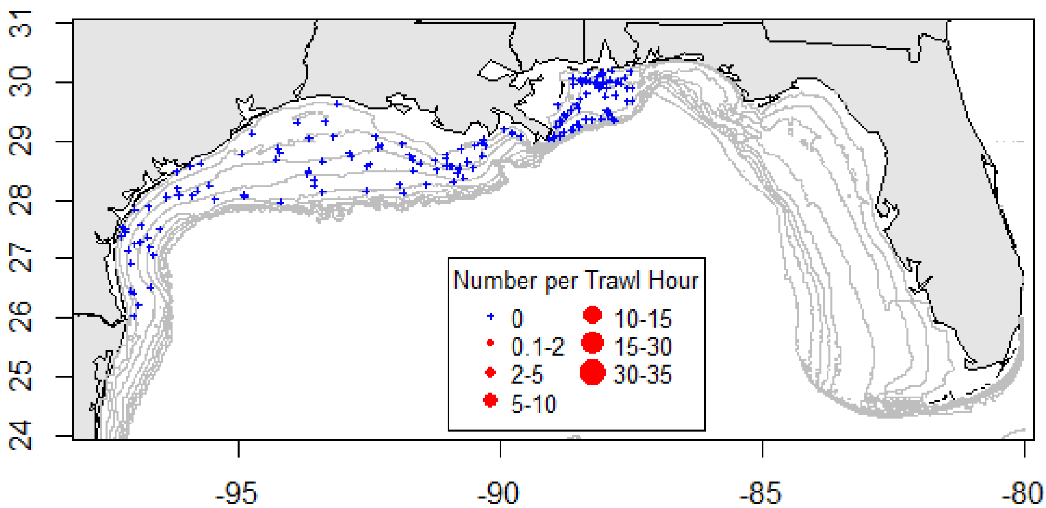
Summer SEAMAP Groundfish Bonnethead 1984



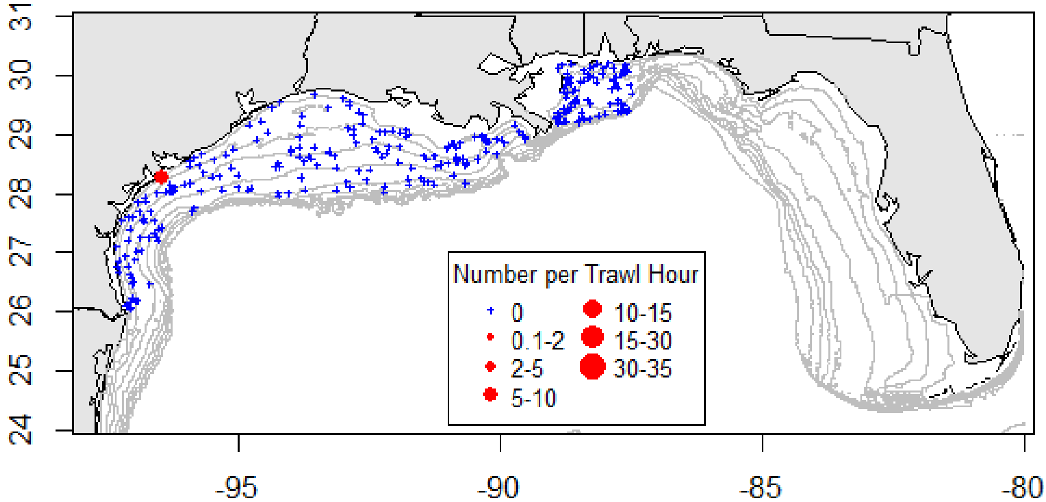
Summer SEAMAP Groundfish Bonnethead 1985



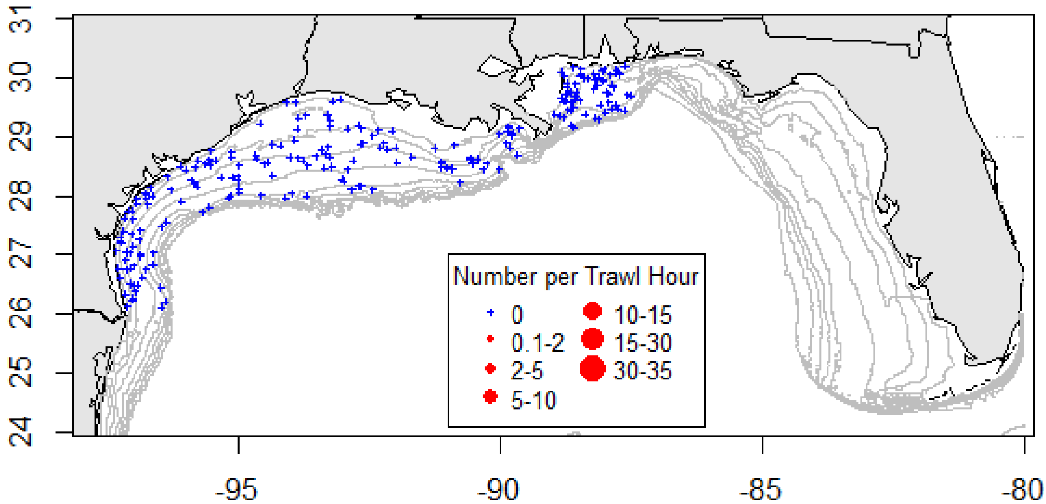
Summer SEAMAP Groundfish Bonnethead 1986



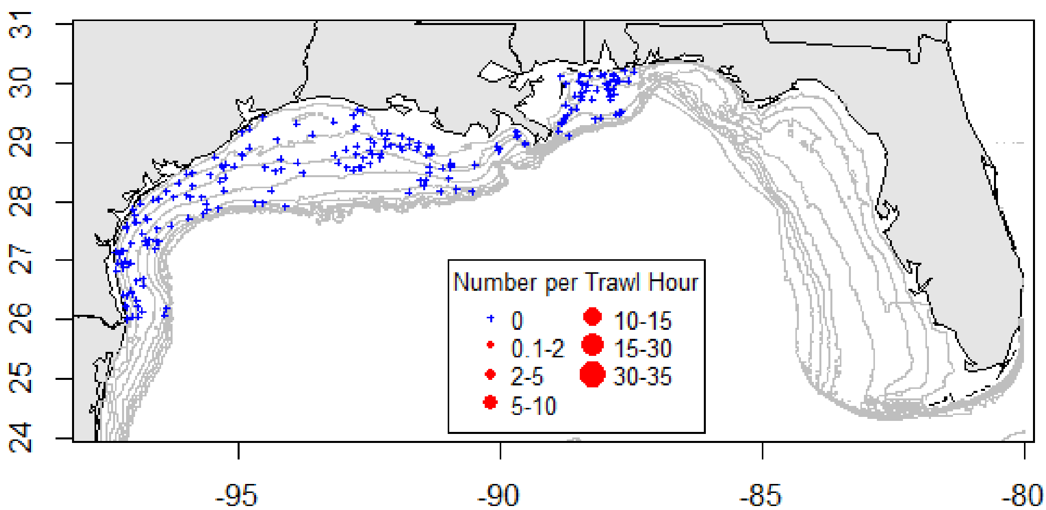
Summer SEAMAP Groundfish Bonnethead 1987



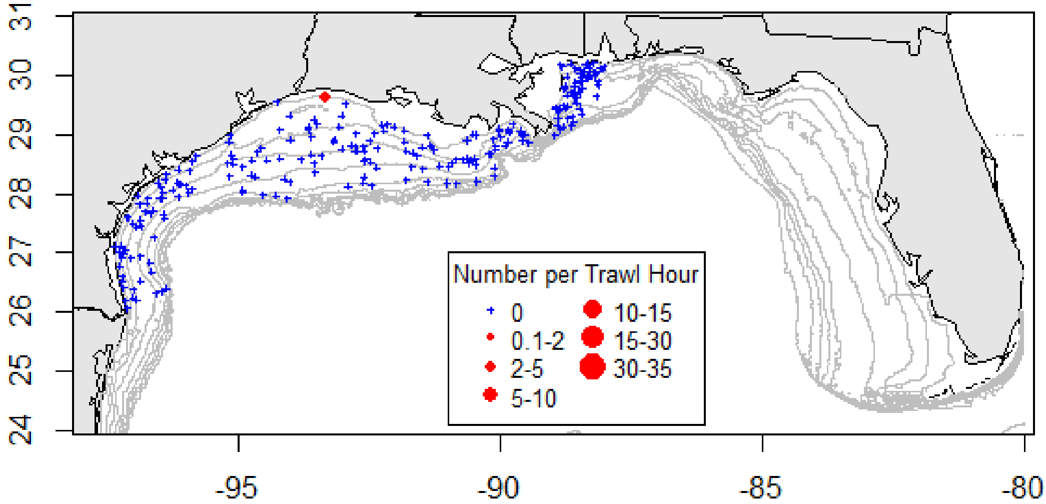
Summer SEAMAP Groundfish Bonnethead 1988



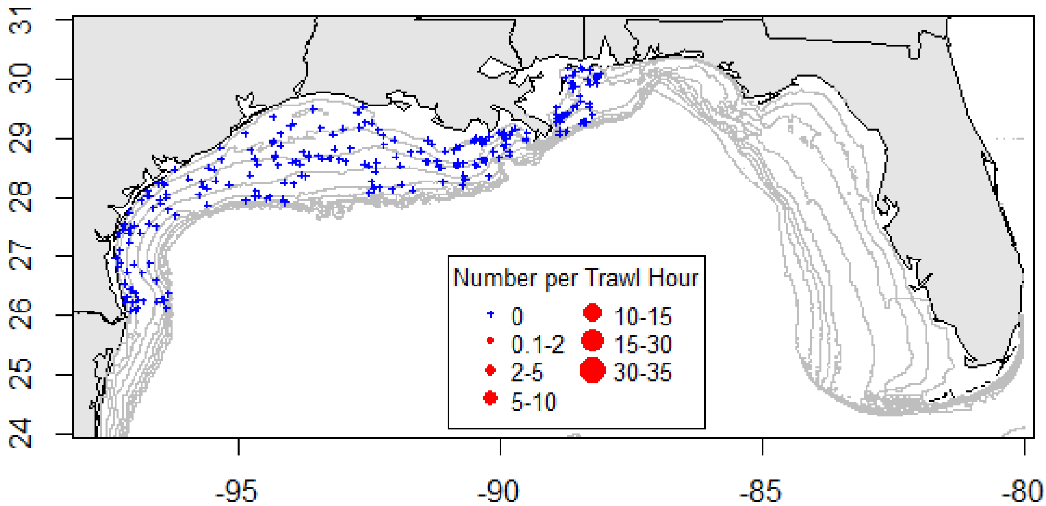
Summer SEAMAP Groundfish Bonnethead 1989



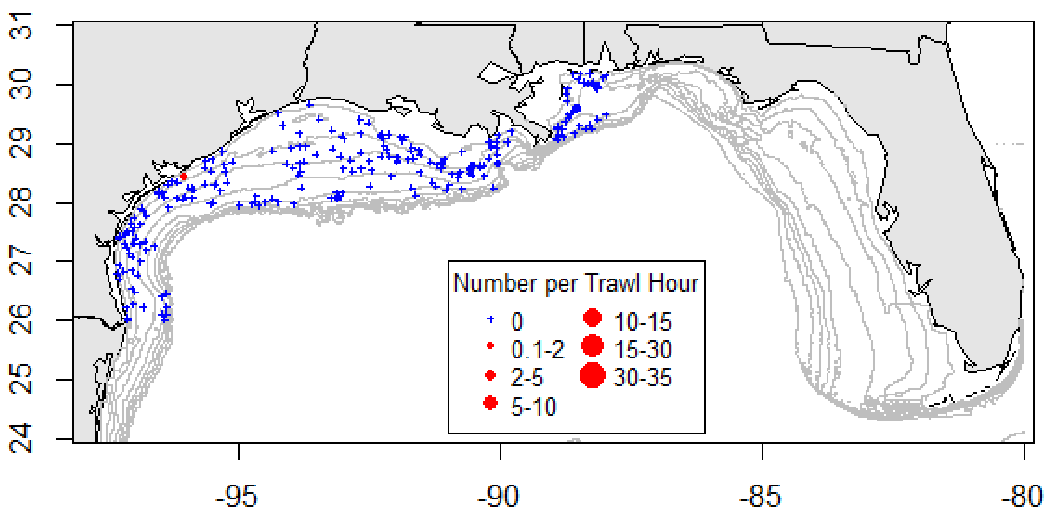
Summer SEAMAP Groundfish Bonnethead 1990



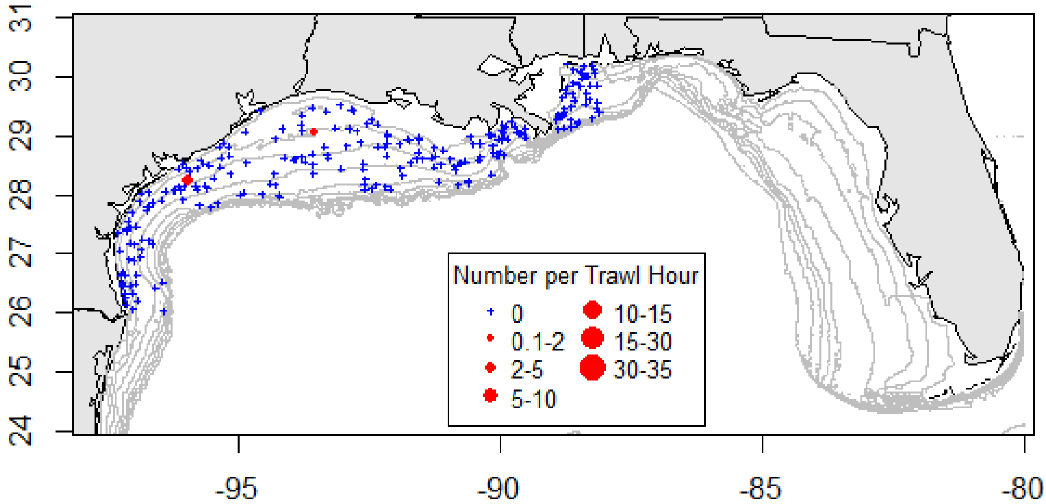
Summer SEAMAP Groundfish Bonnethead 1991



Summer SEAMAP Groundfish Bonnethead 1992



Summer SEAMAP Groundfish Bonnethead 1993



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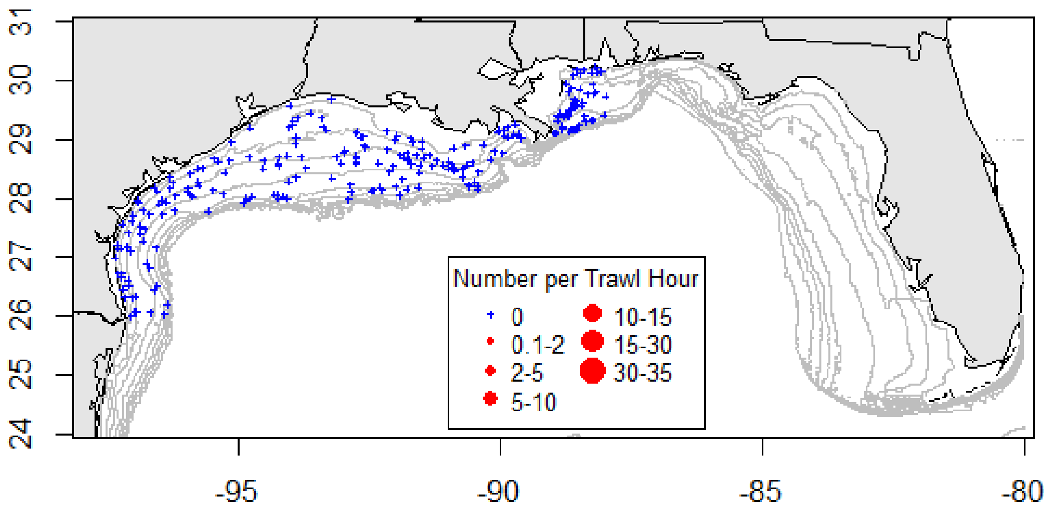
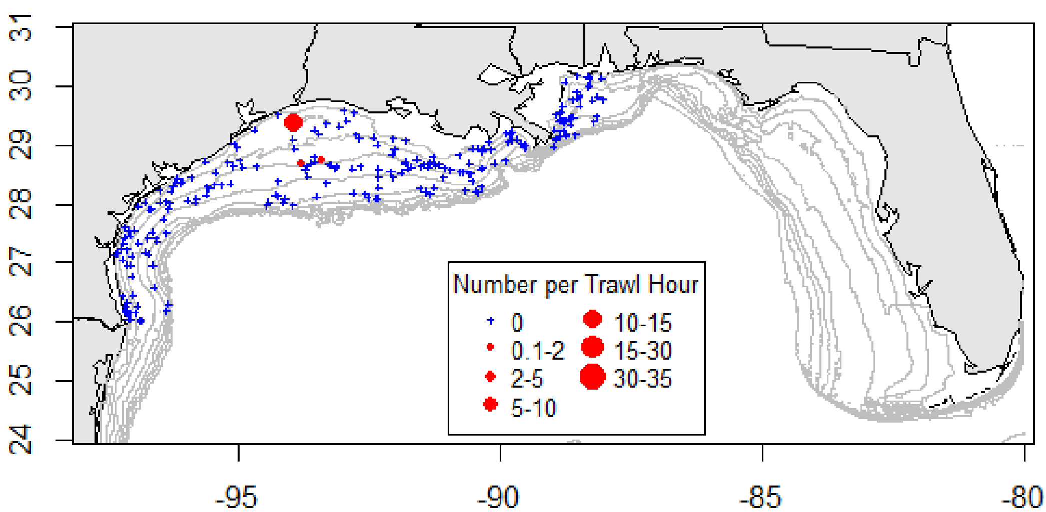


Summer SEAMAP Groundfish Bonnethead 1995



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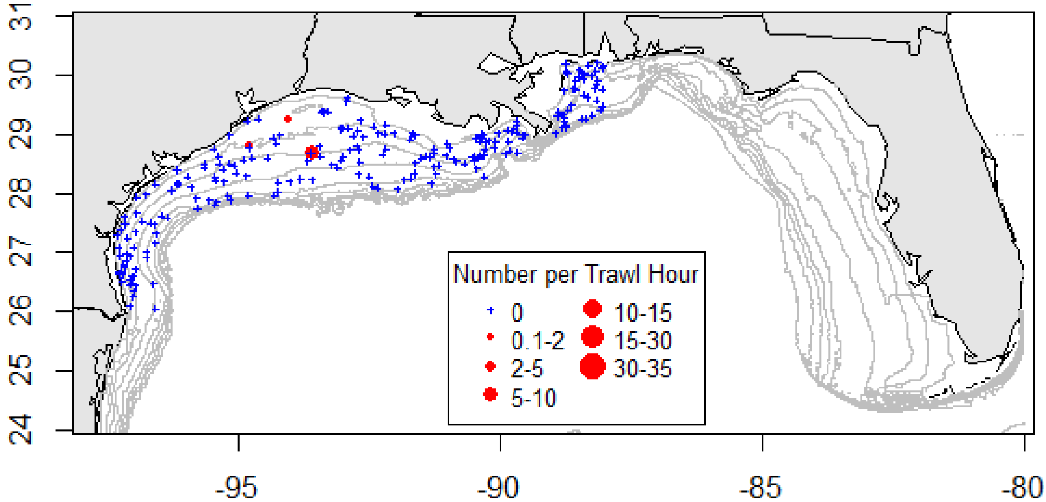
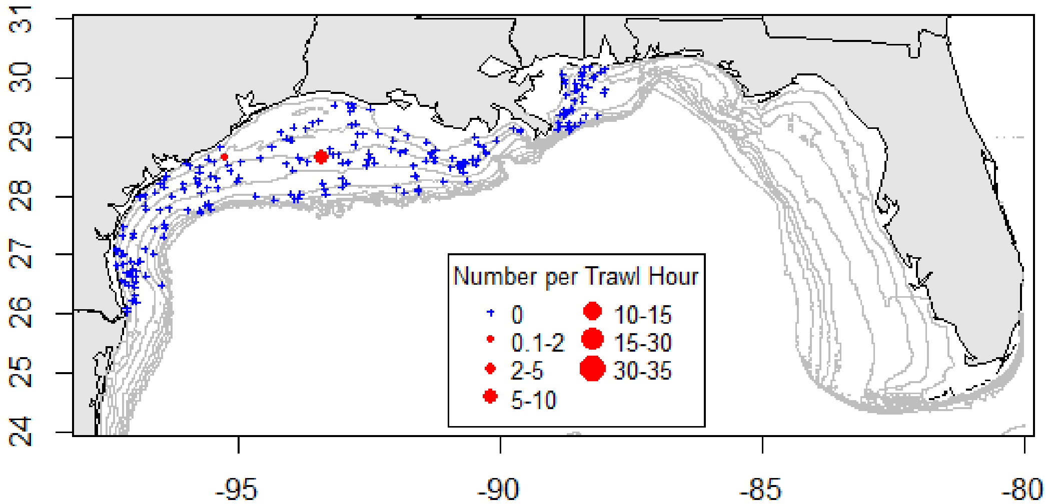
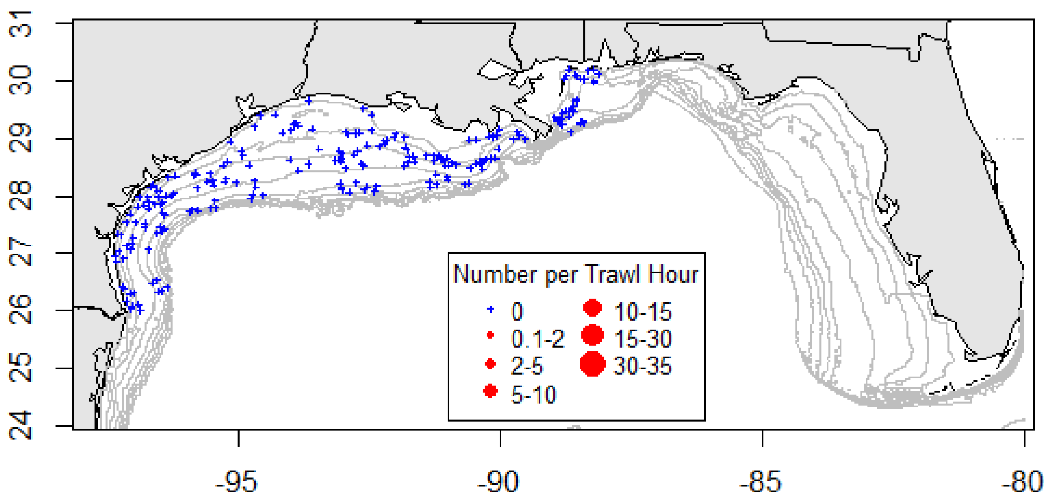


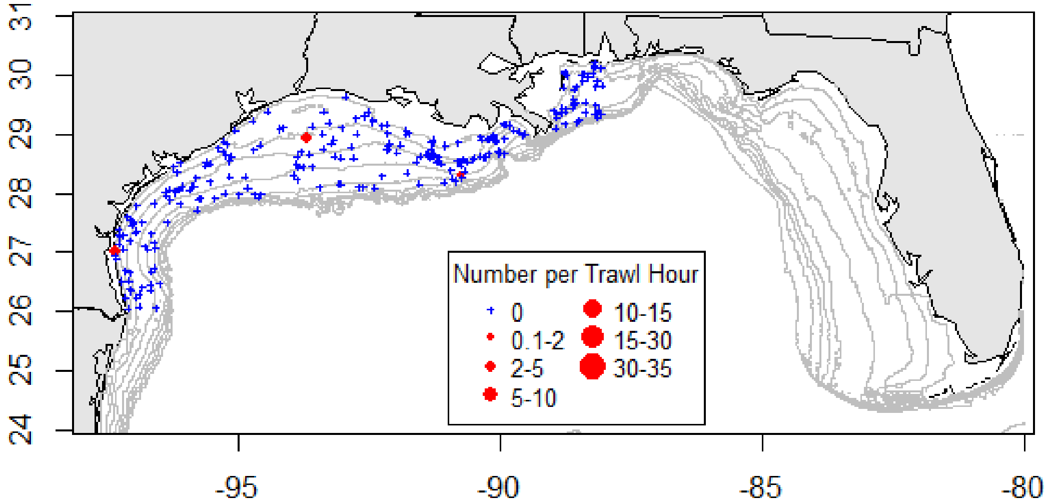
Summer SEAMAP Groundfish Bonnethead 1997



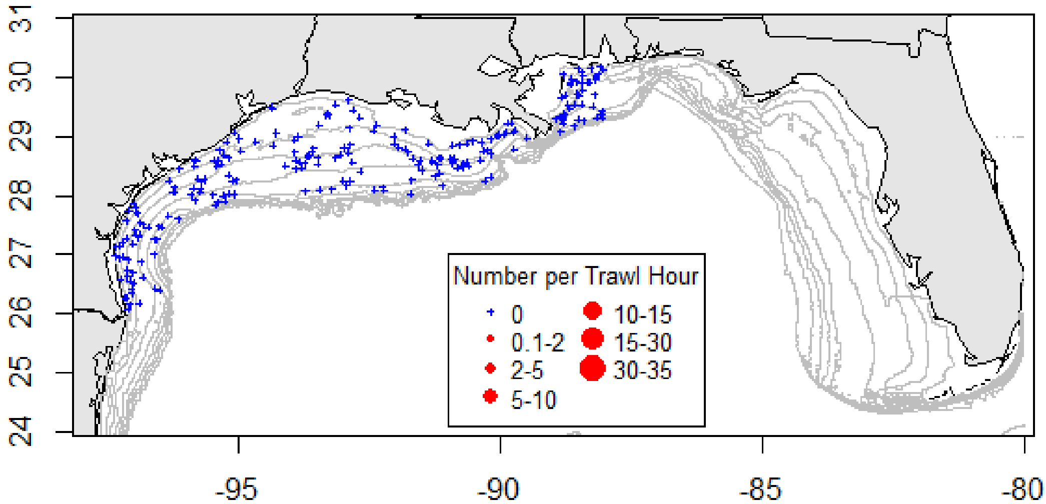
Summer SEAMAP Groundfish Bonnethead 1998



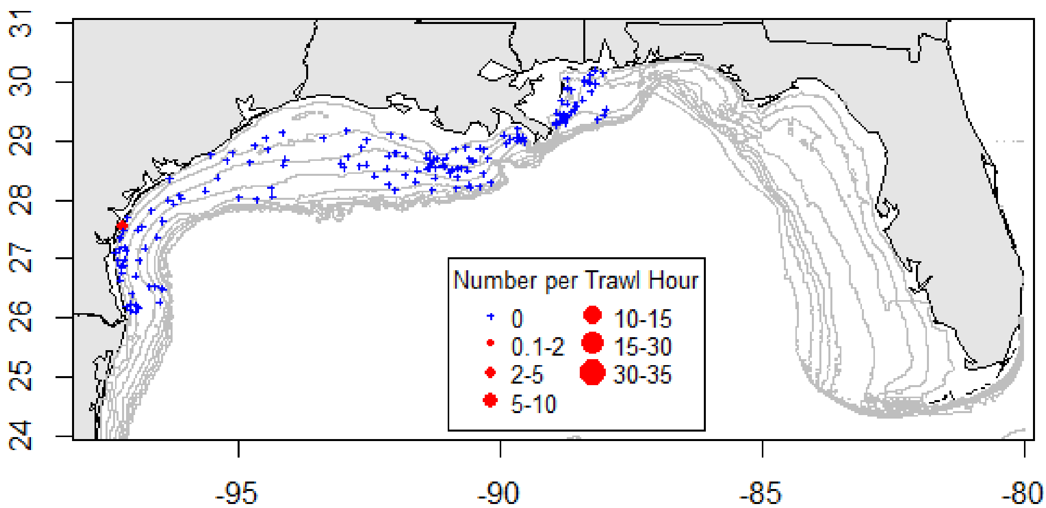
Summer SEAMAP Groundfish Bonnethead 1999



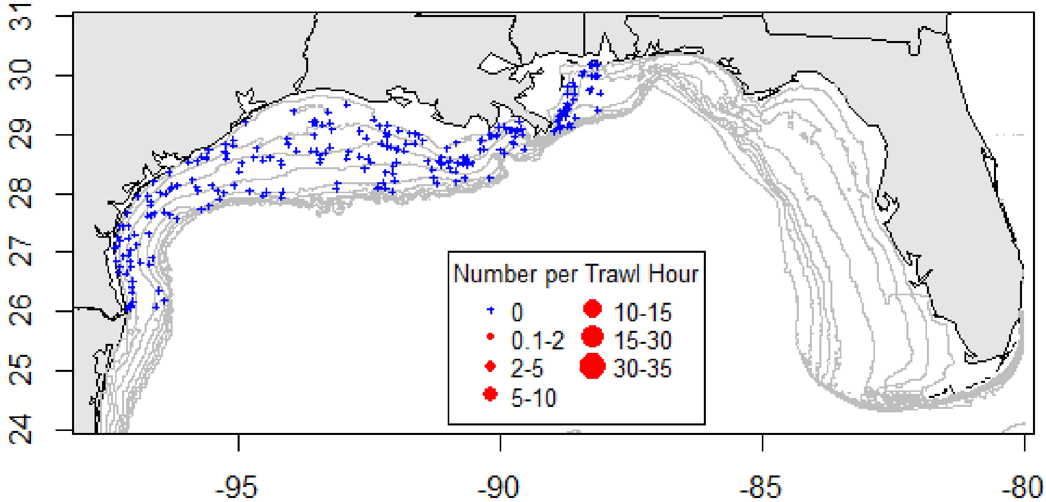
Summer SEAMAP Groundfish Bonnethead 2000



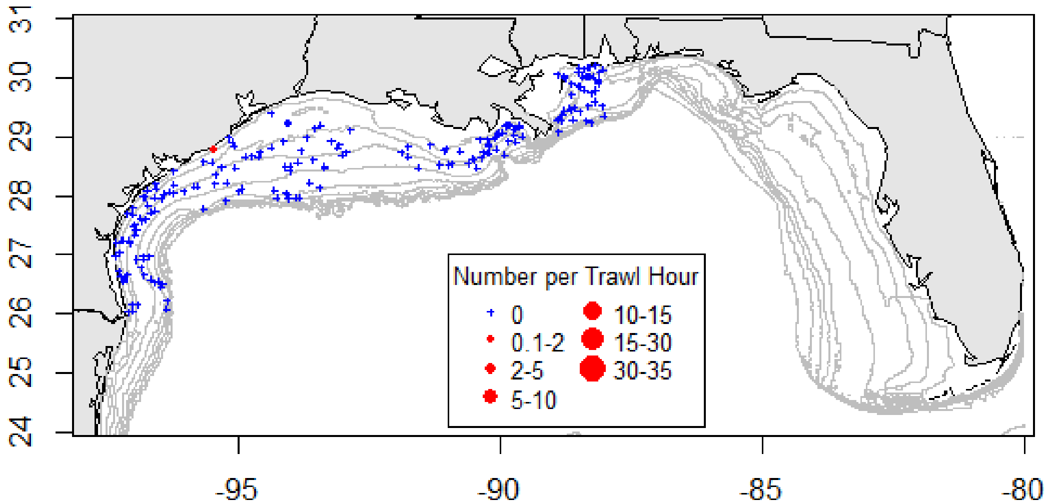
Summer SEAMAP Groundfish Bonnethead 2001



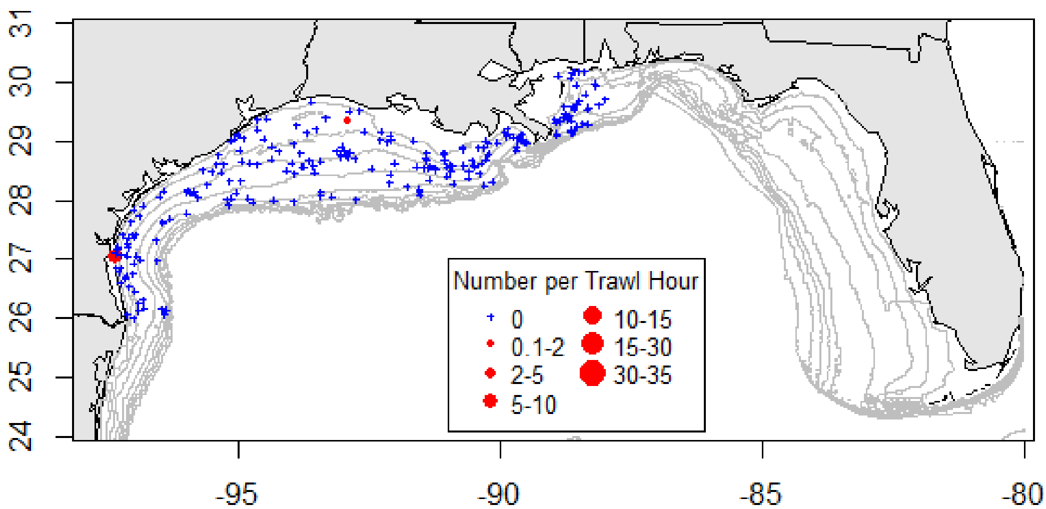
Summer SEAMAP Groundfish Bonnethead 2002

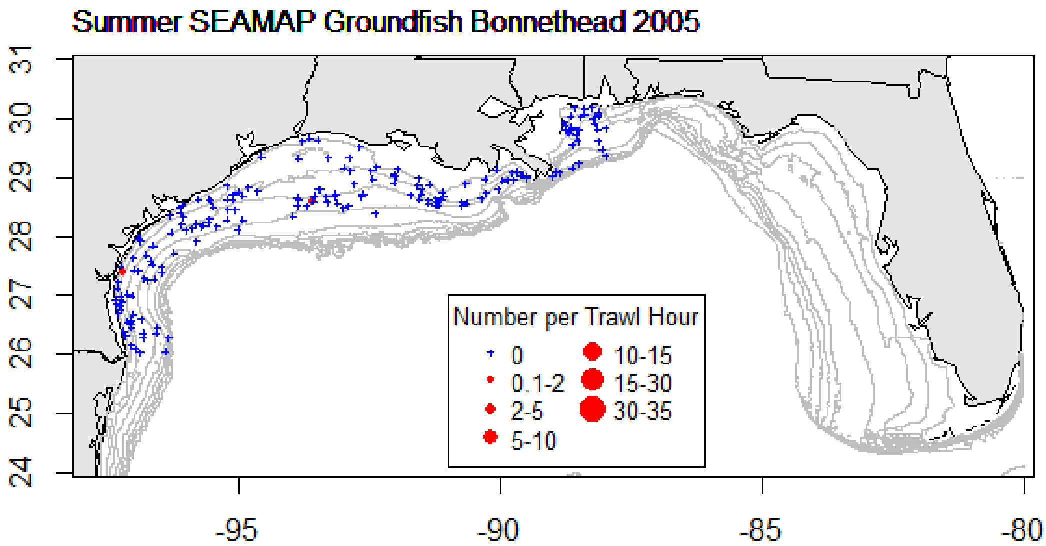


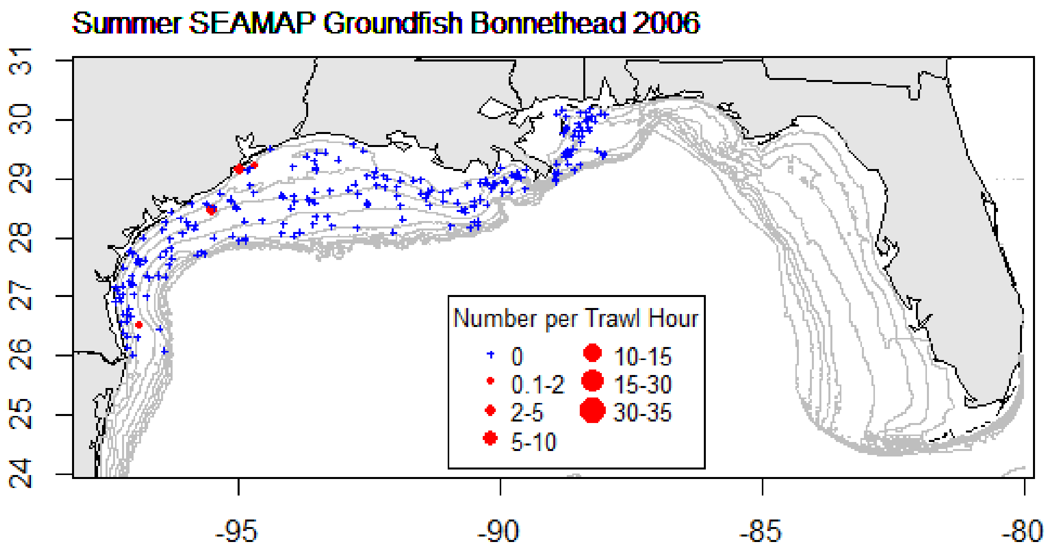
Summer SEAMAP Groundfish Bonnethead 2003



Summer SEAMAP Groundfish Bonnethead 2004




Summer SEAMAP Groundfish Bonnethead 2005
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35
31
30
29
28
27
26
25
24
-95
-90
-85
-80


Summer SEAMAP Groundfish Bonnethead 2006
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35
31
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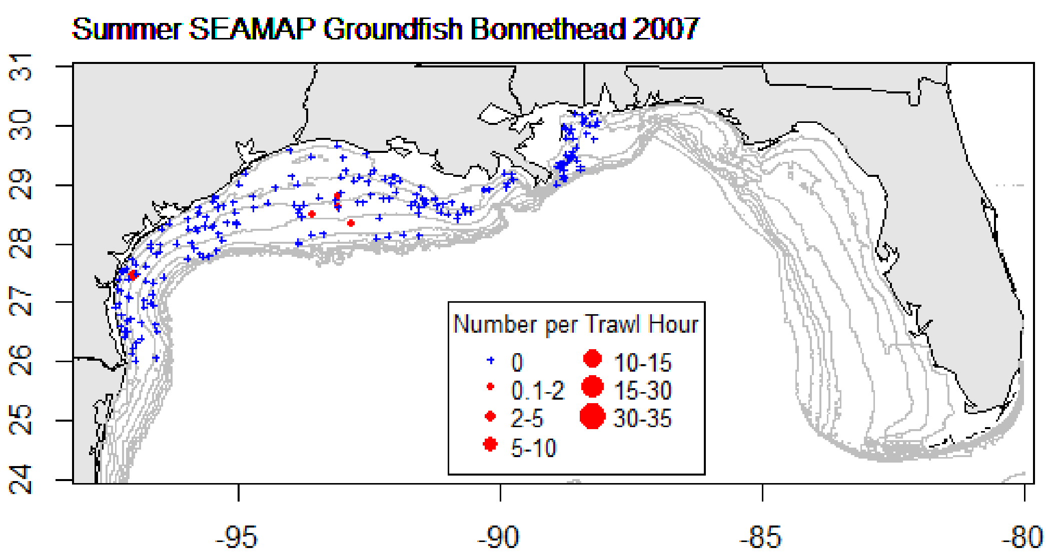
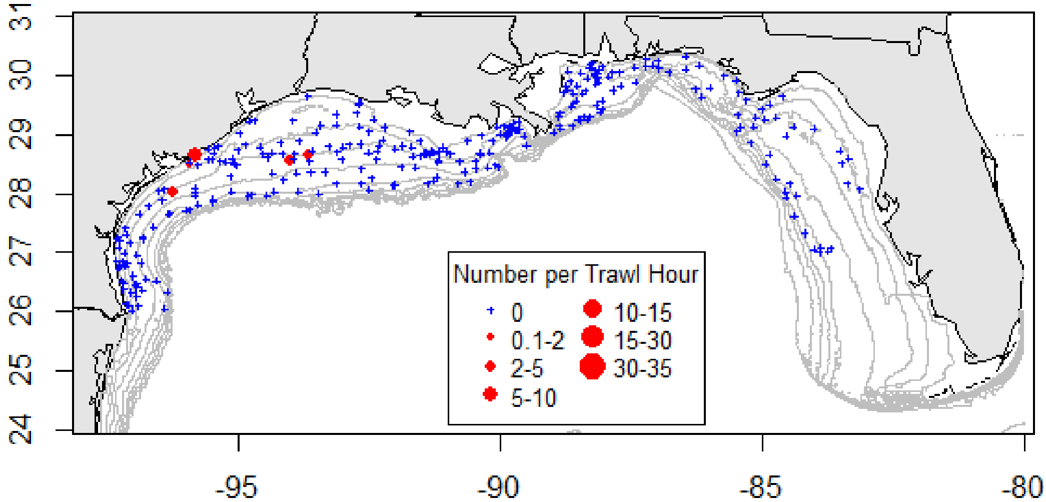
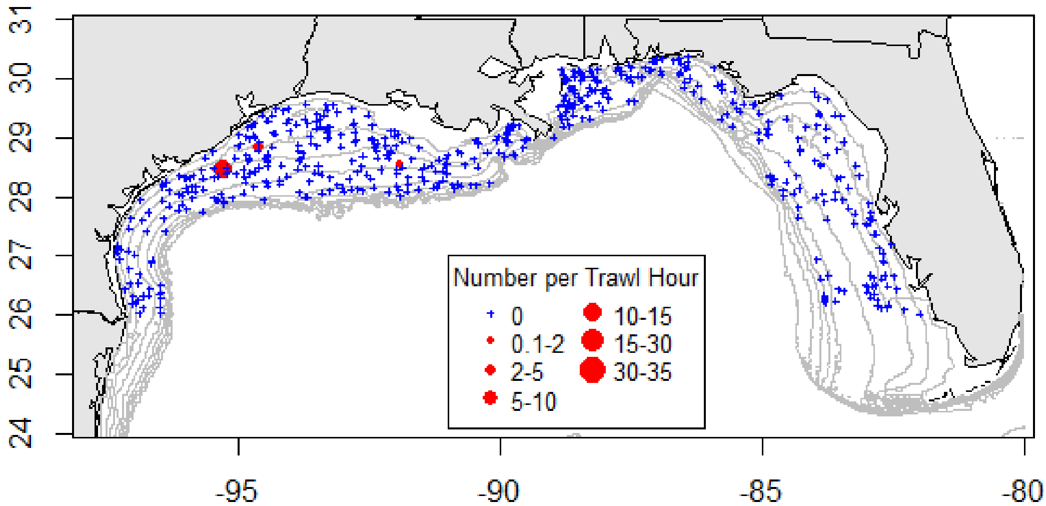
-95
-90
-85
-80


Summer SEAMAP Groundfish Bonnethead 2007
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35
31
30
29
28
27
26
25
24
-95
-90
-85
-80

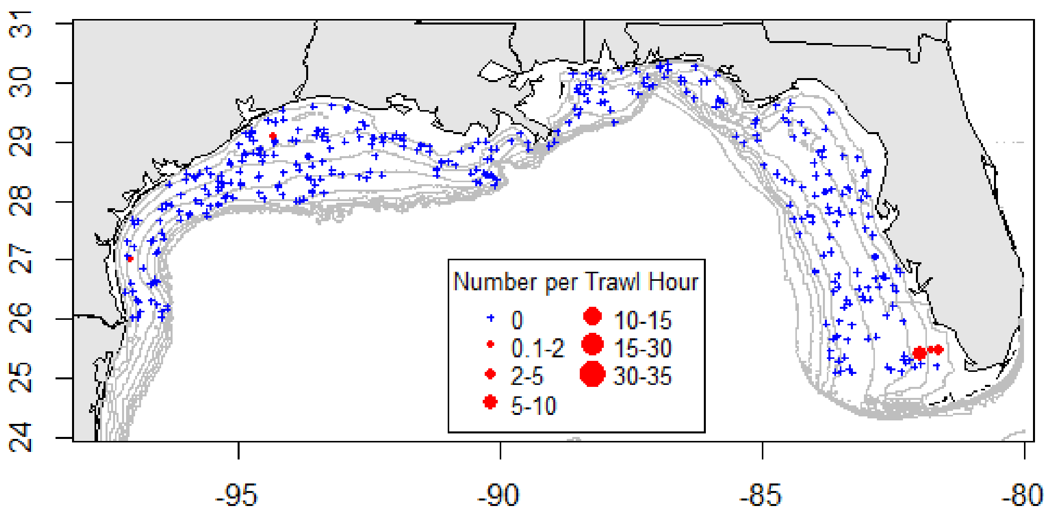
Summer SEAMAP Groundfish Bonnethead 2008

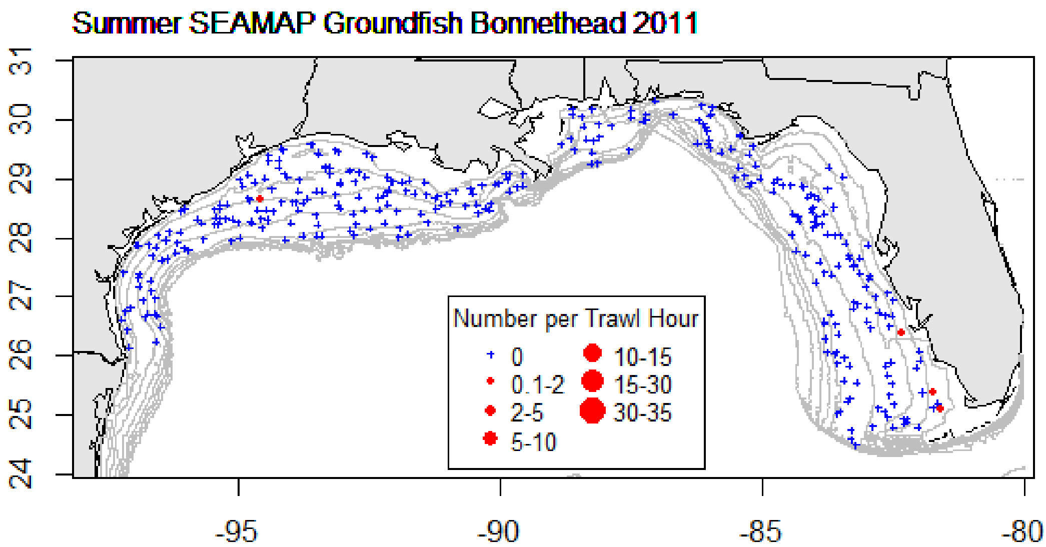


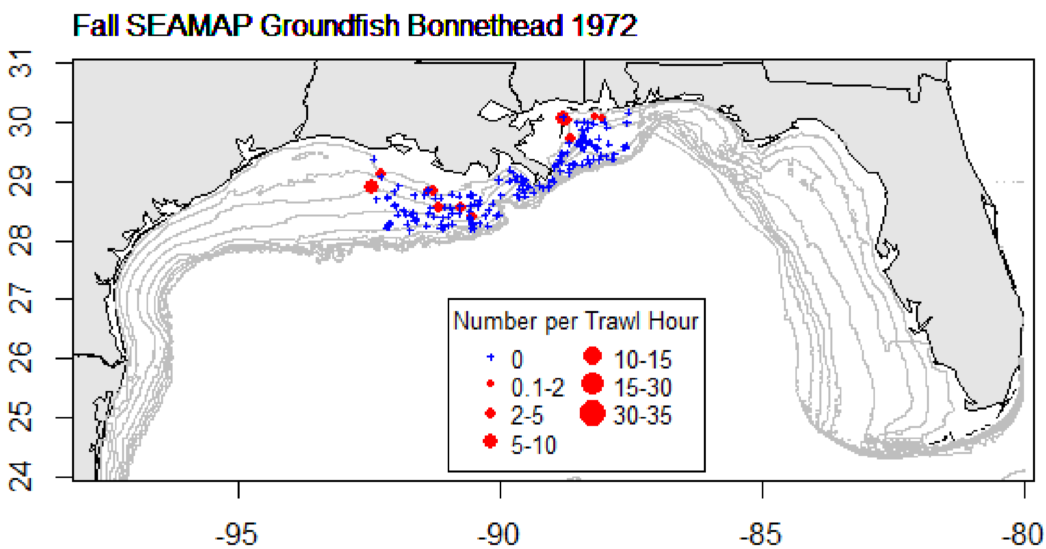
Summer SEAMAP Groundfish Bonnethead 2009

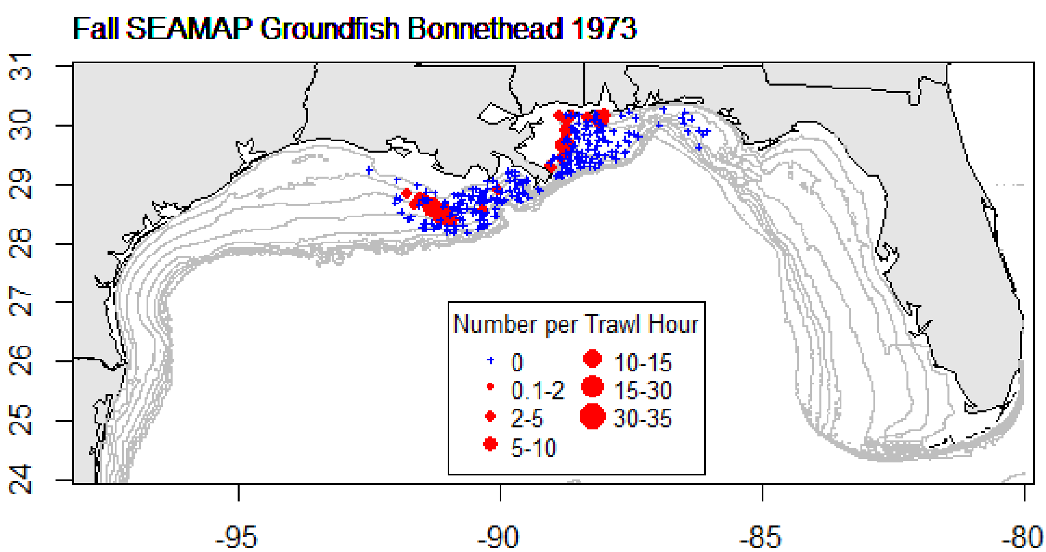


Summer SEAMAP Groundfish Bonnethead 2010

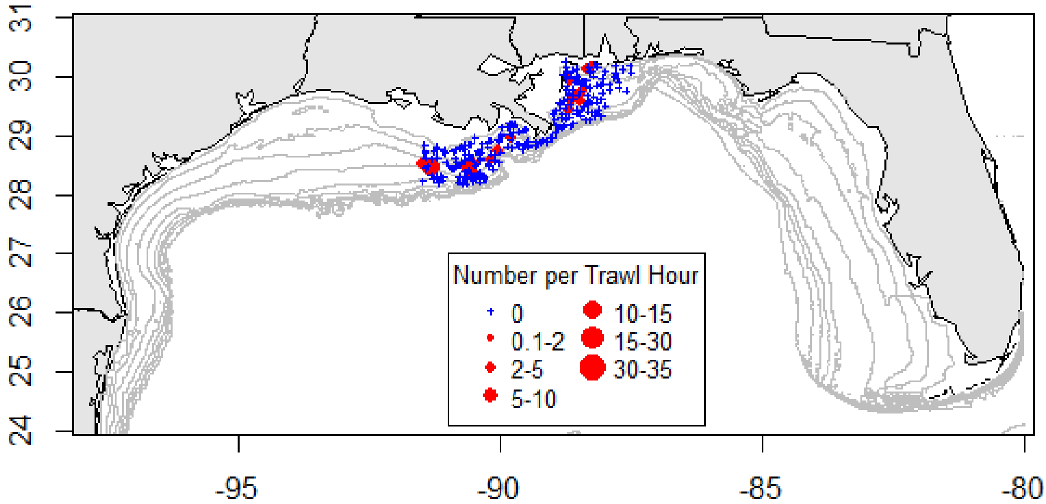



Summer SEAMAP Groundfish Bonnethead 2011
24 25 26 27 28 29 30 31
-95 -90 -85 -80
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35

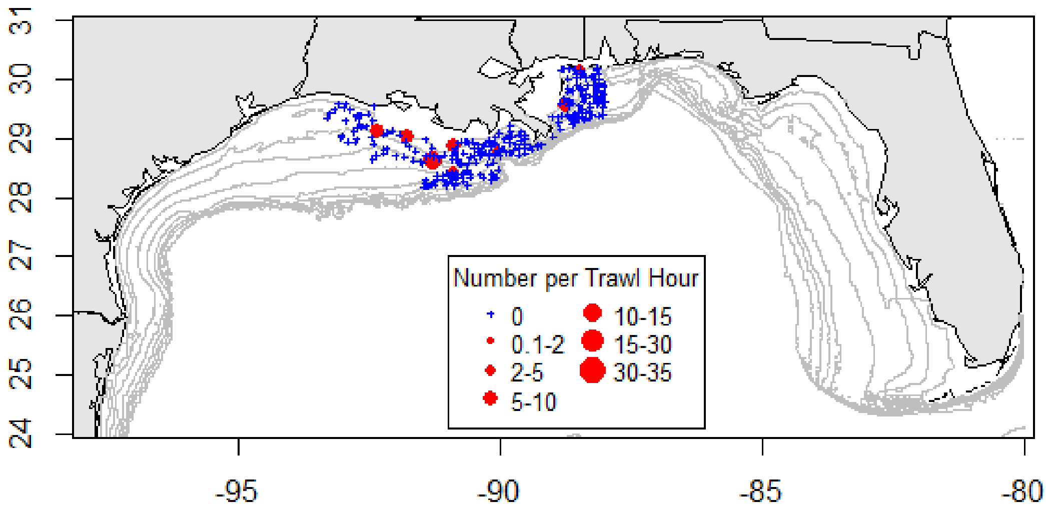

Fall SEAMAP Groundfish Bonnethead 1972
24 25 26 27 28 29 30 31
-95 -90 -85 -80
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35


Fall SEAMAP Groundfish Bonnethead 1973
24 25 26 27 28 29 30 31
-95 -90 -85 -80
Number per Trawl Hour
0
0.1-2
2-5
5-10
10-15
15-30
30-35

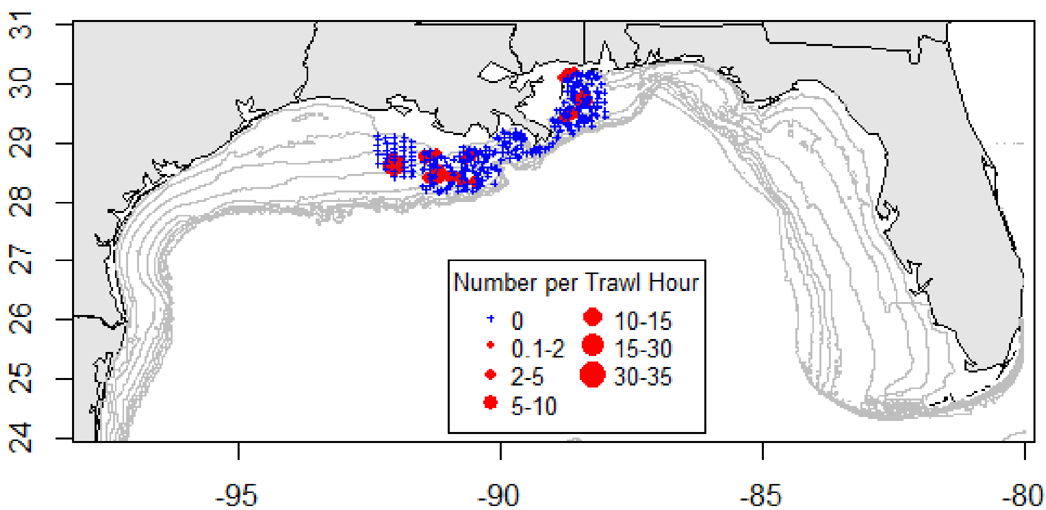
Fall SEAMAP Groundfish Bonnethead 1974



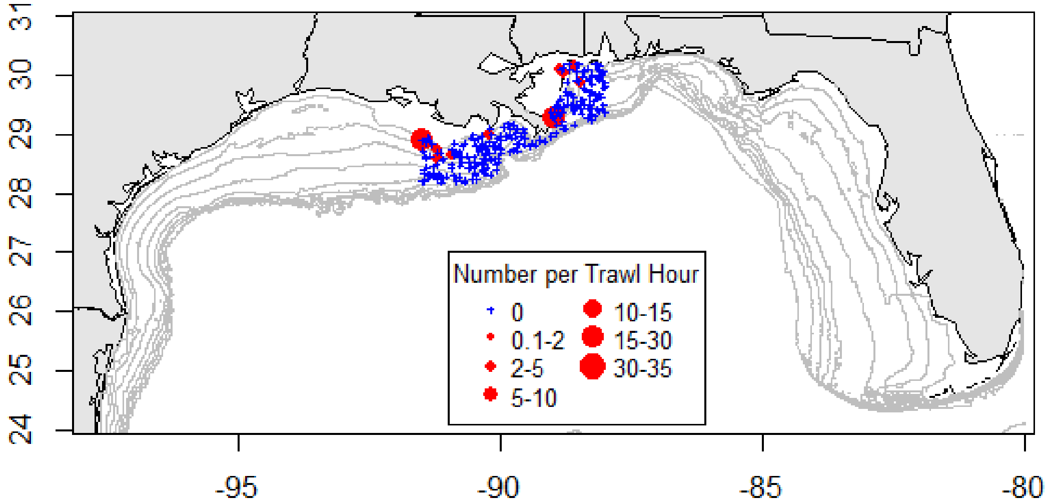
Fall SEAMAP Groundfish Bonnethead 1975



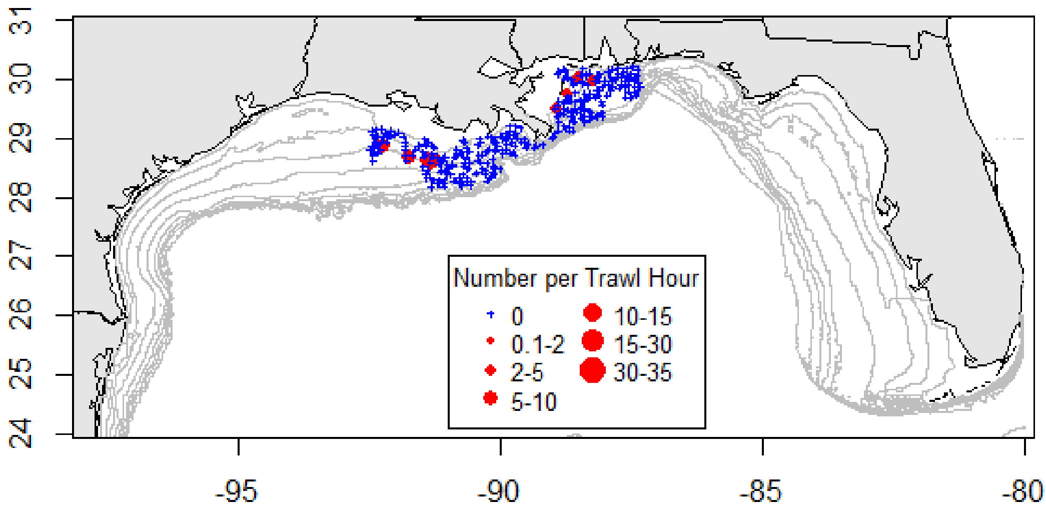
Fall SEAMAP Groundfish Bonnethead 1976



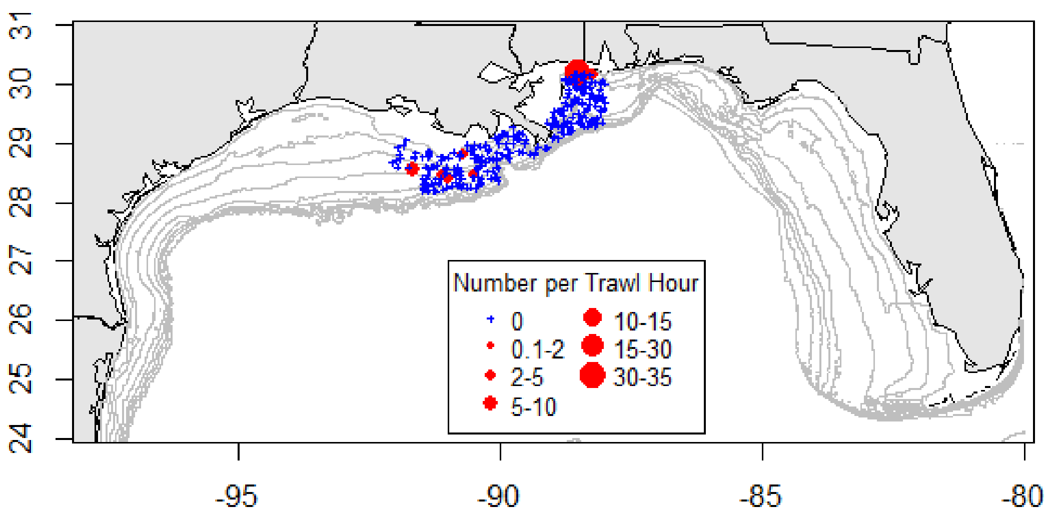
Fall SEAMAP Groundfish Bonnethead 1977



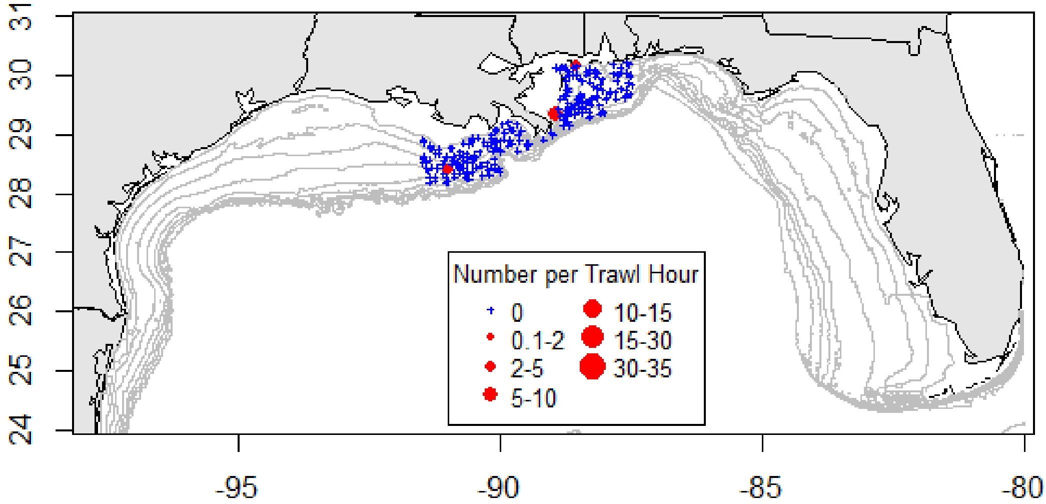
Fall SEAMAP Groundfish Bonnethead 1978



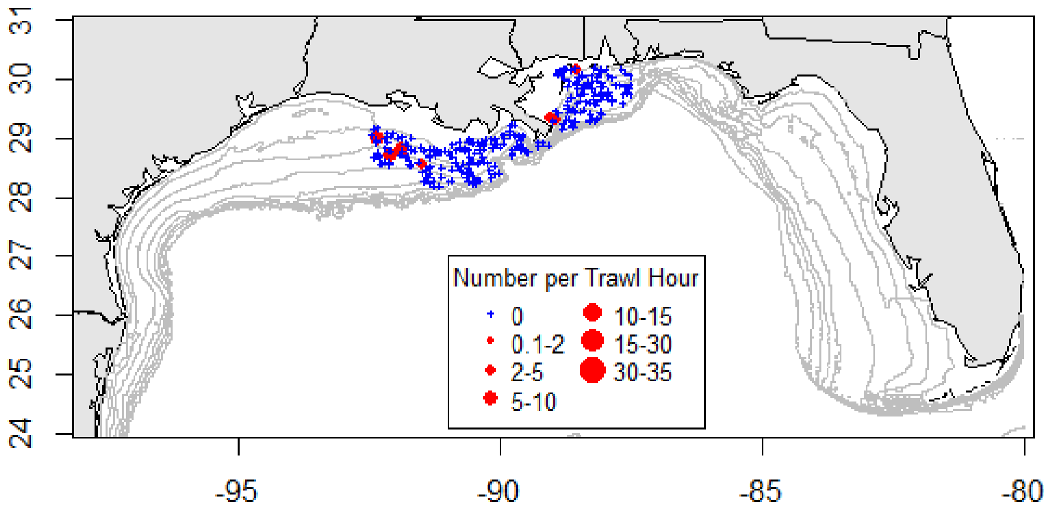
Fall SEAMAP Groundfish Bonnethead 1979



Fall SEAMAP Groundfish Bonnethead 1980



Fall SEAMAP Groundfish Bonnethead 1981



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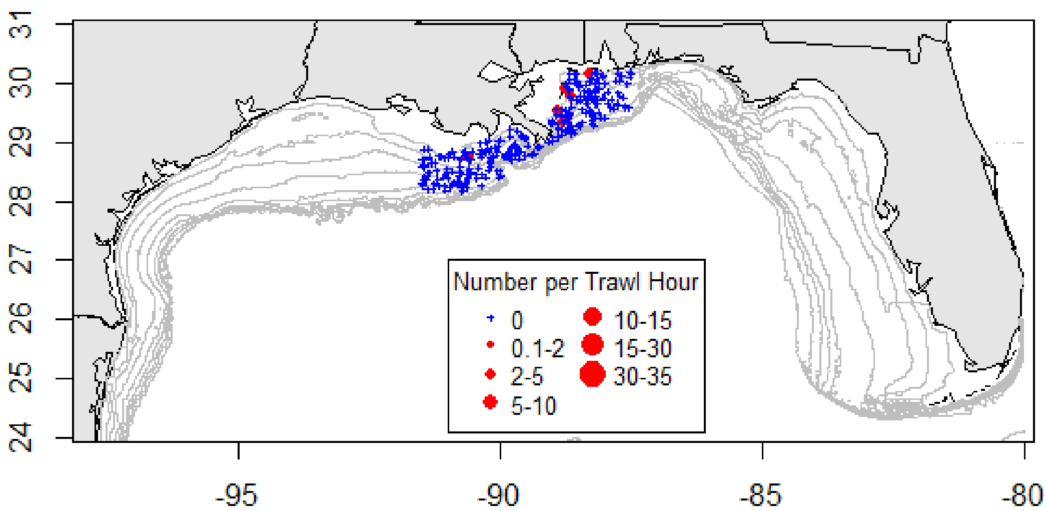

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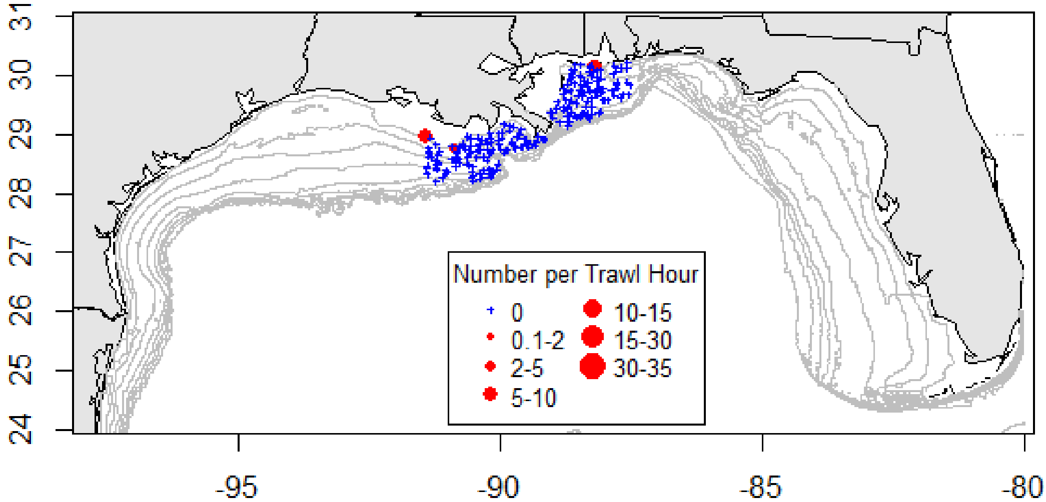

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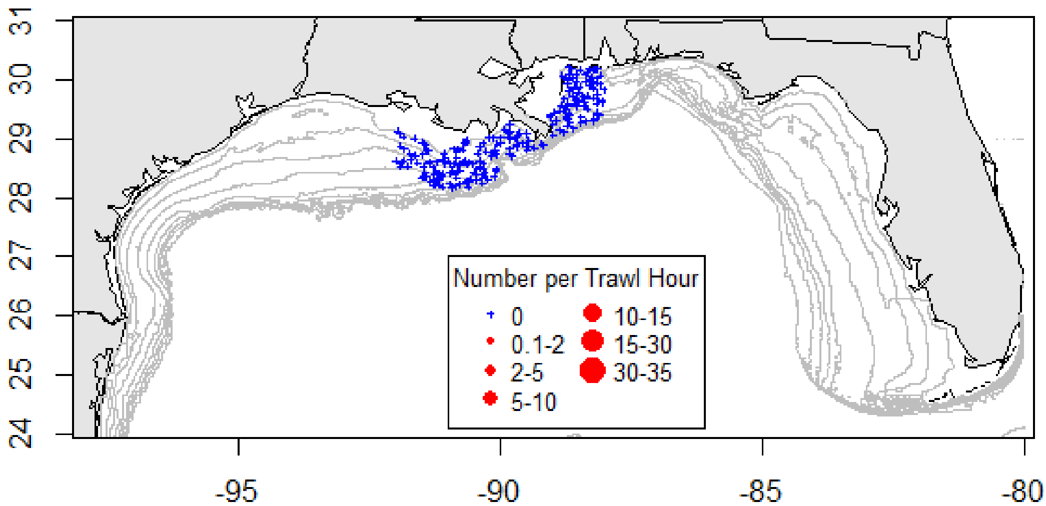

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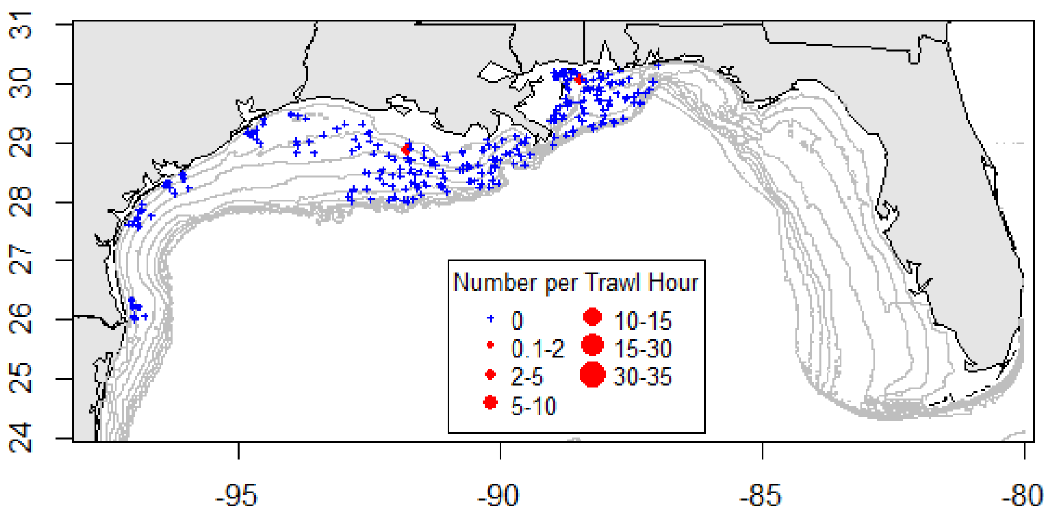

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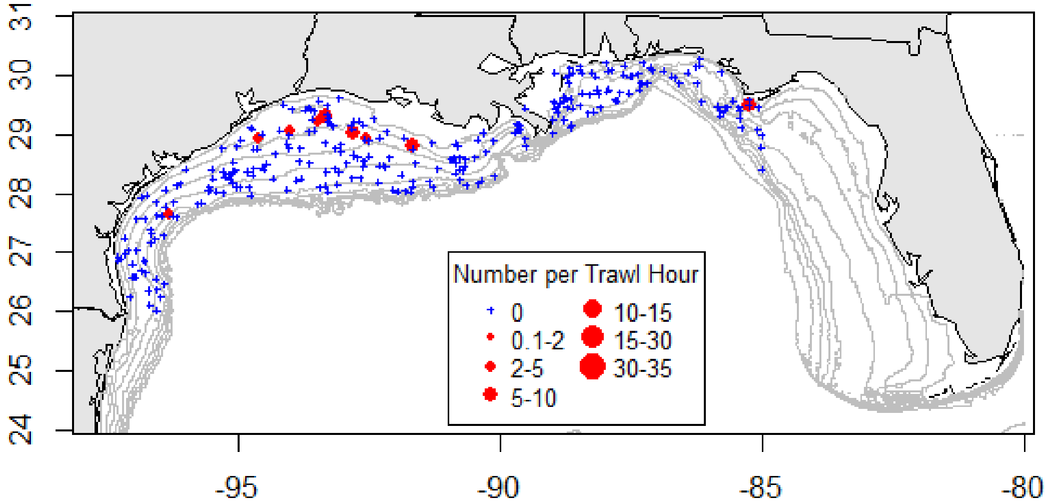

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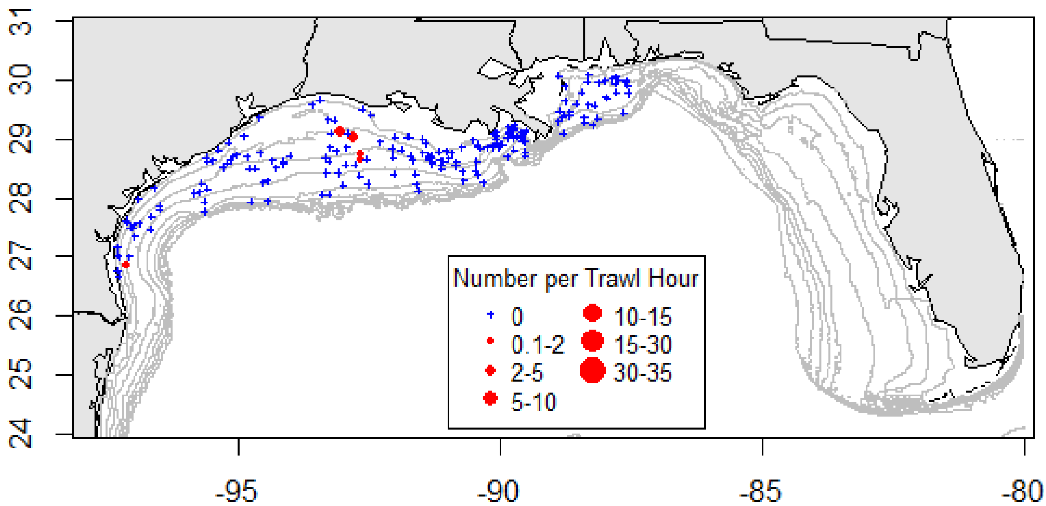

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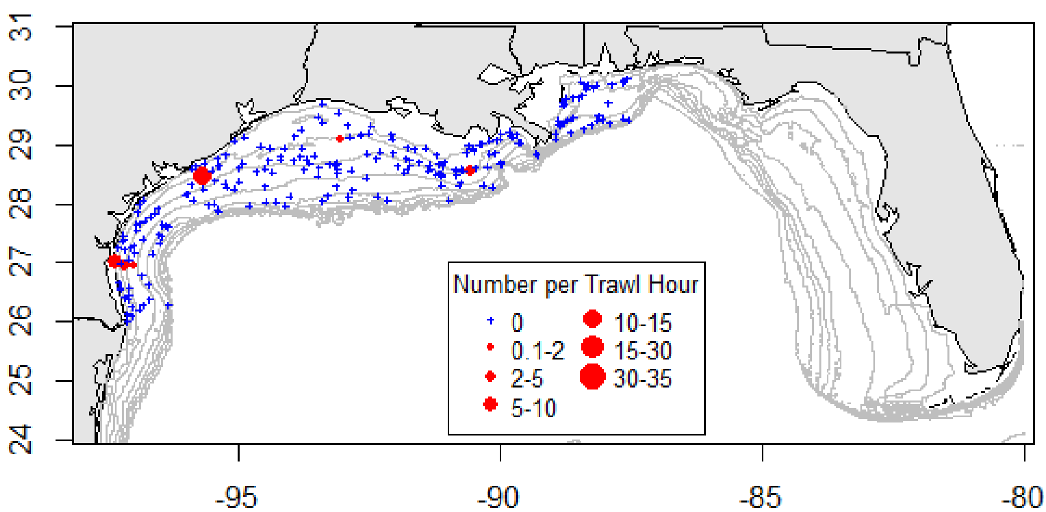

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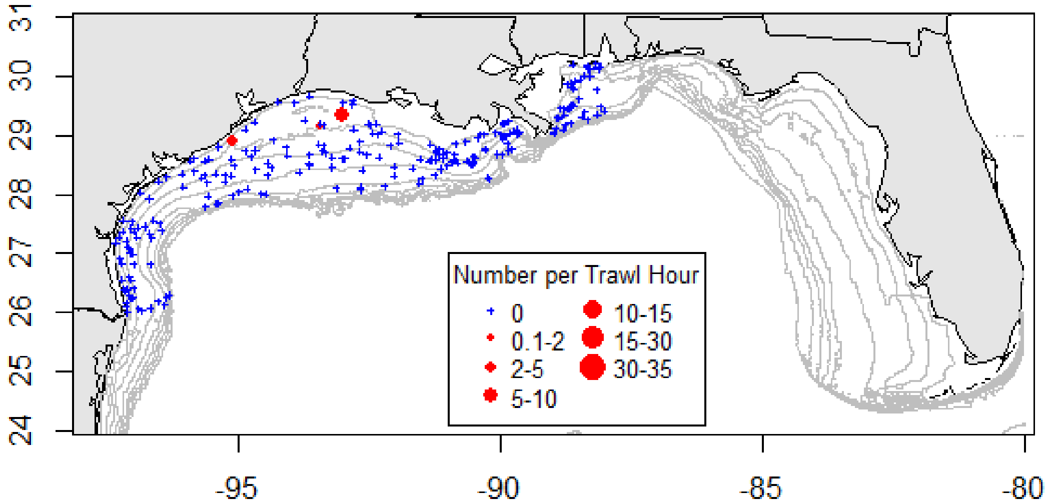

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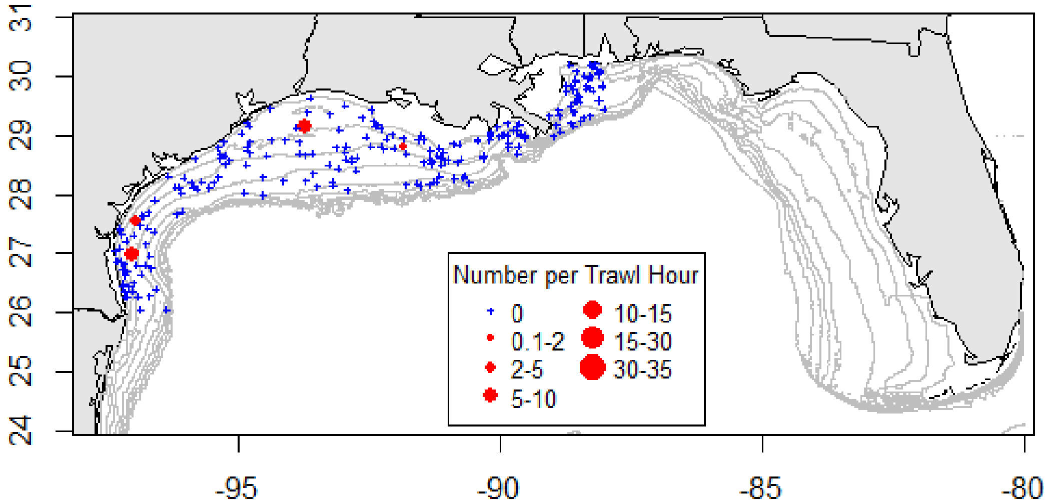

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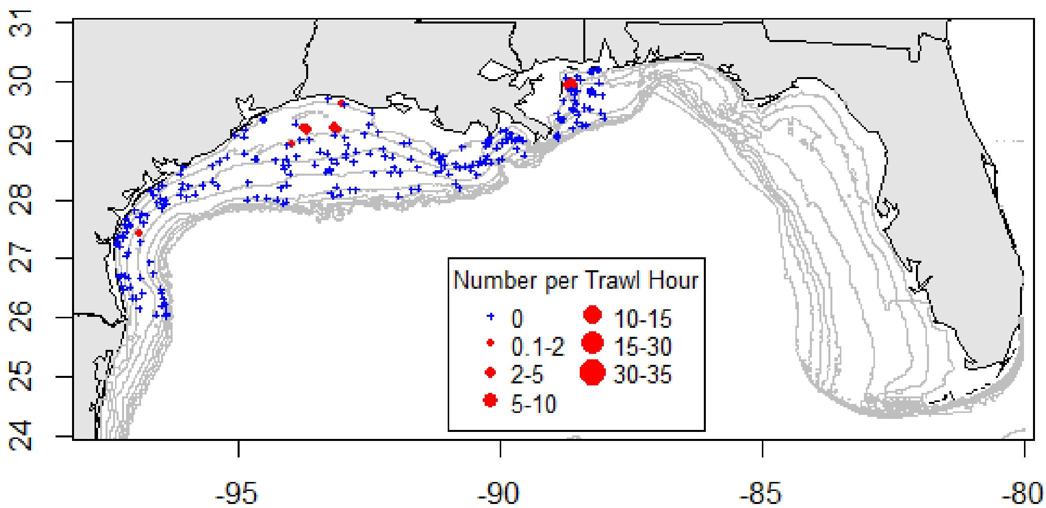

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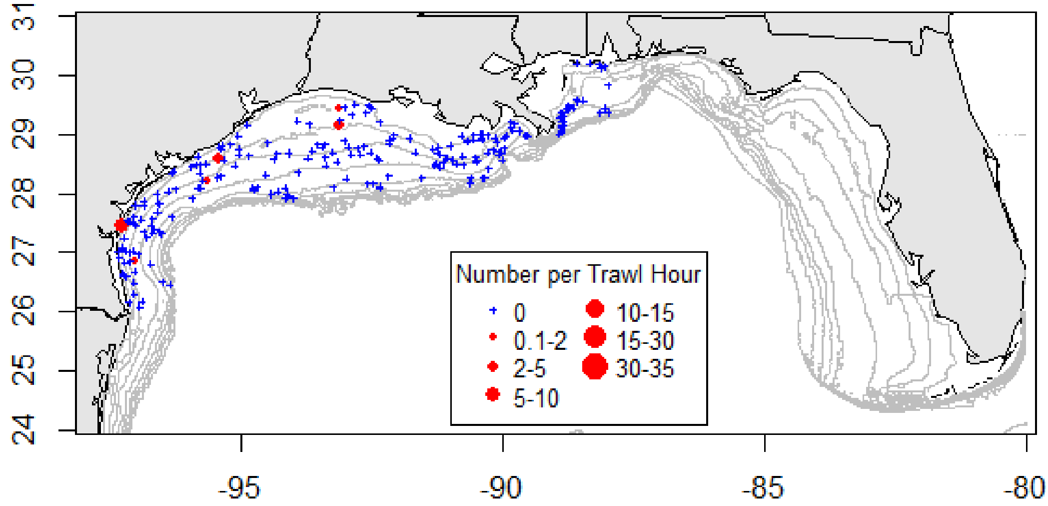

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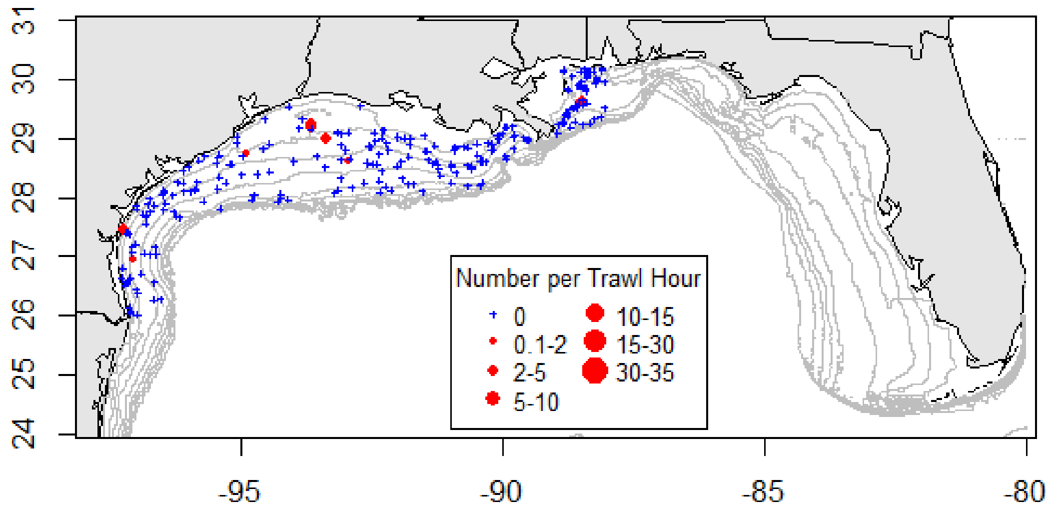

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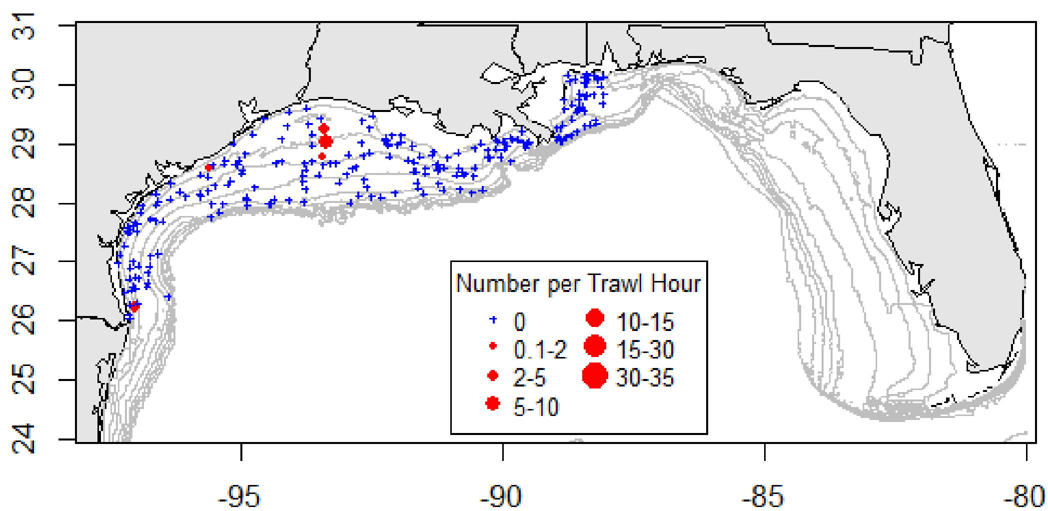

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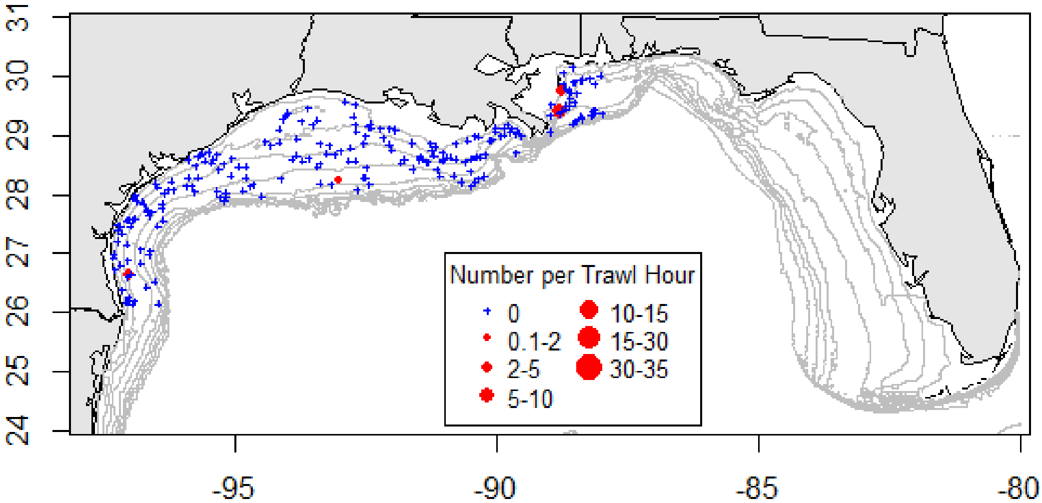

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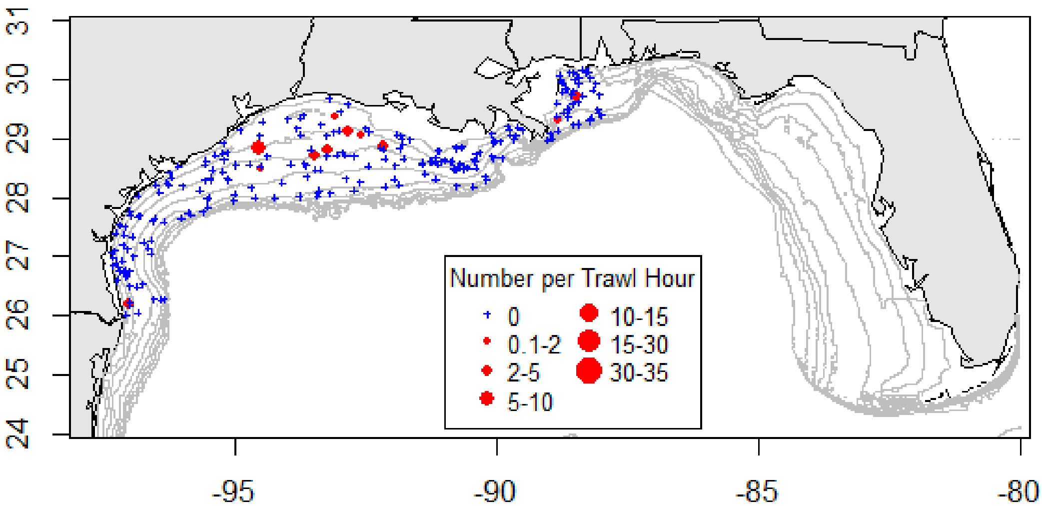

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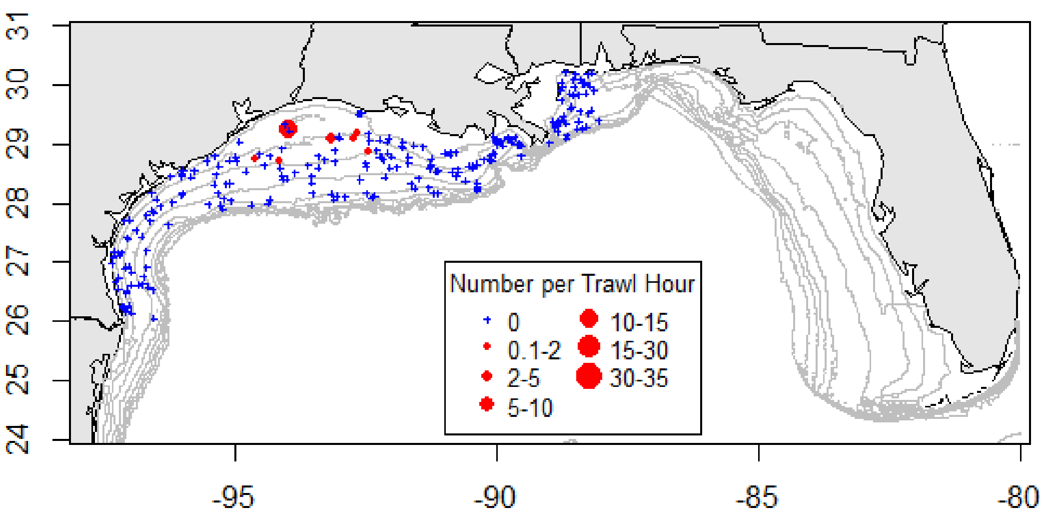

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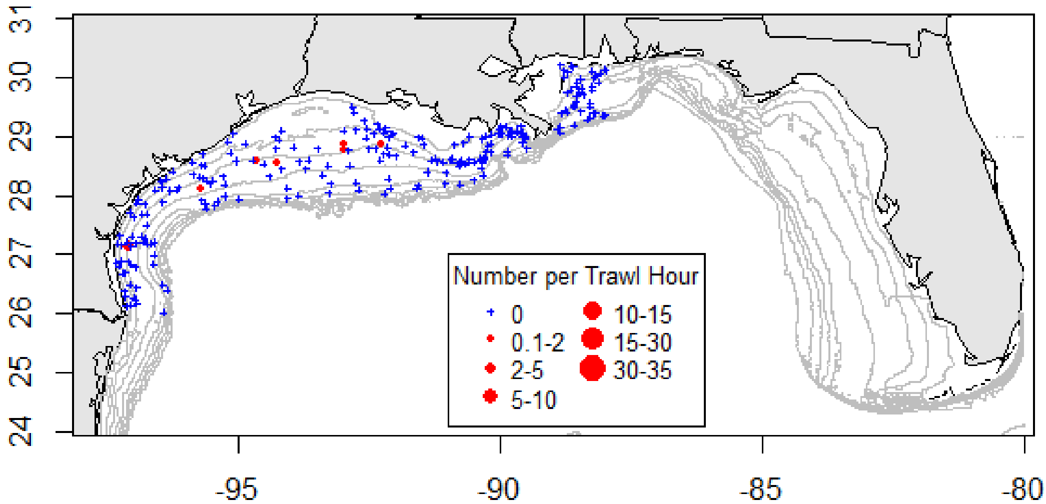

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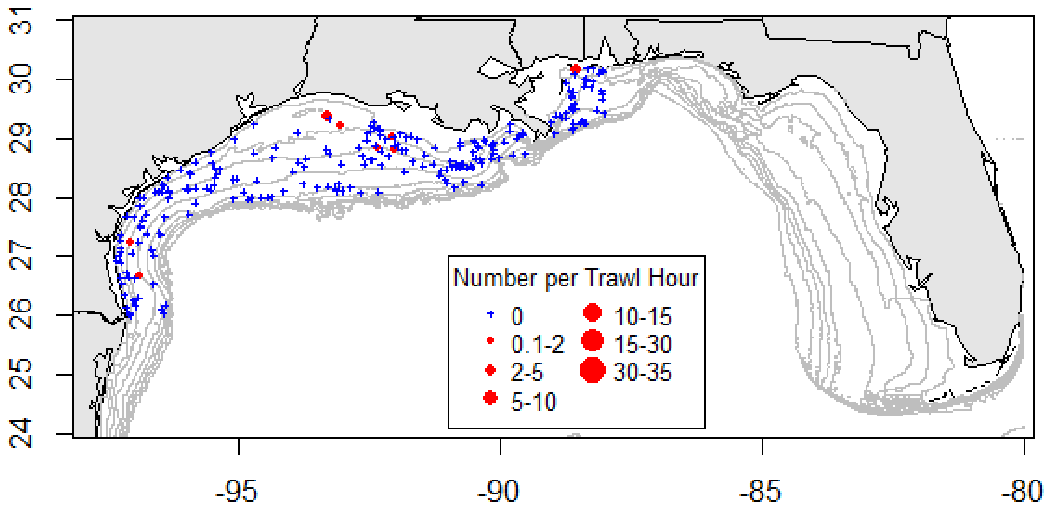

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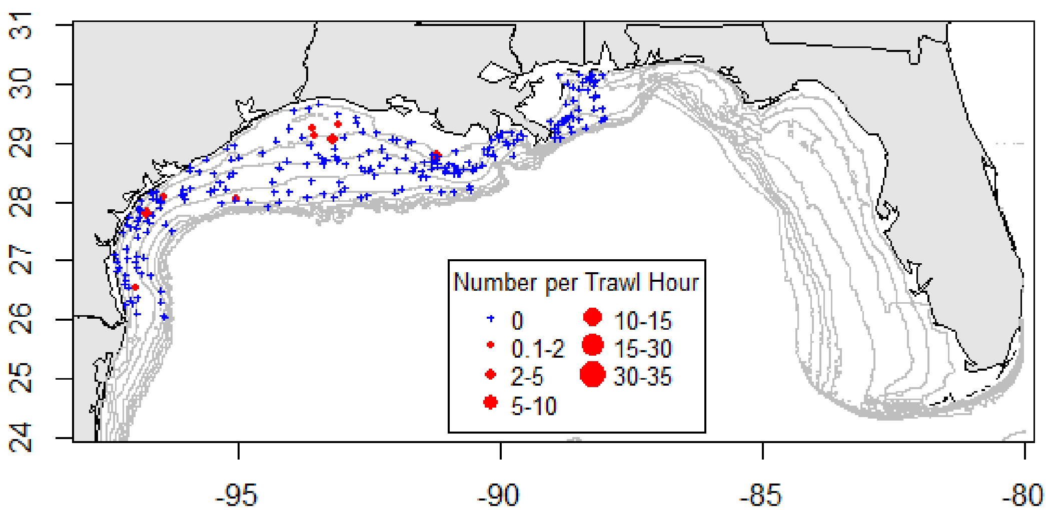

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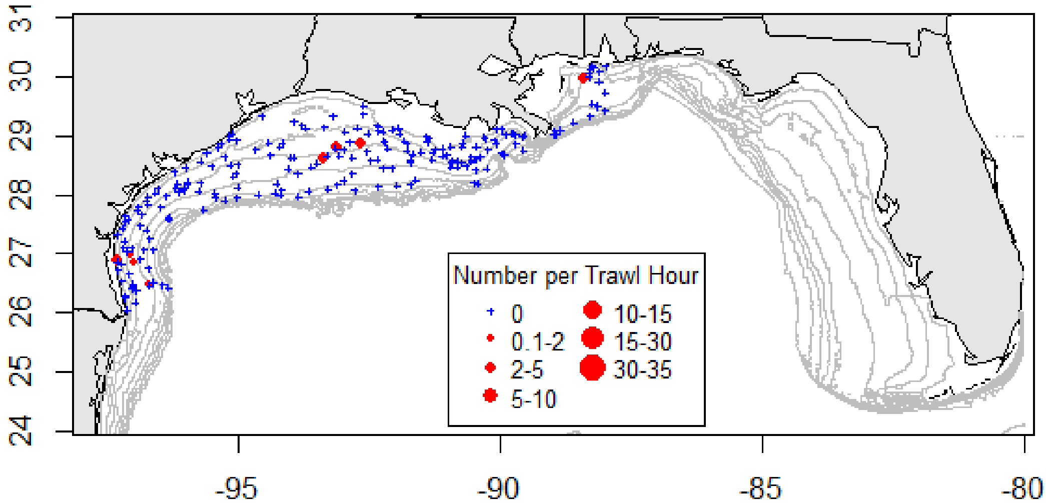

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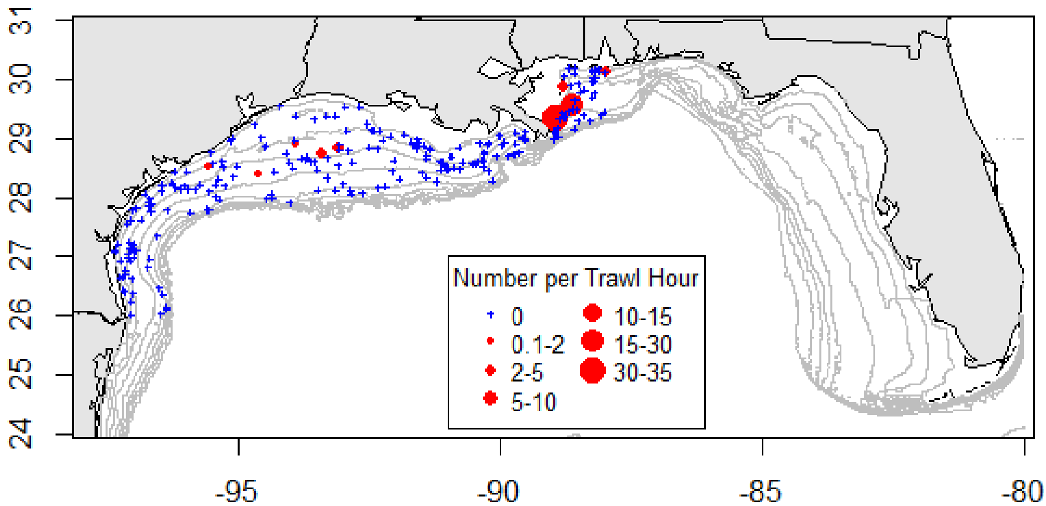

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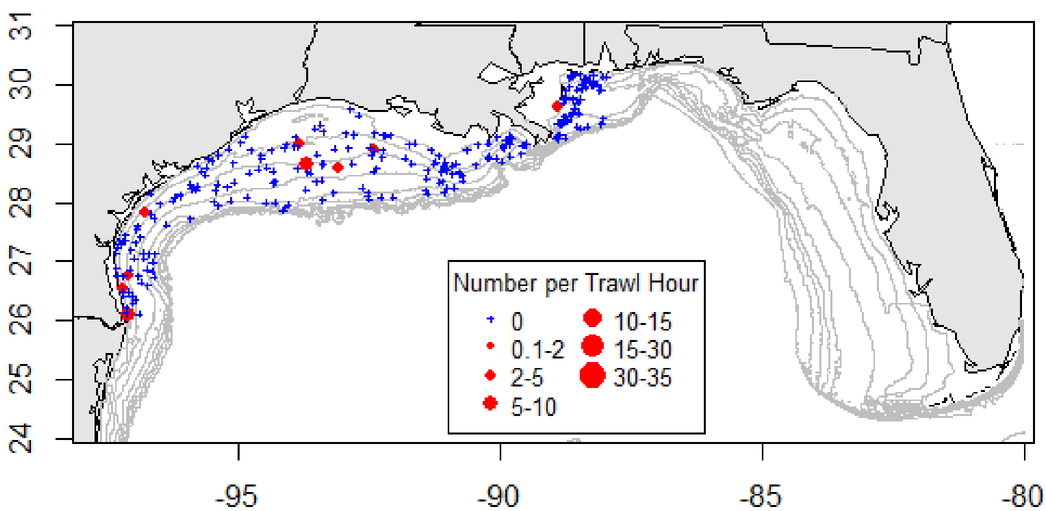

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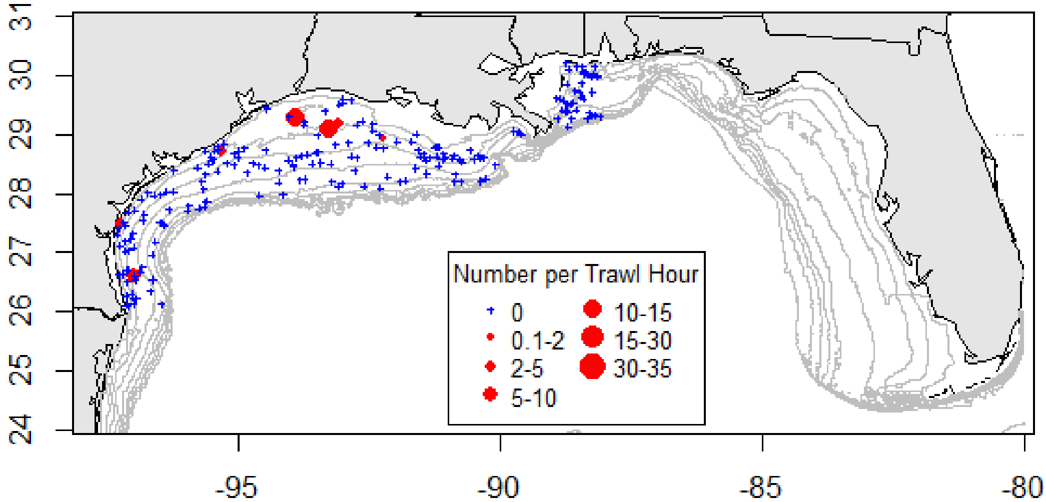

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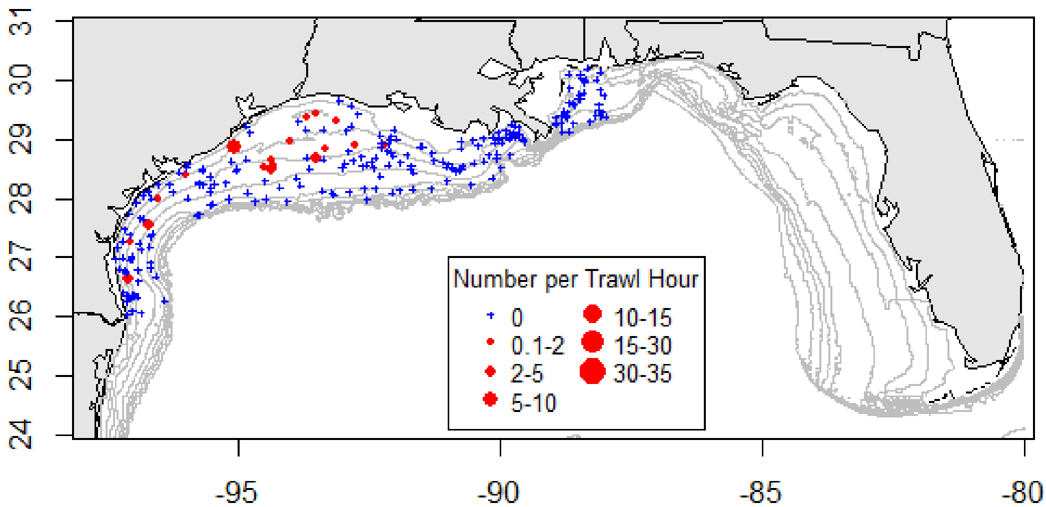
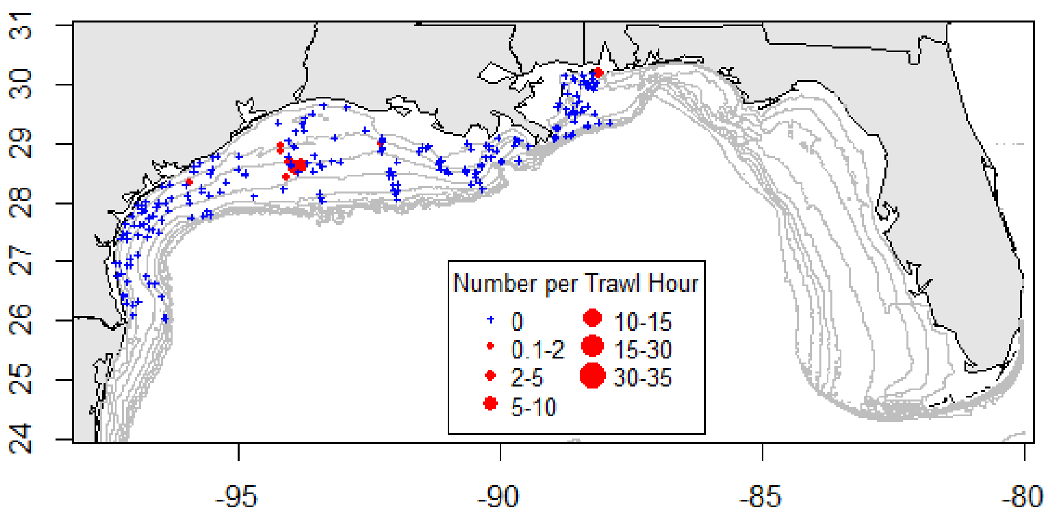


Fall SEAMAP Groundfish Bonnethead 2006



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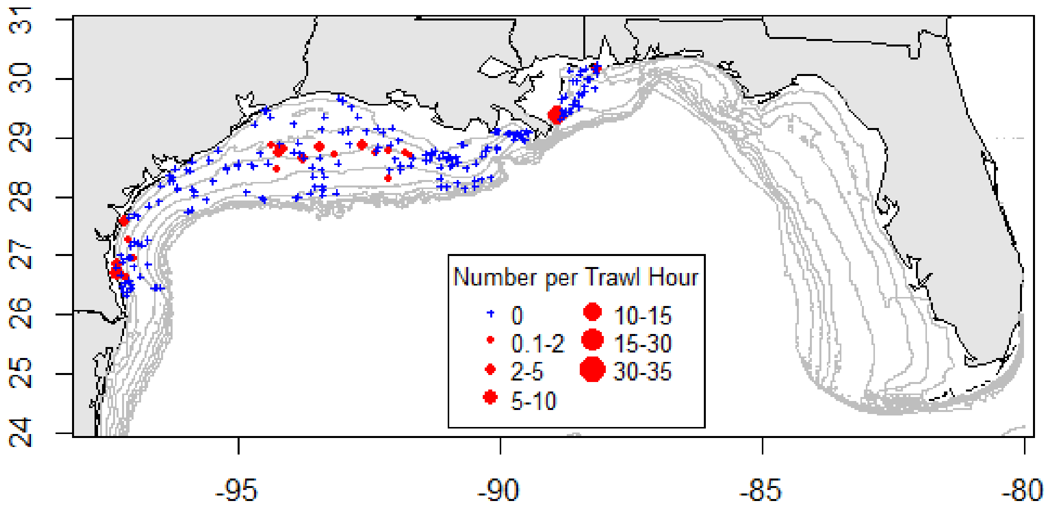
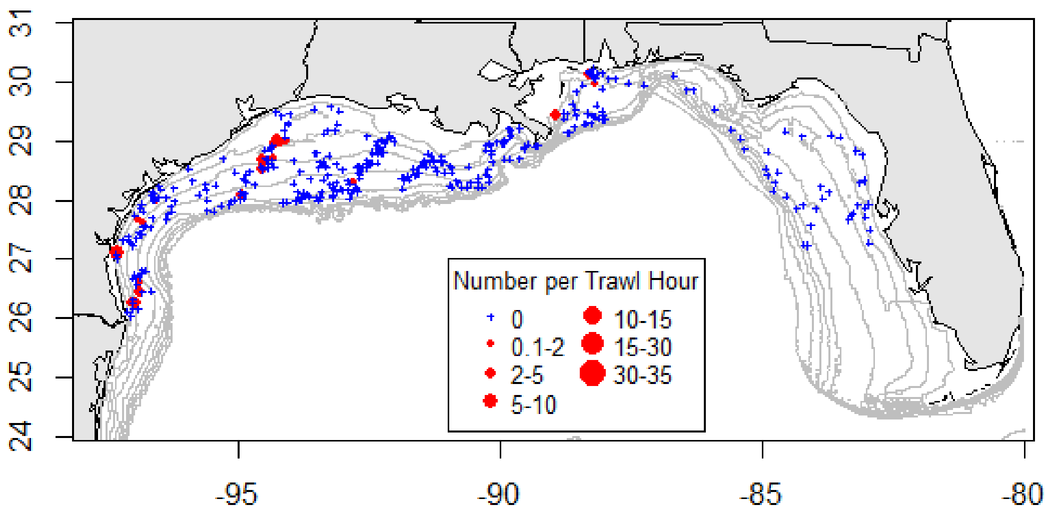


Fall SEAMAP Groundfish Bonnethead 2008



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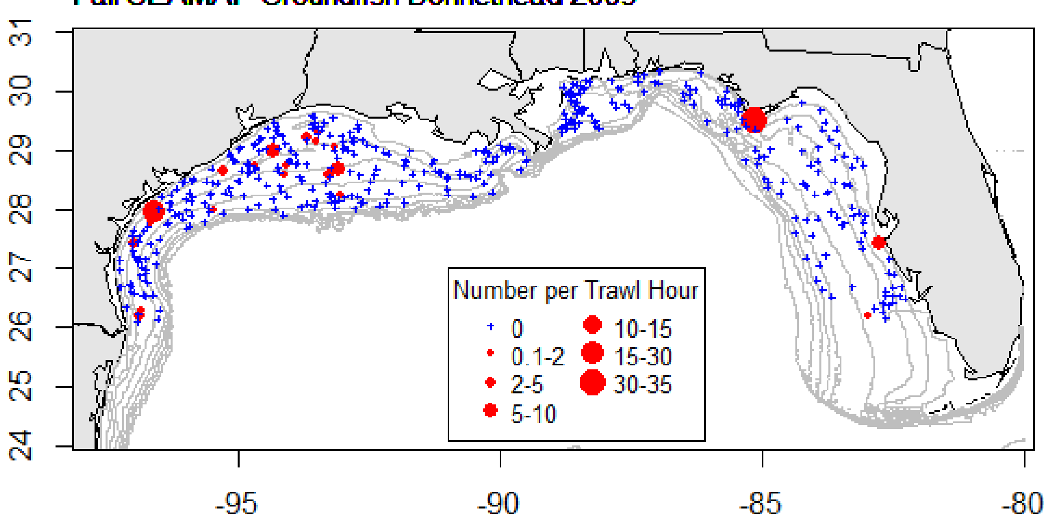

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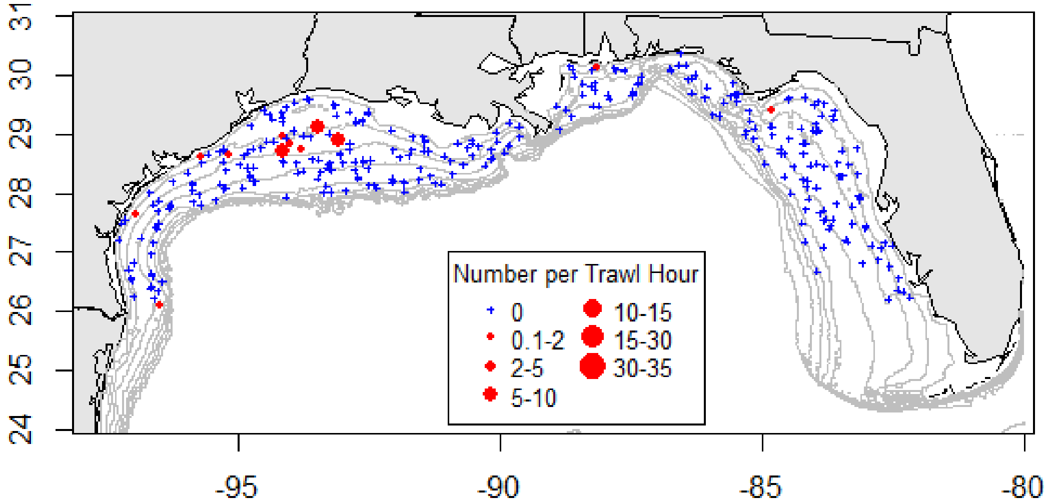

Fall SEAMAP Groundfish Bonnethead 2011