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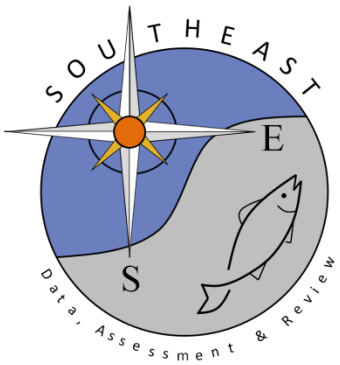

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Sandbar Shark Abundance Indices from NMFS Bottom Longline Surveys in the Northern Gulf of Mexico

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Abstract: *The Southeast Fisheries Science Center Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico, Caribbean, and Western North Atlantic Ocean since 1995. Additionally in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of standardized bottom longline survey effort were maintained from April through October. Data from the MSLABS Bottom Longline Survey and the CSSP Survey were used to produce a relative abundance index for Sandbar Shark. The abundance trend was generally flat from 1995 – 2008. Beginning in 2009 there was a large increase in the relative abundance that has continued through 2015.*

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories (MSLABS) has conducted standardized bottom longline (BLL) surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. The objective of these surveys is to provide fisheries independent data for stock assessment purposes for as many species as possible. These surveys are conducted annually in U.S. waters of the GOM and/or the Atlantic, and provide an important source of fisheries independent information on sharks, snappers and groupers. The evolution of these surveys has been the subject of many documents [e.g., Ingram *et al*. 2005 (LCS05/06-DW-27)] and was not described again in this document.

In 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of survey effort were maintained from April through October (for a full review of the CSSP see Campbell *et al.* 2012). This program was conducted using the same gear as the annual bottom longline survey and a similar survey design. The only difference was the CSSP sampled out to 400 m, whereas, the annual survey samples to a depth of 366 m. The purpose of this document is to provide an abundance index for Sandbar Shark (*Carcharhinus plumbeus*).

Methodology

Survey Design

Details concerning methodologies and evolution of the NMFS BLL have been covered in previous documents (most recently LCS05/06-DW-27) and will not be repeated in this document. Basic sample design was a proportional allocation of stations based on continental

shelf width within statistical zones and stratified by depth (50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m). When the survey began in 1995, J-hooks were the standard gear. Over time a change was made to 15/0 circle hooks. However, Henwood *et al.* (2005) examined the difference in catch rates between the two hooks types and found no significant difference in catch rates for Sandbar Sharks.

Data

Data for the annual BLL survey was obtained from the SEFSC MSLABS Shark Unit and the CSSP data was obtained from SEFSC MSLABS Information Technology Unit. Data from the CSSP was used to fill in gaps in the annual bottom longline survey due to vessel breakdowns and weather delays in 2011. As to not over represent any one area of the GOM, data from the August survey was used for the Eastern GOM, while data from September was used for the Western and Central GOM. These time frames historically match up with when the annual BLL survey sampled those areas. For this document, the combined dataset will be hereafter referred to as NMFS BLL.

Data Exclusions

We used the time series of data between 1995 and 2015 to develop Sandbar Shark abundance indices (Table 1). Depth was used to limit the data, with no stations deeper than 183 m being included, since there were no records of Sandbar Sharks being caught any deeper. In 2005, additional sampling was done in October and November (43 stations) since most of the survey was canceled due to Hurricane Katrina. However, there was little temporal overlap in other years (17 stations in 2004), so all stations done outside of June, July, August and September were removed. After limiting the data, 3,767 stations were used in the analysis.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for Sandbar Shark (Pennington, 1983; Bradu & Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (*cf.* Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) was estimated as:

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

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

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

and

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

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE (c_y) and SE (p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated using the delta method approximation

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

A covariance term is not included in the variance estimator since there is no correlation between the estimator of the proportion positive and the mean CPUE given presence. The two estimators are derived independently and have been shown to not covary for a given year (Christman, unpublished).

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. 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 (GOM)

Year: 1995 – 1997, 1999 – 2015
Depth: 9 – 183 m (continuous)
Area: Atlantic, Eastern GOM, Central GOM, Western GOM
Hook Type: Circle hook, J-hook

Results and Discussion

Size and Distribution

The distribution of Sandbar Shark is presented in Figure 1, with annual abundance and distribution presented in Appendix Figure 1. There were 5 to 163 Sandbar Sharks captured per year (Table 2). Of the 1,184 Sandbar Shark captured, a total of 683 were measured from 1995 – 2015 with an average fork length of 1490 mm. In addition, there were also 481 individuals that only had an estimated length taken, mainly prior to 2005 when a sling was developed to allow for measurements of large sharks (Figure 2). Even with the addition of the estimated lengths, the average fork length only increases to 1497 mm.

Abundance Index

For the NMFS BLL abundance index of Sandbar Shark, year, area and depth were retained in the binomial submodel, while only year was retained in the lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 3 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 18,907.4 and 1,116.3, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 3, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 4 and Figure 4.

Literature Cited

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Table 1. Summary of the total number of stations sampled per year used in the analysis.

Year	Atlantic	Gulf of Mexico			Total
		East	Central	West	
1995	43	34	27	13	117
1996	30	37	25	17	109
1997	64	61	32	71	228
1998					
1999		57	104		161
2000	58	63	51	23	195
2001		114	58	77	249
2002	177	39	67	93	376
2003		144	51	60	255
2004	40	123	55	33	251
2005	27	47			74
2006	58	53	32	43	186
2007		60	32	42	134
2008	37	64	3	21	125
2009	30	80	39	46	195
2010	26	78	26	27	157
2011	49	151	40	53	293
2012	41	63	30	28	162
2013	36	65	40	40	181
2014	46	51	17	23	137
2015	43	74	29	36	182
Total	*805*	*1458*	*758*	*746*	*3767*

Table 2. Summary of the Sandbar Shark length data (measured not estimated) collected from NMFS Bottom Longline surveys conducted between 1995 and 2015.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
1995	117	29	25	850	1830	1388	277
1996	109	12	6	1344	1750	1582	138
1997	228	59	2	1460	1687	1573	161
1998							
1999	161	11	2	1185	1200	1192	11
2000	195	29	3	915	1065	975	80
2001	249	53	4	573	1433	1119	408
2002	376	65	6	844	1620	1376	278
2003	255	45	6	553	1420	958	285
2004	251	34	5	760	1446	1064	246
2005	74	5	5	897	1600	1392	283
2006	186	16	12	905	1690	1414	273
2007	134	27	21	120	2160	1526	204
2008	125	23	17	1195	1630	1403	119
2009	195	85	69	545	1775	1469	199
2010	157	99	53	740	1760	1456	244
2011	293	132	86	1270	1810	1543	104
2012	162	118	97	735	2111	1523	170
2013	181	102	69	575	1901	1508	187
2014	137	77	52	950	1800	1571	126
2015	182	163	143	756	1886	1514	223

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured	Overall Mean Fork Length (mm)
20	3767	1184	683	1490

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for Sandbar Shark index of relative abundance from 1995 to 2015.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 18911.0)*						*Lognormal Submodel Type 3 Tests (AIC 1129.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	3739	145.57	7.66	<.0001	<.0001	19	579	2.36	0.0010
Depth	1	3739	4.73	4.73	0.0297	0.0297	1	579	3.49	0.0623
Area	3	3739	33.22	11.07	<.0001	<.0001	3	579	1.93	0.1235
Hook Type	1	3739	0.38	0.38	0.5358	0.5358	1	579	0.29	0.5886
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 18907.4)*						*Lognormal Submodel Type 3 Tests (AIC 1128.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	3740	166.26	8.75	<.0001	<.0001	19	580	2.70	0.0001
Depth	1	3740	4.72	4.72	0.0298	0.0299	1	580	3.42	0.0649
Area	3	3740	33.21	11.07	<.0001	<.0001	3	580	1.91	0.1274
Hook Type				Dropped				Dropped		
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 18907.4)*						*Lognormal Submodel Type 3 Tests (AIC 1123.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	3740	166.26	8.75	<.0001	<.0001	19	583	2.60	0.0003
Depth	1	3740	4.72	4.72	0.0298	0.0299	1	583	2.34	0.1270
Area	3	3740	33.21	11.07	<.0001	<.0001		Dropped		
Hook Type				Dropped				Dropped		
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 18907.4)*						*Lognormal Submodel Type 3 Tests (AIC 1116.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	3740	166.26	8.75	<.0001	<.0001	19	585	2.57	0.0003
Depth	1	3740	4.72	4.72	0.0298	0.0299		Dropped		
Area	3	3740	33.21	11.07	<.0001	<.0001		Dropped		
Hook Type				Dropped				Dropped		

Table 4. Indices of Sandbar Shark abundance developed using the delta-lognormal model for 1995-2015. 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
1995	0.17094	117	0.21488	0.79034	0.24825	0.48462	1.28891
1996	0.08257	109	0.10990	0.40422	0.37906	0.19425	0.84117
1997	0.10088	228	0.19935	0.73323	0.23672	0.45964	1.16965
1998							
1999	0.06211	161	0.08995	0.33085	0.36197	0.16400	0.66742
2000	0.09744	195	0.13709	0.50423	0.26062	0.30197	0.84195
2001	0.12048	249	0.20537	0.75535	0.20680	0.50165	1.13735
2002	0.11170	376	0.15145	0.55703	0.17850	0.39089	0.79379
2003	0.11765	255	0.17020	0.62599	0.20899	0.41398	0.94659
2004	0.10757	251	0.13113	0.48230	0.21983	0.31234	0.74475
2005	0.06757	74	0.04899	0.18018	0.51554	0.06824	0.47577
2006	0.06452	186	0.08287	0.30480	0.33119	0.15988	0.58109
2007	0.10448	134	0.21422	0.78790	0.30261	0.43588	1.42422
2008	0.13600	125	0.16240	0.59730	0.27527	0.34789	1.02551
2009	0.23590	195	0.40878	1.50353	0.16031	1.09332	2.06764
2010	0.26752	157	0.47825	1.75905	0.16705	1.26234	2.45119
2011	0.21502	293	0.37066	1.36333	0.14070	1.03035	1.80391
2012	0.34568	162	0.63563	2.33789	0.13944	1.77131	3.08570
2013	0.23204	181	0.44292	1.62907	0.16709	1.16897	2.27026
2014	0.25547	137	0.47991	1.76513	0.18471	1.22372	2.54608
2015	0.34426	182	0.70371	2.58829	0.13265	1.98745	3.37077

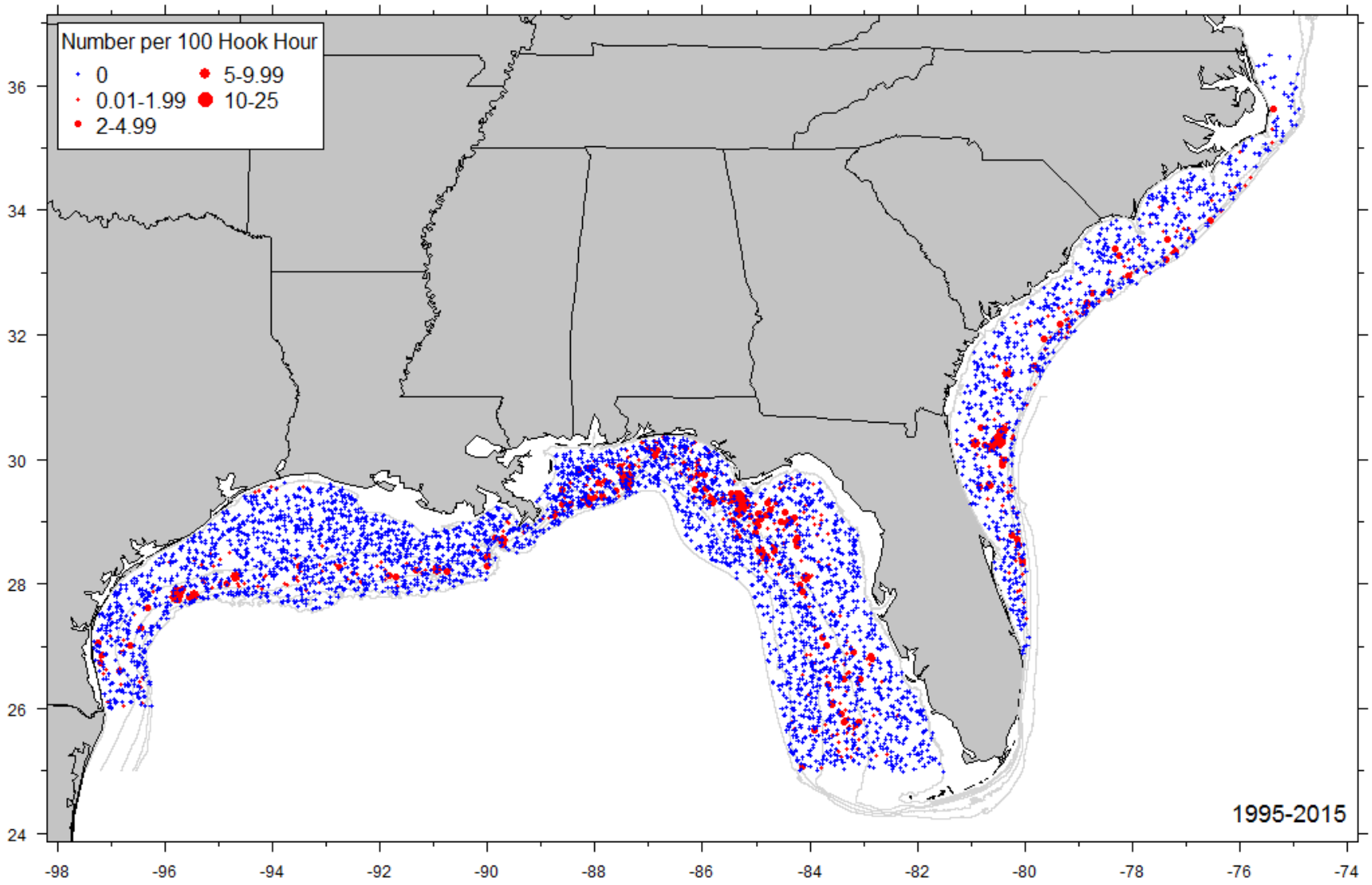


Figure 1. Stations sampled from 1995 to 2015 during the NMFS Bottom Longline Survey with the CPUE for Sandbar Shark.

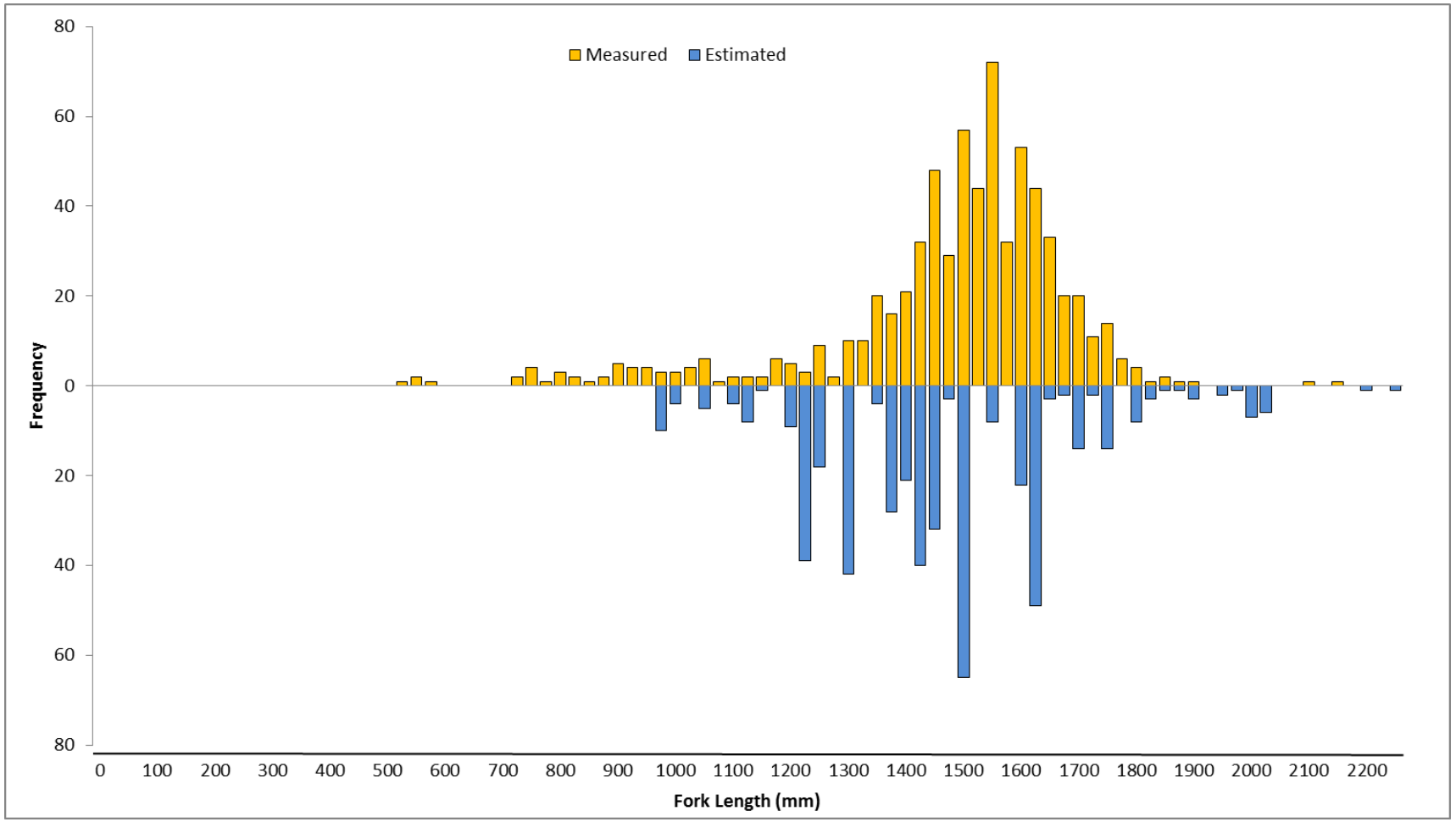


Figure 2. Length frequency histogram for measured and length estimated Sandbar Sharks captured in the Atlantic and Gulf of Mexico during the NMFS Bottom Longline Survey from 1995-2015.

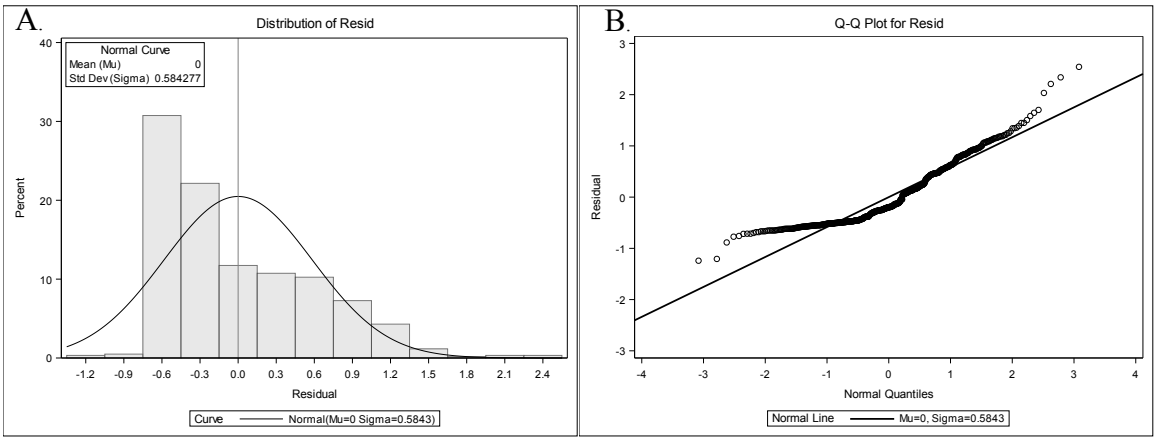


Figure 3. Diagnostic plots for lognormal component of the Sandbar Shark NMFS Bottom Longline Surveys model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

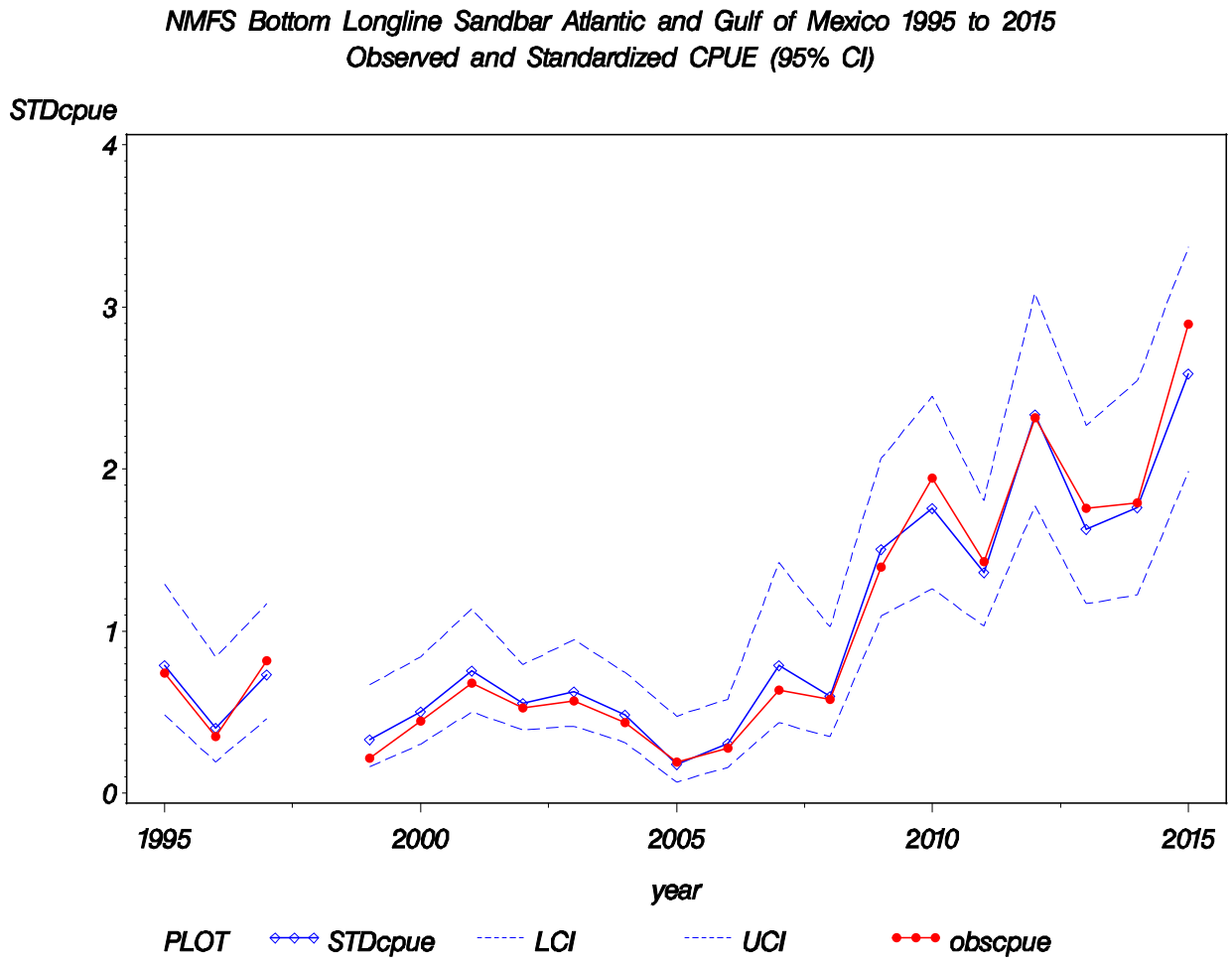


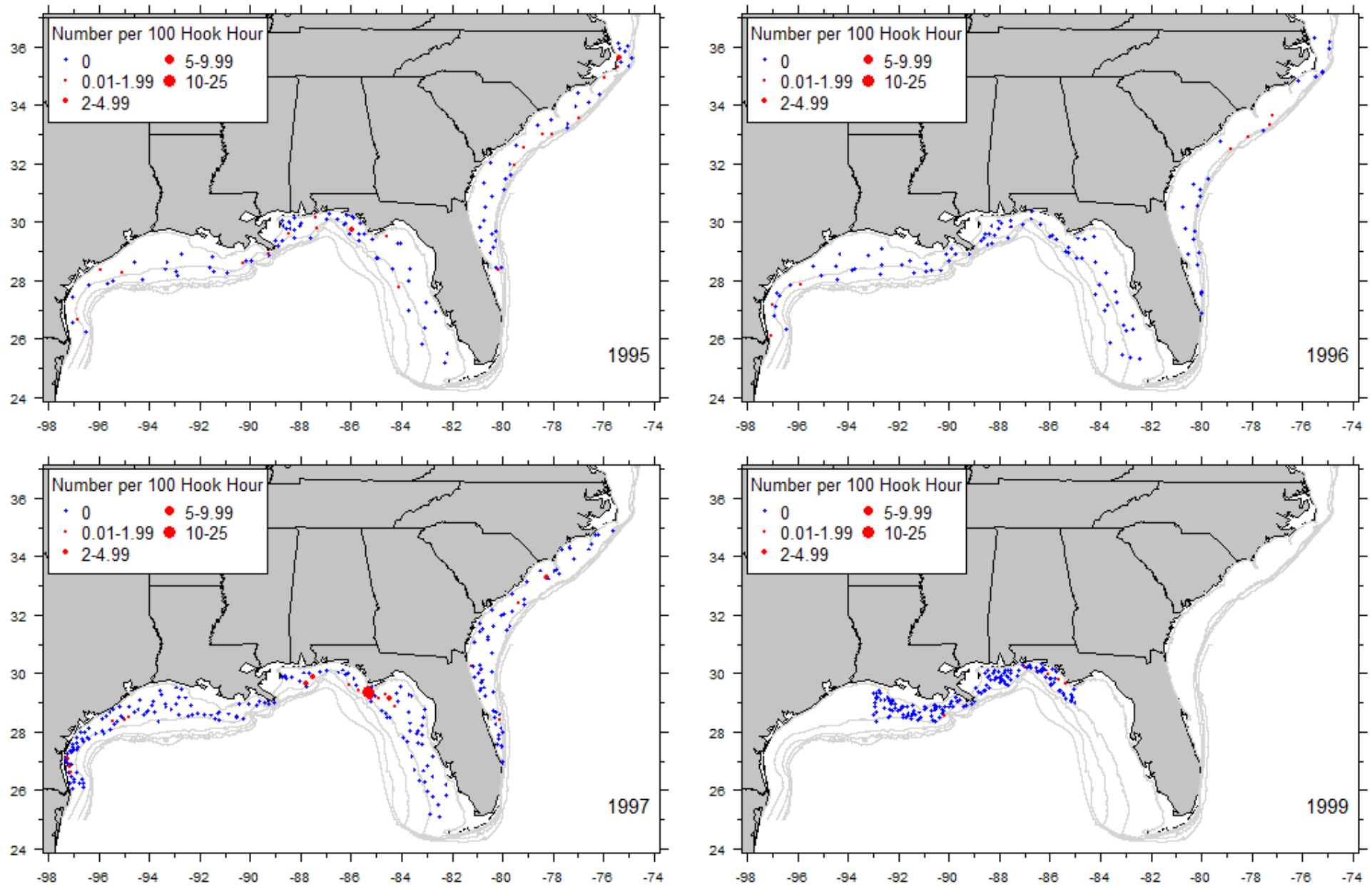
Figure 4. Annual index of abundance for Sandbar Shark from the NMFS Bottom Longline Surveys from 1995 – 2015.

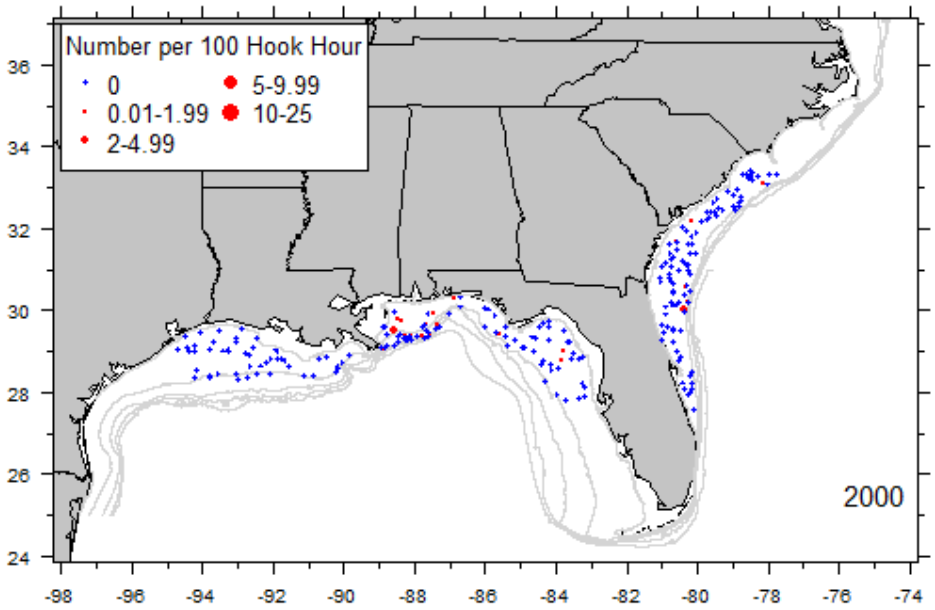
Appendix

Appendix Table 1. Summary of the factors used in constructing the Sandbar Shark abundance index from the NMFS bottom longline survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	1995	117	20	0.17094	0.22762
Year	1996	109	9	0.08257	0.10666
Year	1997	228	23	0.10088	0.25123
Year	1999	161	10	0.06211	0.06646
Year	2000	195	19	0.09744	0.13670
Year	2001	249	30	0.12048	0.20910
Year	2002	376	42	0.11170	0.16221
Year	2003	255	30	0.11765	0.17440
Year	2004	251	27	0.10757	0.13368
Year	2005	74	5	0.06757	0.05898
Year	2006	186	12	0.06452	0.08559
Year	2007	134	14	0.10448	0.19568
Year	2008	125	17	0.13600	0.17699
Year	2009	195	46	0.23590	0.42849
Year	2010	157	42	0.26752	0.59702
Year	2011	293	63	0.21502	0.43920
Year	2012	162	56	0.34568	0.71169
Year	2013	181	42	0.23204	0.53905
Year	2014	137	35	0.25547	0.55002
Year	2015	183	63	0.34426	0.88890
Area	Atlantic	806	152	0.18859	0.36327
Area	Eastern GOM	1458	282	0.19342	0.37171
Area	Central GOM	758	76	0.10026	0.21426
Area	Western GOM	746	95	0.12735	0.20345
Hook Type	Circle hook	3051	533	0.17470	0.33685
Hook Type	J hook	717	72	0.10042	0.16900

Appendix Figure 1. Annual survey effort and catch of Sandbar Shark from the NMFS bottom longline survey (1995-2015).

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5-9.99
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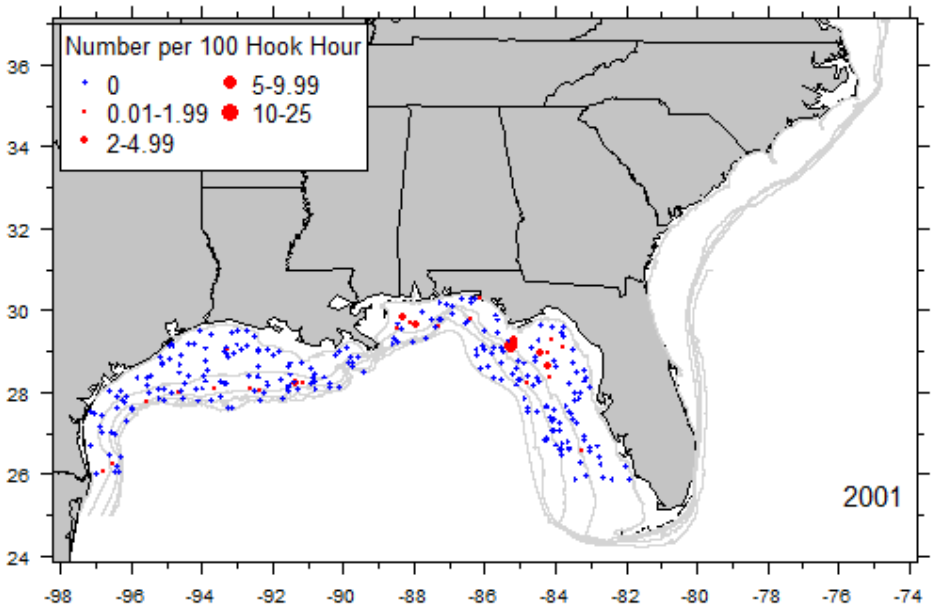
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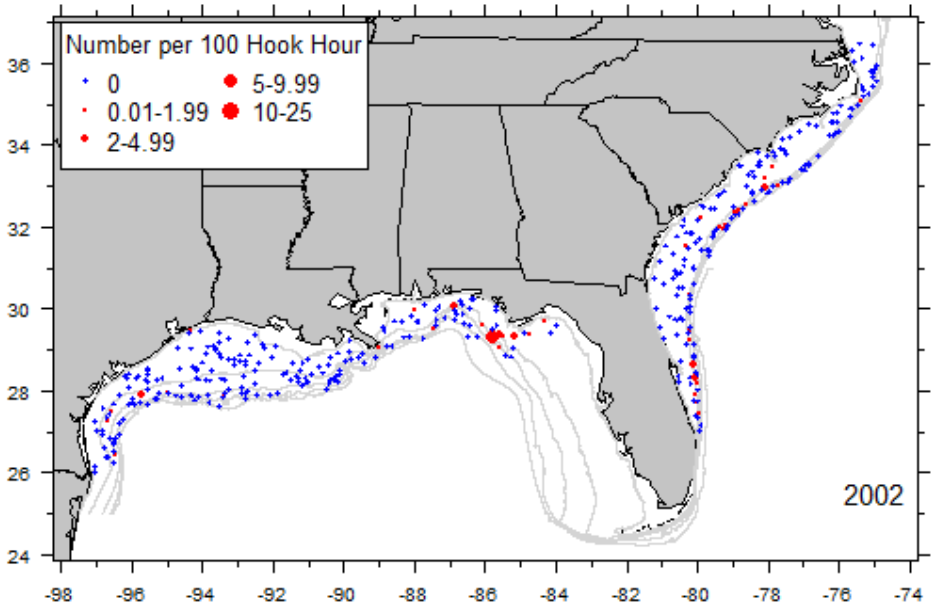
5-9.99
10-25
2001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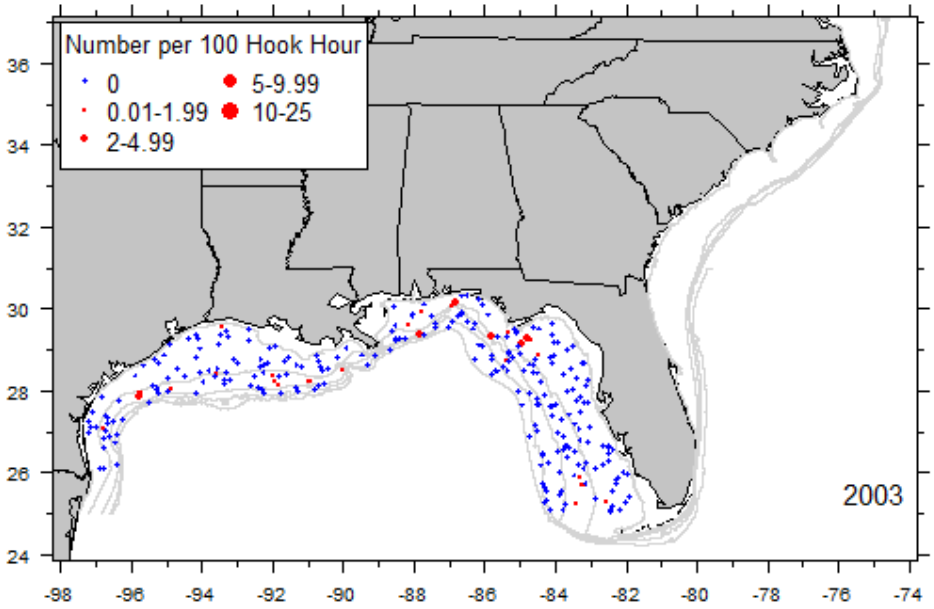
2-4.99
5-9.99
10-25
2002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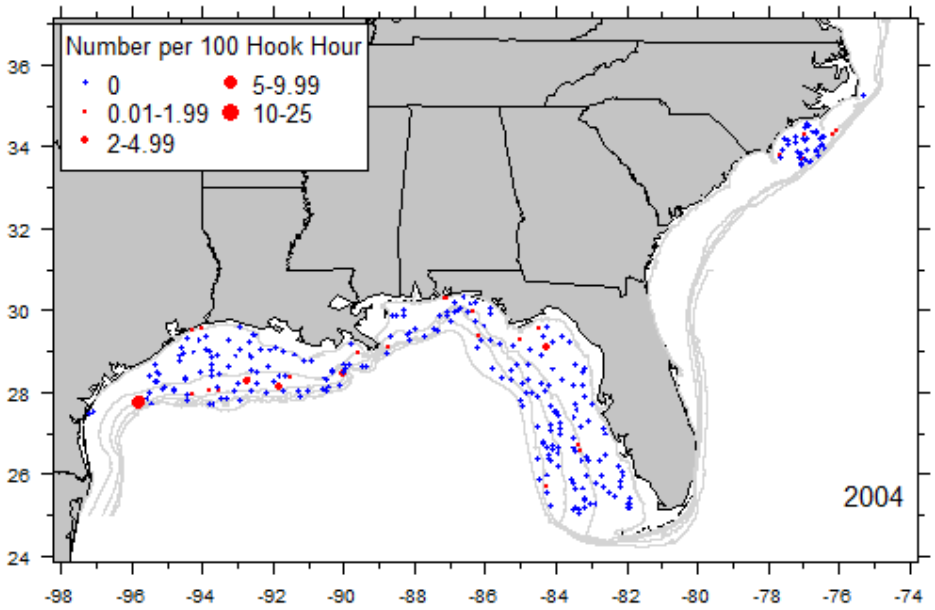
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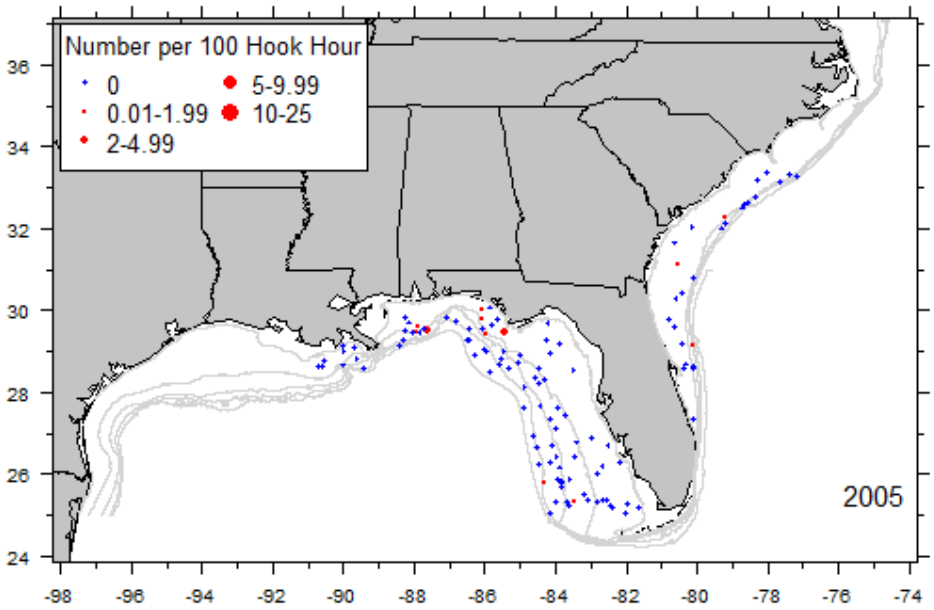
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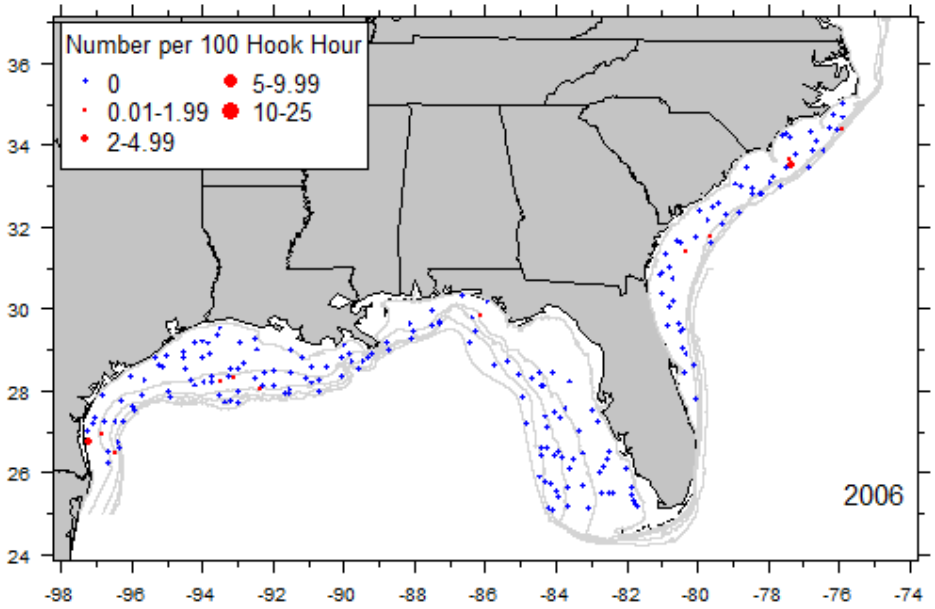
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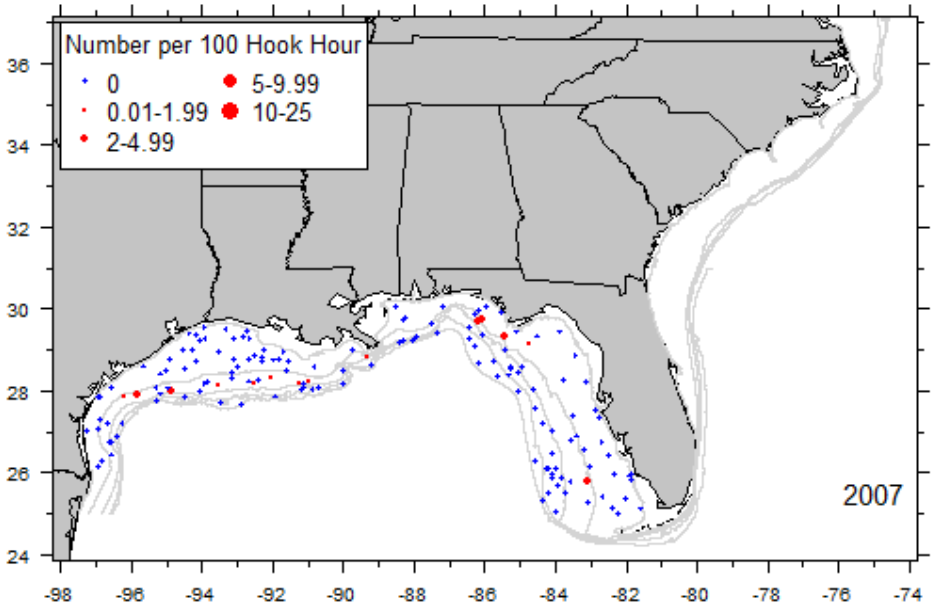
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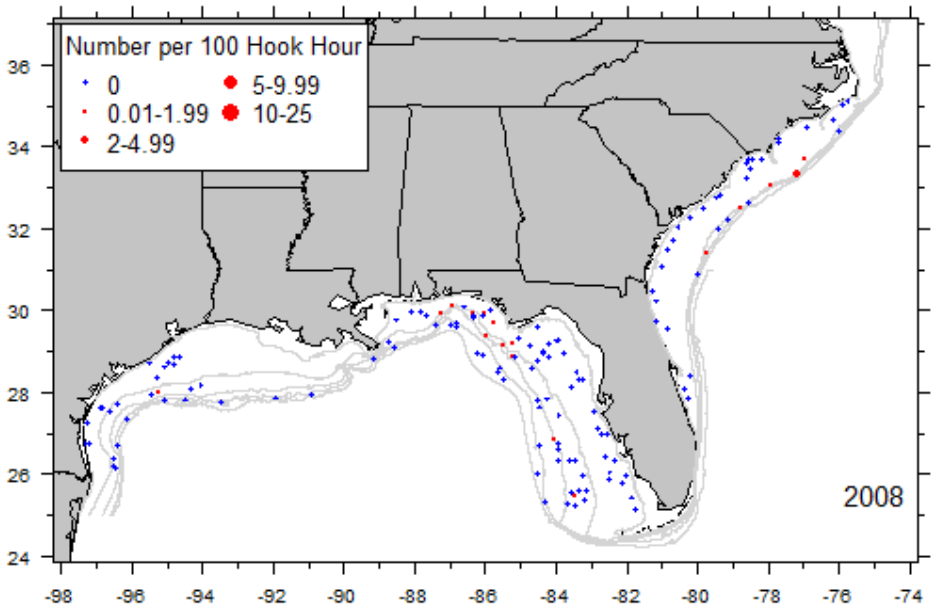
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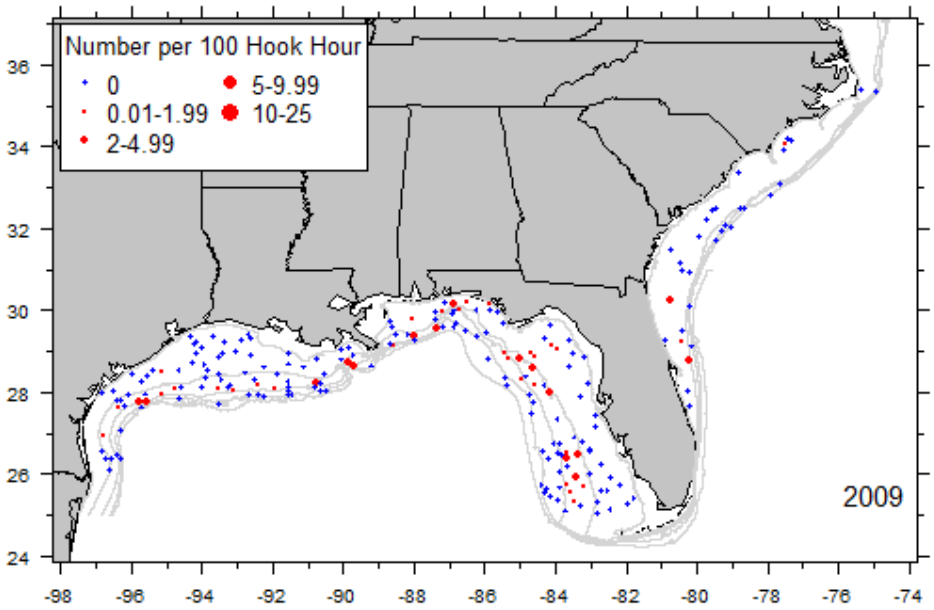
2-4.99
5-9.99
10-25
2008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10-25
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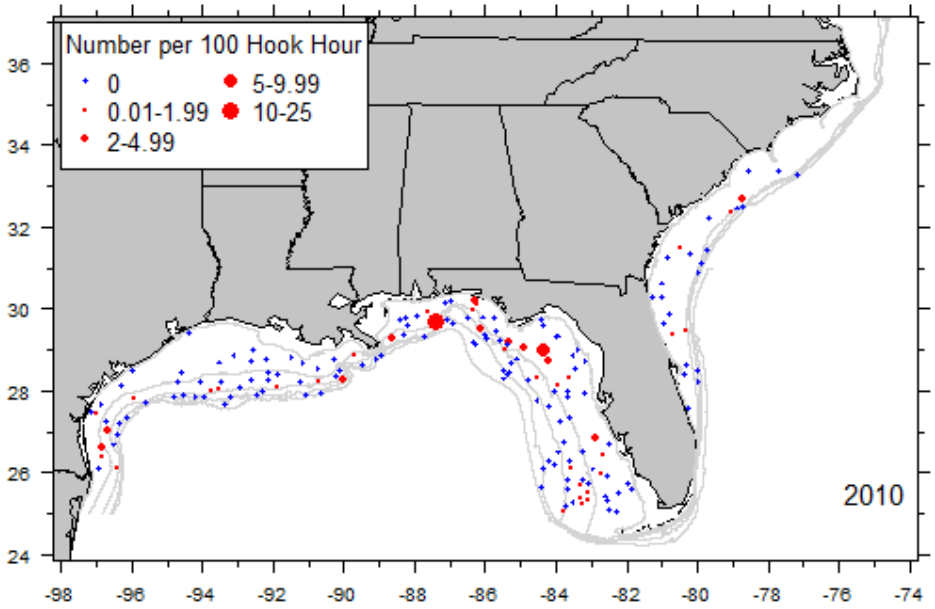
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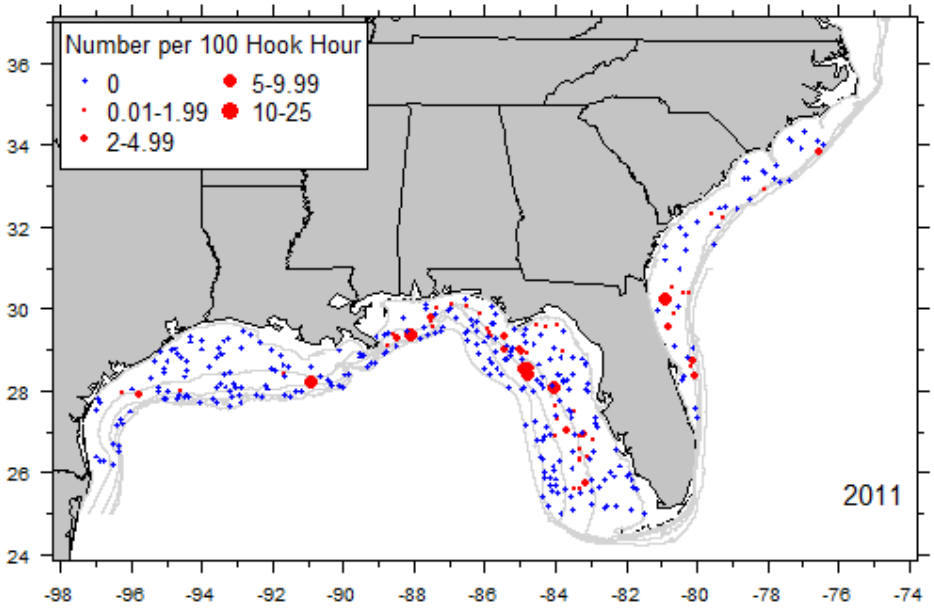
10-25
2010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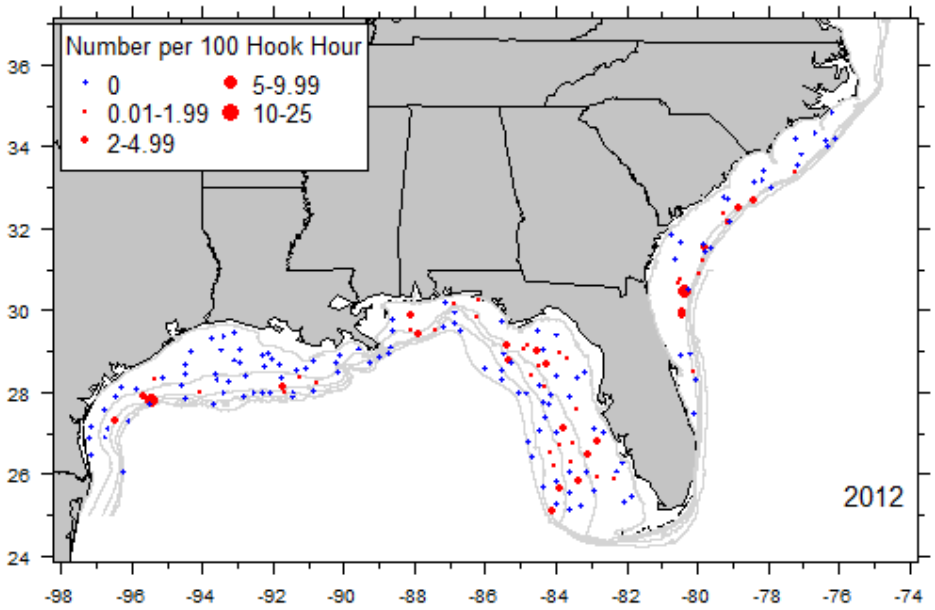
2-4.99
5-9.99
10-25
2011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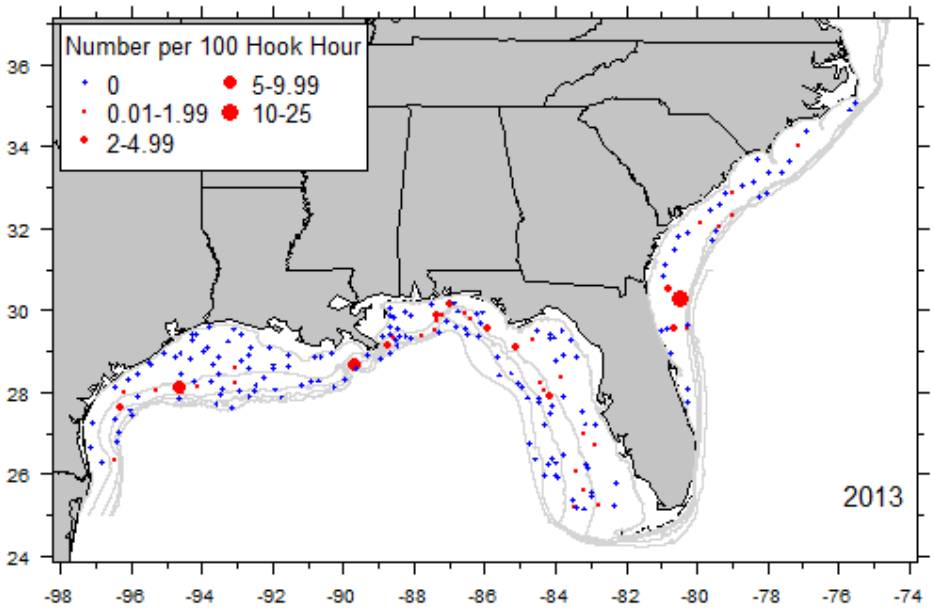
10-25
2012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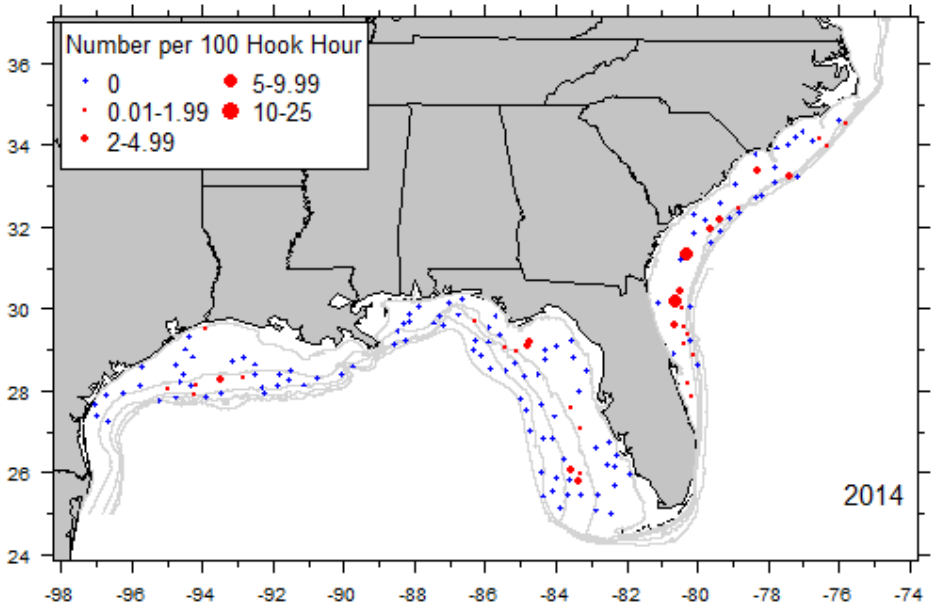
5-9.99
10-25
2013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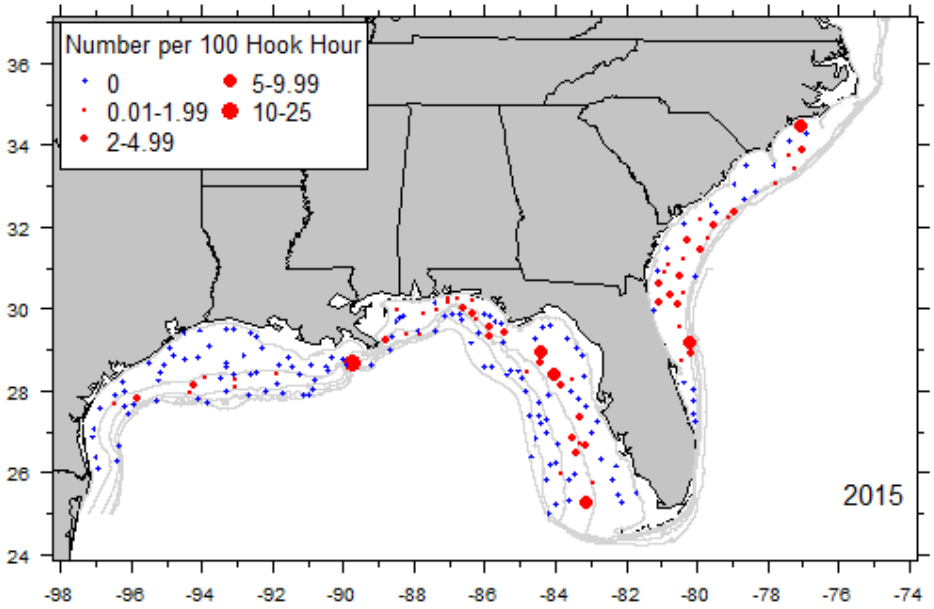
2-4.99
5-9.99
10-25
2014


Number per 100 Hook Hour
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0.01-1.99
2-4.99
5-9.99
10-25
2015