Standardized catch rates of Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) collected during a bottom longline survey in Mississippi coastal waters, 2004-2011

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STANDARDIZED CATCH RATES OF ATLANTIC SHARPNOSE SHARKS (*RHIZOPRIONODON TERRAENOVAE*) COLLECTED DURING A BOTTOM LONGLINE SURVEY IN MISSISSIPPI COASTAL WATERS, 2004-2011.

Eric R. Hoffmayer[1], Jill M. Hendon[2], and Adam G. Pollack[1]

In 2004, a standardized monthly (March to October) bottom longline survey, conducted in Mississippi coastal waters, was initiated. This fisheries independent dataset was developed to monitor the abundance and distribution of various elasmobranch and teleost species within Mississippi state waters. As a result of 323 sets and 418 hours of effort, 733 Atlantic sharpnose sharks were caught. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution. Other than a slight decline observed in the standardized index for 2008 and 2009, Atlantic sharpnose shark catch rates remained stable across the time series.

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INTRODUCTION

The University of Southern Mississippi Gulf Coast Research Laboratory (GCRL) developed a standardized bottom longline survey within Mississippi state waters of the Mississippi Sound. This survey was initiated in 2004 and has been conducted annually during the months of March to October. The Mississippi bottom longline survey is funded by the Mississippi Department of Marine Resources through the U.S. Fish and Wildlife Service (Sport Fish Restoration Act). The primary objective of this survey is to collect data on the seasonal abundance and distribution of local shark and teleost species in Mississippi coastal waters.

METHODOLOGY

Sampling Locations

From 2004 to 2011 sharks were collected at various sites along the Mississippi coast from Petit Bois Island to St. Louis Bay. In general, collections were made from March to October with five to seven locations sampled each month. Sampling was confined to the waters of the Mississippi Sound, which was broken into twelve 10.6 km^2 sampling regions, from which monthly sampling locations were randomly selected. The sampling regions included eastern and western Cat, East and West Ship, Deer, eastern and western Horn, Round, Sand, and eastern and western Petit Bois Islands (Figure 1).

Sampling Protocol

Sampling was conducted with a 152.4 m bottom longline that consisted of 50 1.0 m gangions (2.0 mm) outfitted with 12/0 circle hooks and baited with menhaden (*Brevoortia patronus*). The longline was typically fished between the hours of 0800 and 2000, and was allowed to fish for 1 hour prior to retrieval. The soak time was defined by the time between the setting of the first hook and the retrieval of the last hook. Each captured shark was removed from the gear, identified by species and sex (and maturity, if possible), measured (fork length, FL) and weighed (kg) prior to release. Water temperature (°C), salinity, and dissolved oxygen (mg/l) were measured at the water's surface and bottom at each sampling location. Water depth (m) and latitude and longitude were also recorded at each station.

Analysis

For the purpose of analysis, age-0 or young-of-the-year (YOY) sharks were excluded from the abundance index for Atlantic sharpnose sharks resulting in an age-1+ index. Catch rates were standardized as catch per unit effort (CPUE) in sharks per 100 hook * hour. Length frequency distributions were constructed for Atlantic sharpnose sharks ranging from 350 to 900 mm FL using 50 mm increments.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for Atlantic sharpnose sharks (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) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \text{Cov}(c, p),$$

where:

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

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 $\alpha = 0.10$. 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.

For all indices developed, the factors YEAR, MONTH, AREA, SET TIME, MONTHLY RAINFALL (MONTHLY R), PREVIOUS MONTH RAINFALL (PREV MON R), BOTTOM (BOT) TEMPERATURE (TEMP), SALANITY (SAL), and DISSOLVED OXYGEN (DO) were examined for inclusion in the catch rate models. The factor MONTH includes the months that sampling was conducted from March to October. The Mississippi Sound was divided into four zones (east to west 1 to 4) which is represented by the factor AREA. The factor SET TIME refers to the time of day the bottom longline was first deployed at the sampling location. The factors MONTHLY R and PREV MON R included the mean monthly and previous monthly rainfall (inches) in Mississippi's three coastal counties, and was obtained through NOAA's regional climate center website (http://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers). The factors DEPTH, TEMP, SAL, and DO included values present in the data set. The factor YEAR included each year in the time series from 2004 to 2011, and was included in the model whether it explained the data or not, so that an annual catch rate series was produced.

RESULTS

From 2004 to 2011, 323 locations in Mississippi coastal waters were sampled resulting in 418 hours of effort. During this time 733 Atlantic sharpnose sharks were captured (Figure 2). The total number of Atlantic sharpnose sharks caught each year ranged from 47 to 124 sharks (Table 1). Approximately 55% of the stations contained positive catches of Atlantic sharpnose sharks.

Atlantic sharpnose sharks ranged in size from 360 to 912 mm FL (mean: 656.5 ± 4.1 mm FL). The length frequency histogram (Figure 3) indicated that 92.6% of the sharks were between 450 and 800 mm FL. Two peaks were prominent in the data set; one between 450-550 mm FL and the other between 600-800 mm FL (Figure 3). The nominal CPUE and number of stations with a positive catch for Atlantic sharpnose sharks are presented in Figures 4-5, which indicated annual variation in nominal CPUE, with varying proportion of positive catches over the years.

Atlantic Sharpnose Shark Catch

For the Atlantic sharpnose shark model, YEAR, MONTH, AREA, and SALBOT were retained in the binomial submodel and the variables retained in the lognormal submodel were YEAR, MONTH, and AREA. Table 2 summarizes the 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 1567.5 and 455.5, respectively. 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 Figure 8 and Table 3. Nominal and standardized Atlantic sharpnose catch rates remained relatively stable throughout the survey with a slight decline in abundance occurring in standardized index during 2008 and 2009 (Figure 8).

REFERENCES

Carlson, J.K., J.R. Sulikowski, and I.E. Baremore. 2006. Do differences in life history exist for blacktip sharks, *Carcharhinus limbatus*, from the United States South Atlantic Bight and Eastern Gulf of Mexico? Environmental Biology of Fishes 25:279-292.

Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

Ortiz, M. 2006. Standardized catch rates for gag grouper (*Mycteroperca microlepis*) from the marine recreational fisheries statistical survey (MRFSS). Southeast Data Assessment and Review (SEDAR) Working Document S10 DW-09

Parsons, G.R. and E.R. Hoffmayer. (2005). Seasonal changes in the distribution and availability of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, in the north central Gulf of Mexico. Copeia 2005:313-319.

Parsons, G.R. and E.R. Hoffmayer. 2007. Identification and characterization of shark nursery grounds along the Mississippi and Alabama gulf coasts. *In:* Shark nursery grounds of the U.S. Atlantic and Gulf of Mexico. (Eds. C. McCandless). AFS Publication 50:301-316.

Table 1. Summary of the Atlantic sharpnose shark data used in these analyses collected during the Mississippi bottom longline survey conducted between 2004 and 2011.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2004	46	119	114	360	912	704	99
2005	27	65	65	510	840	710	82
2006	34	105	101	431	835	625	106
2007	43	114	107	435	885	653	121
2008	31	47	46	482	845	687	92
2009	31	56	56	473	821	670	91
2010	57	124	117	432	825	649	105
2011	54	103	98	421	804	583	110
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
8	323	733	704			656	

Table 2. Summary of the backward selection procedure for building delta-lognormal submodels for Atlantic sharpnose shark full index of relative abundance from 2004 to 2011.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 1620.6)*						*Lognormal Submodel Type 3 Tests (AIC 501.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	133	17.24	2.40	0.0159	0.0242	7	155	1.04	0.4034
Month	7	235	30.67	4.37	<.0001	0.0001	7	155	1.82	0.0863
Area	3	250	20.35	6.78	0.0001	0.0002	3	155	5.03	0.0023
Set_Time	1	196	0.90	0.90	0.3436	0.3448	1	155	0.01	0.9192
Tempbot	1	217	0.00	0.00	0.9815	0.9816	1	155	0.27	0.6043
Salbot	1	232	8.04	8.04	0.0046	0.0050	1	155	0.07	0.7961
DObot	1	223	0.43	0.43	0.5107	0.5113	1	155	0.02	0.8989
Monthly_R	1	136	0.97	0.97	0.3258	0.3275	1	155	0.06	0.8029
Prev_Mon_R	1	203	0.11	0.11	0.7396	0.7400	1	155	0.17	0.6795

Model Run #2	*Binomial Submodel Type 3 Tests (AIC 1617.9)*						*Lognormal Submodel Type 3 Tests (AIC 479.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	131	18.84	2.62	0.0087	0.0144	7	156	1.07	0.3822
Month	7	244	31.69	4.52	<.0001	<.0001	7	156	1.95	0.0660
Area	3	254	20.93	6.97	0.0001	0.0002	3	156	5.08	0.0022
Set_Time	1	199	0.92	0.92	0.3382	0.3393			Dropped	
Tempbot					Dropped		1	156	0.27	0.6050
Salbot	1	234	8.94	8.94	0.0028	0.0031	1	156	0.07	0.7979

Model Run #2	*Binomial Submodel Type 3 Tests (AIC 1617.9)*						*Lognormal Submodel Type 3 Tests (AIC 479.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
DObot	1	223	0.44	0.44	0.5055	0.5062	1	156	0.02	0.8911
Monthly_R	1	132	1.01	1.01	0.3148	0.3166	1	156	0.06	0.8080
Prev_Mon_R	1	206	0.11	0.11	0.7419	0.7423	1	156	0.18	0.6687

Model Run #3	*Binomial Submodel Type 3 Tests (AIC 1613.0)*						*Lognormal Submodel Type 3 Tests (AIC 475.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	124	20.85	2.89	0.0040	0.0078	7	157	1.11	0.3577
Month	7	247	32.52	4.64	<.0001	<.0001	7	157	2.13	0.0439
Area	3	255	21.03	7.01	0.0001	0.0002	3	157	5.32	0.0016
Set_Time	1	199	1.02	1.02	0.3125	0.3137			Dropped	
Tempbot					Dropped		1	157	0.27	0.6010
Salbot	1	238	9.15	9.15	0.0025	0.0028	1	157	0.12	0.7279
DObot	1	224	0.45	0.45	0.5031	0.5038			Dropped	
Monthly_R	1	136	1.64	1.64	0.2004	0.2026	1	157	0.07	0.7893
					Dropped		1	157	0.21	0.6509

Model Run #4	*Binomial Submodel Type 3 Tests (AIC 1610.6)*						*Lognormal Submodel Type 3 Tests (AIC 470.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	124	21.07	2.92	0.0037	0.0073	7	158	1.11	0.3585
Month	7	252	33.32	4.75	<.0001	<.0001	7	158	2.12	0.0441
Area	3	258	22.12	7.37	<.0001	<.0001	3	158	5.31	0.0016
Set_Time	1	201	0.85	0.85	0.3579	0.3590			Dropped	
Tempbot					Dropped		1	158	0.26	0.6094
Salbot	1	240	8.93	8.93	0.0028	0.0031	1	158	0.11	0.7379
DObot					Dropped				Dropped	
Monthly_R	1	141	1.79	1.79	0.1809	0.1831			Dropped	
					Dropped		1	158	0.40	0.5275

Model Run #5	*Binomial Submodel Type 3 Tests (AIC 1603.0)*						*Lognormal Submodel Type 3 Tests (AIC 464.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	122	21.37	2.96	0.0033	0.0067	7	159	1.11	0.3605
Month	7	251	33.43	4.77	<.0001	<.0001	7	159	2.26	0.0319
Area	3	255	23.19	7.73	<.0001	<.0001	3	159	5.43	0.0014
Set_Time					Dropped				Dropped	
Tempbot					Dropped		1	159	0.18	0.6706
Salbot	1	241	8.97	8.97	0.0027	0.0030			Dropped	
DObot					Dropped				Dropped	
Monthly_R	1	147	2.30	2.30	0.1290	0.1311			Dropped	
					Dropped		1	159	0.36	0.5493

Model Run #6	*Binomial Submodel Type 3 Tests (AIC 1567.5)*						*Lognormal Submodel Type 3 Tests (AIC 459.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	121	23.77	3.29	0.0012	0.0031	7	160	1.14	0.3437
Month	7	261	36.88	5.26	<.0001	<.0001	7	160	2.27	0.0316
Area	3	268	22.76	7.58	<.0001	<.0001	3	160	6.52	0.0003
Set_Time					Dropped				Dropped	
Tempbot					Dropped				Dropped	
Salbot	1	244	8.50	8.50	0.0036	0.0039			Dropped	
DObot					Dropped				Dropped	
Monthly_R					Dropped				Dropped	
					Dropped		1	160	0.34	0.5629

Model Run #7	*Binomial Submodel Type 3 Tests (AIC 1567.5)*						*Lognormal Submodel Type 3 Tests (AIC 454.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	121	23.77	3.29	0.0012	0.0031	7	161	1.14	0.3386
Month	7	261	36.88	5.26	<.0001	<.0001	7	161	2.35	0.0258
Area	3	268	22.76	7.58	<.0001	<.0001	3	161	6.61	0.0003
Set_Time					Dropped				Dropped	
Tempbot					Dropped				Dropped	
Salbot	1	244	8.50	8.50	0.0036	0.0039			Dropped	
DObot					Dropped				Dropped	
Monthly_R					Dropped				Dropped	
					Dropped				Dropped	

Table 3. Indices for Atlantic sharpnose shark catch rates from 2004 to 2011 developed using the delta-lognormal model. The nominal frequency of occurrence, the number of samples (n), the Lo Index (numbers per 100 hook per hour), the Lo 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*	*Lo Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
2004	0.56522	46	5.78836	1.55276	0.28523	0.88752	2.71660
2005	0.70370	27	5.65452	1.51685	0.23208	0.95939	2.39824
2006	0.55882	34	4.30951	1.15605	0.34467	0.59151	2.25939
2007	0.72093	43	4.13391	1.10894	0.21722	0.72178	1.70378
2008	0.51613	31	1.68621	0.45234	0.44597	0.19298	1.06023
2009	0.45161	31	1.48623	0.39869	0.53189	0.14693	1.08185
2010	0.63158	57	3.99724	1.07228	0.22880	0.68251	1.68465
2011	0.33333	54	2.76639	0.74210	0.36342	0.36689	1.50101

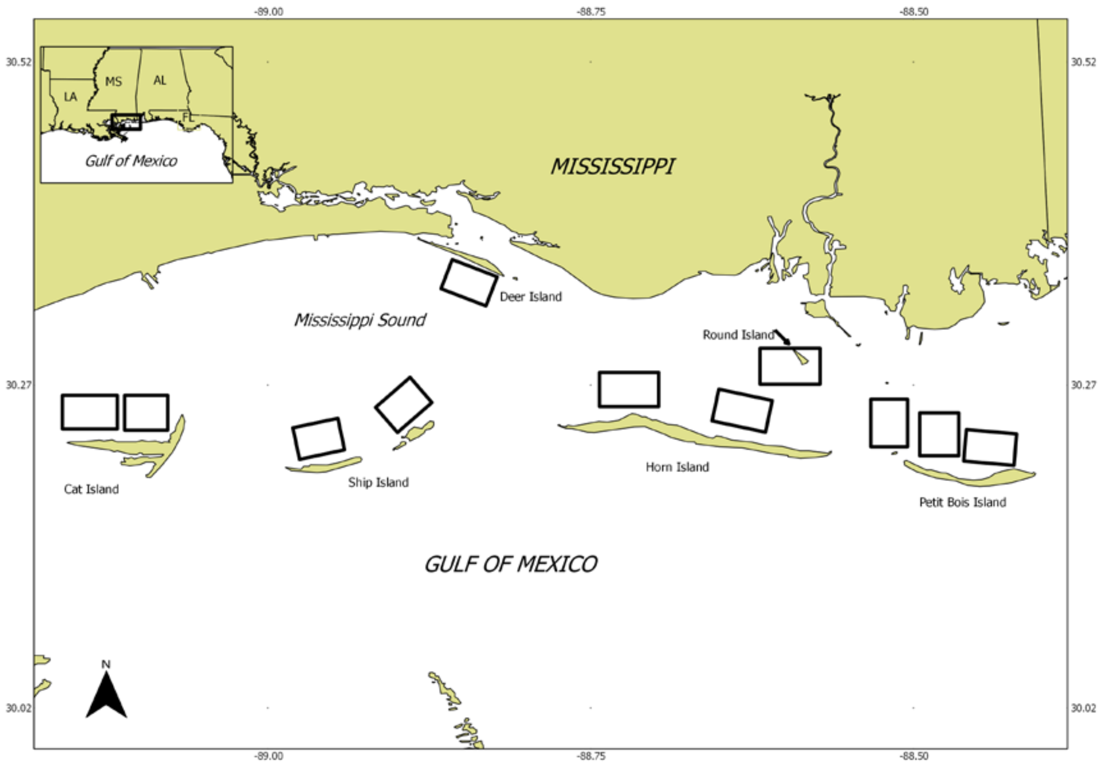


Figure 1. Sampling universe for the Mississippi bottom longline survey. Each rectangle (~10.6 km^2) represents a sampling region where sampling locations were randomly selected.

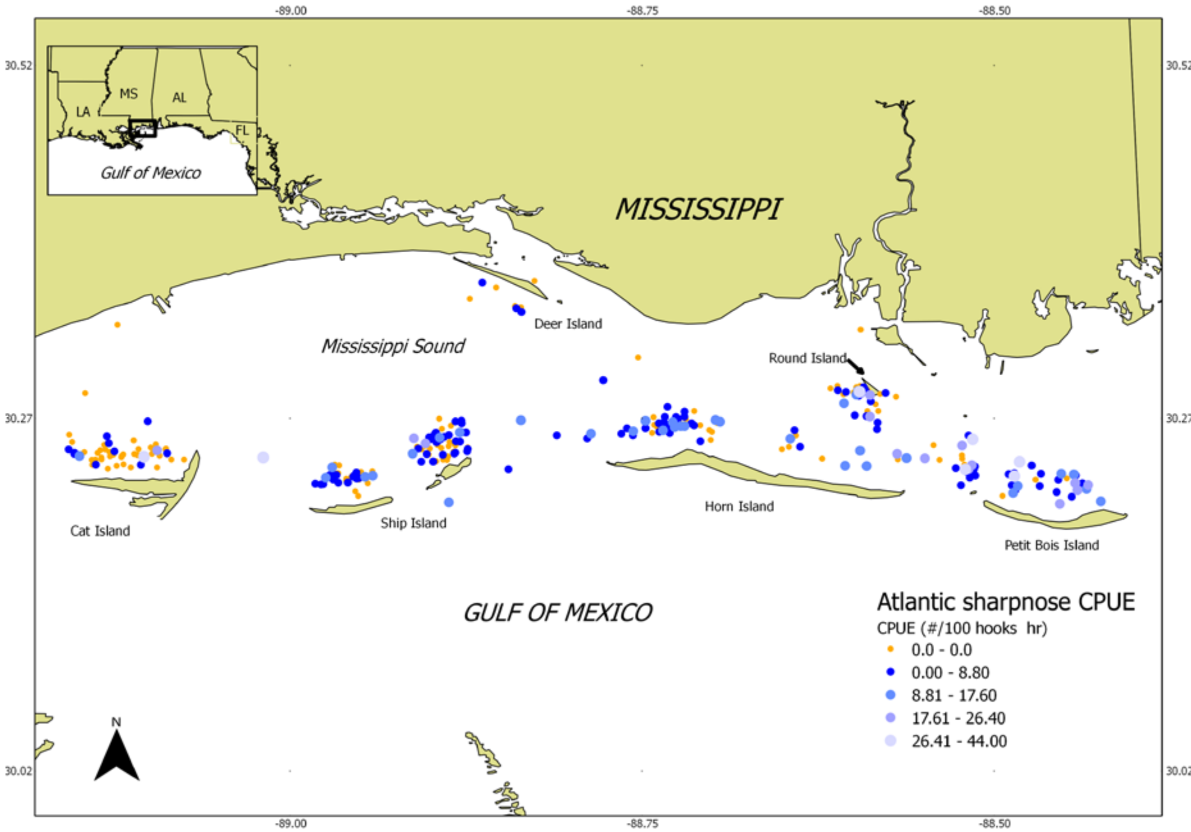


Figure 2. Stations sampled from 2004 to 2011 during the Mississippi bottom longline survey with Atlantic sharpnose shark CPUE presented.

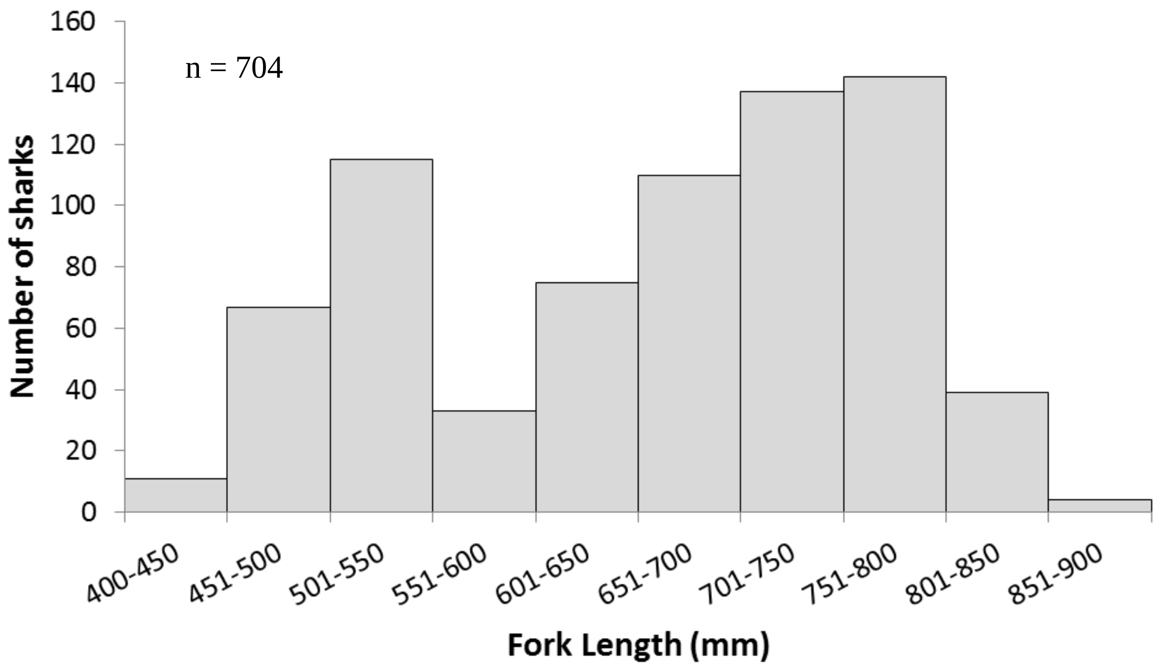


Figure 3. Length frequency distribution for Atlantic sharpnose sharks caught during the Mississippi bottom longline survey from 2004-2011.

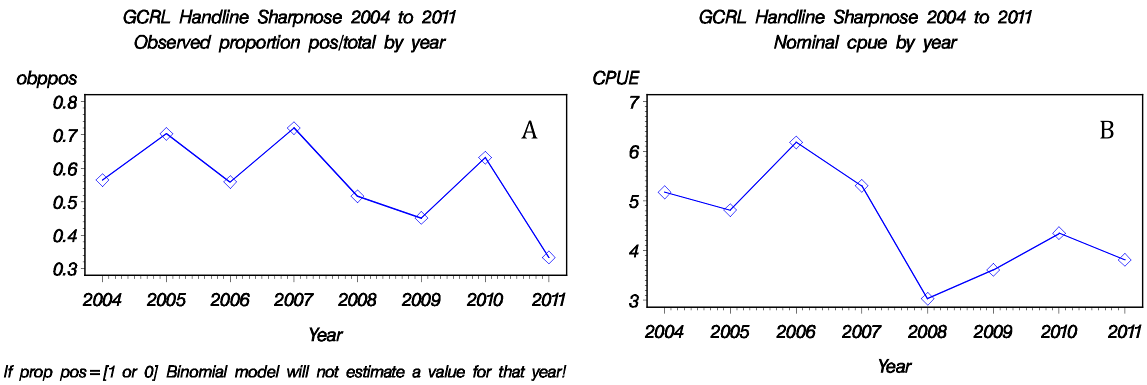


Figure 4. Annual trends for Atlantic sharpnose sharks captured during Mississippi bottom longline surveys from 2004 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

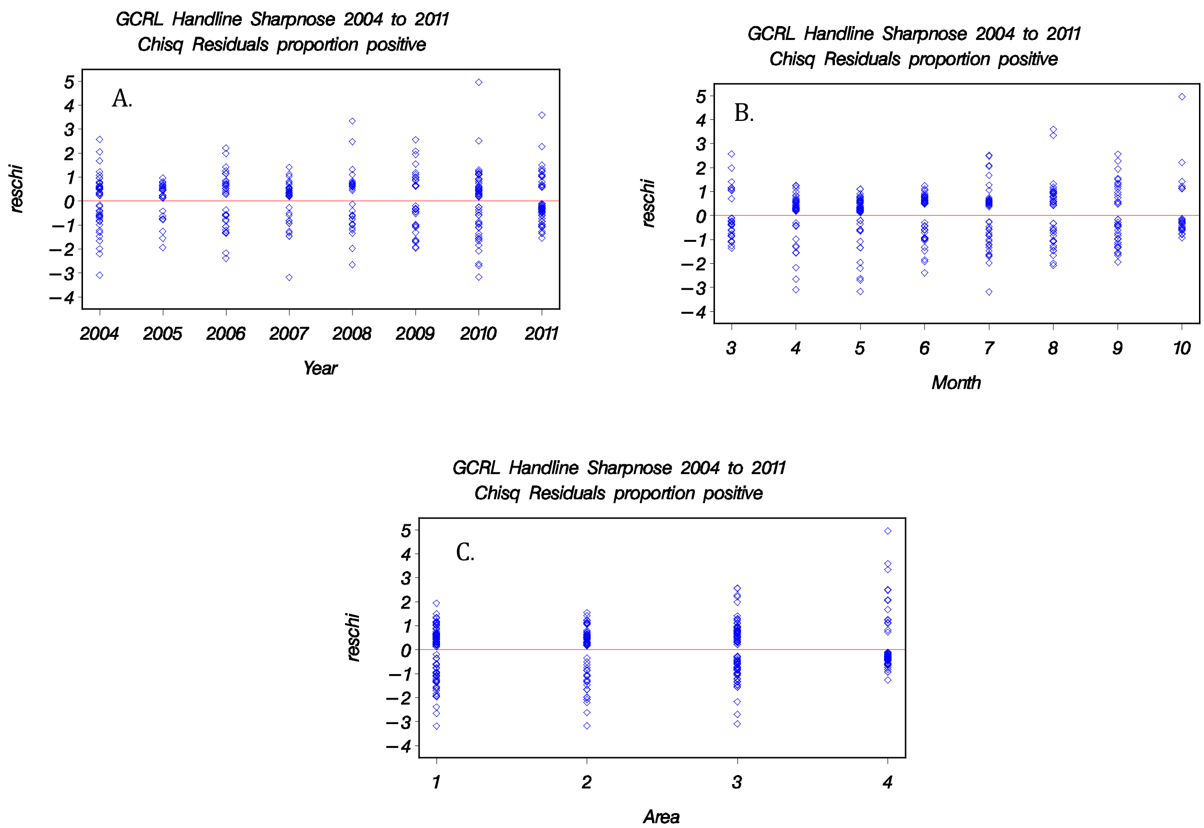


Figure 5. Diagnostic plots for the binomial component of the Atlantic sharpnose shark Mississippi bottom longline survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by month, and **C.** the Chi-Square residuals by area.

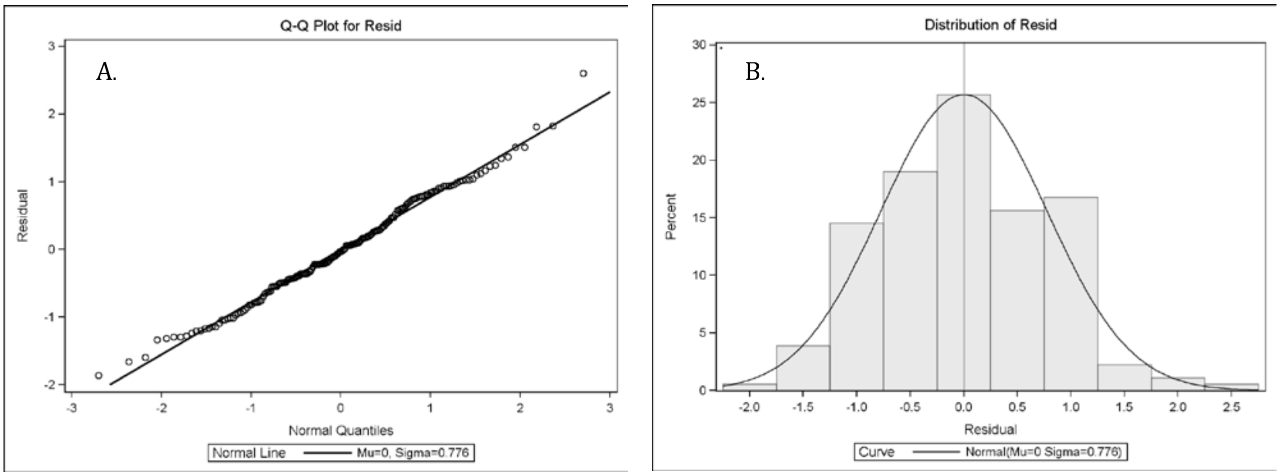


Figure 6. Diagnostic plots for the lognormal component of the Atlantic sharpnose shark Mississippi bottom longline survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

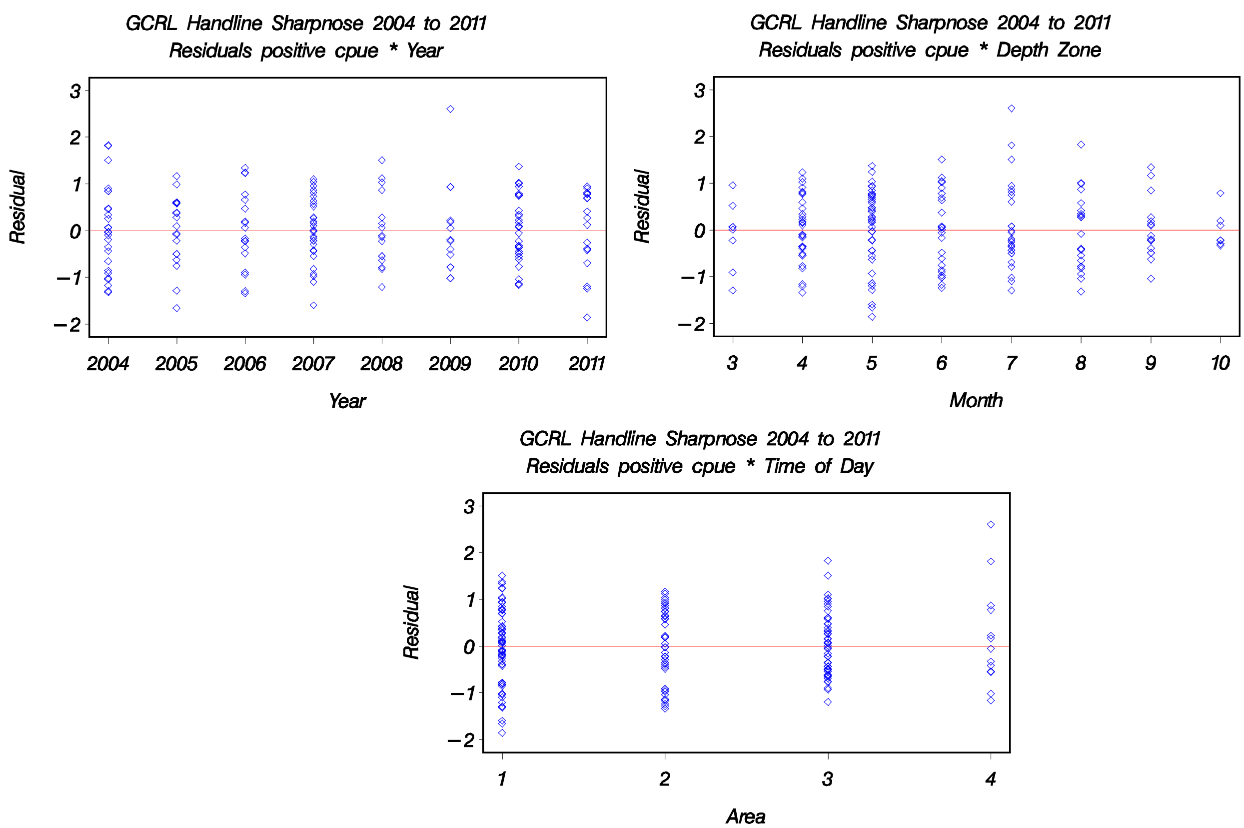


Figure 7. Diagnostic plot of the Chi-Square residuals for the lognormal component of the Atlantic sharpnose shark Mississippi bottom longline survey model: survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by month, and **C.** the Chi-Square residuals by area.

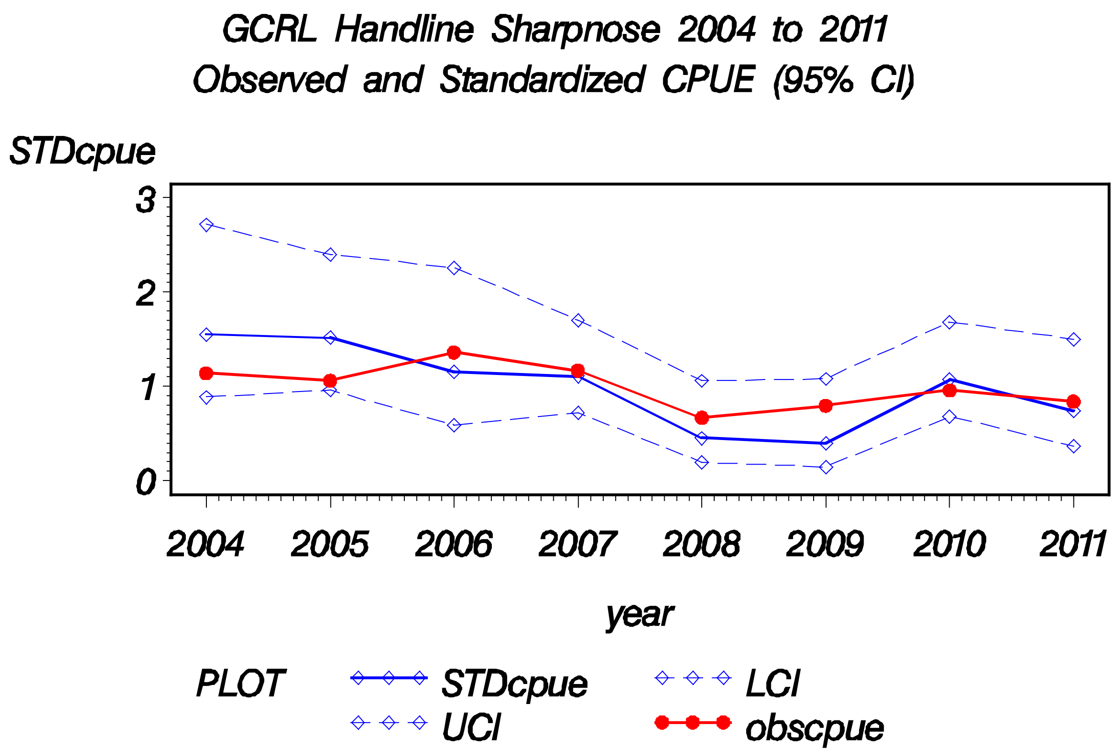
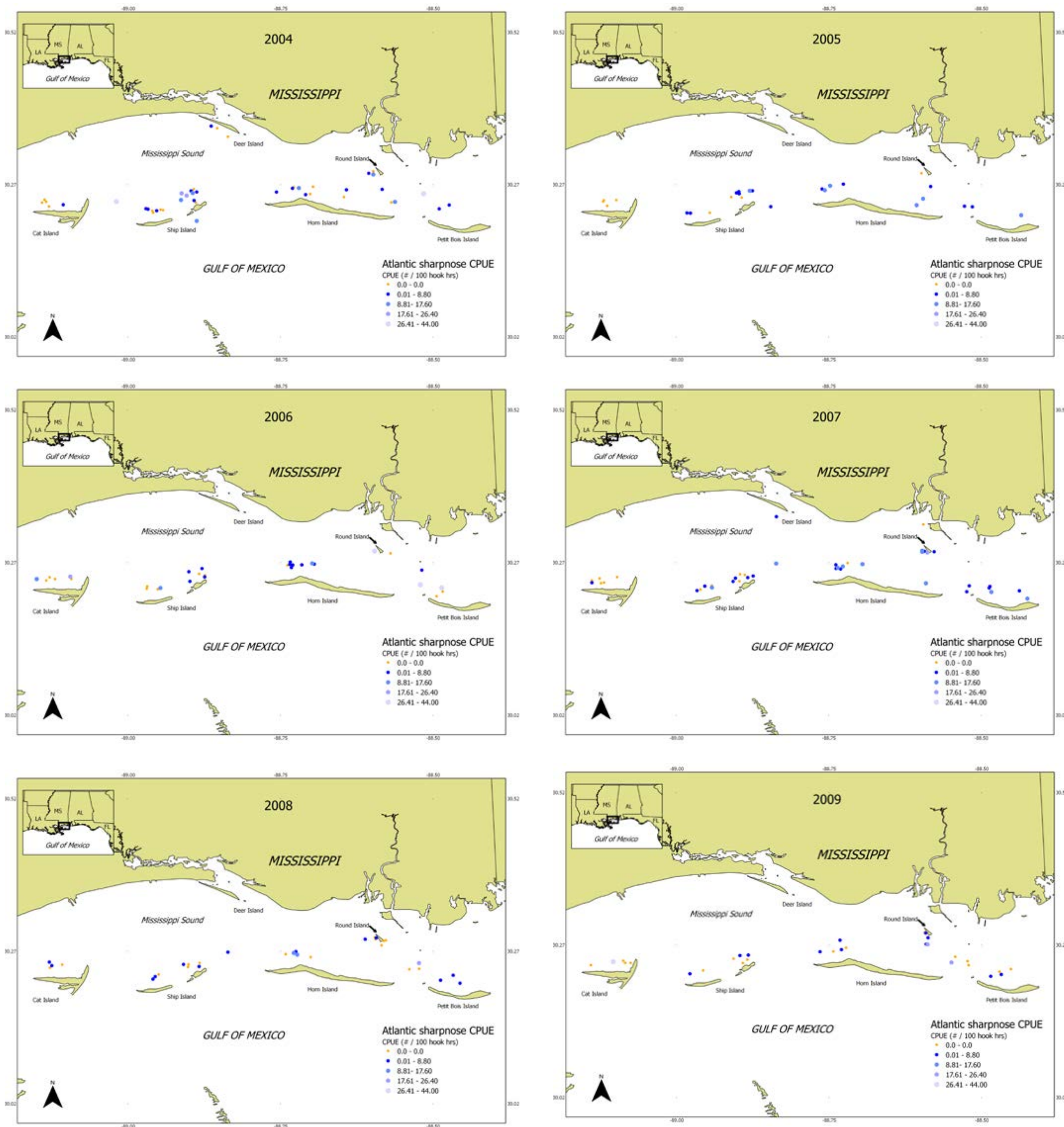


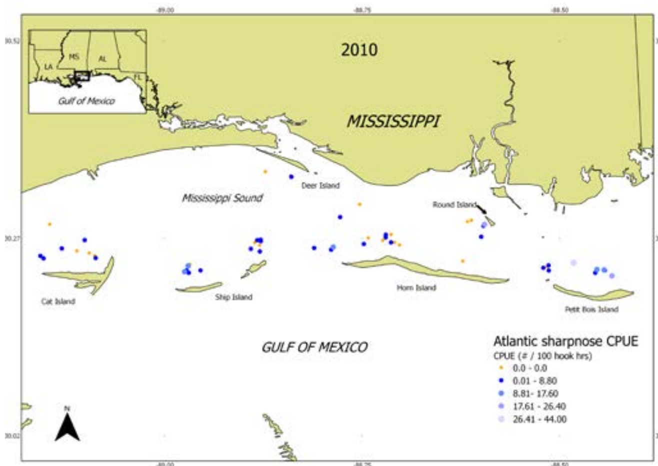
Figure 8. Observed and standardized CPUE for Atlantic sharpnose shark catch in the Mississippi bottom longline survey from 1998-2011.

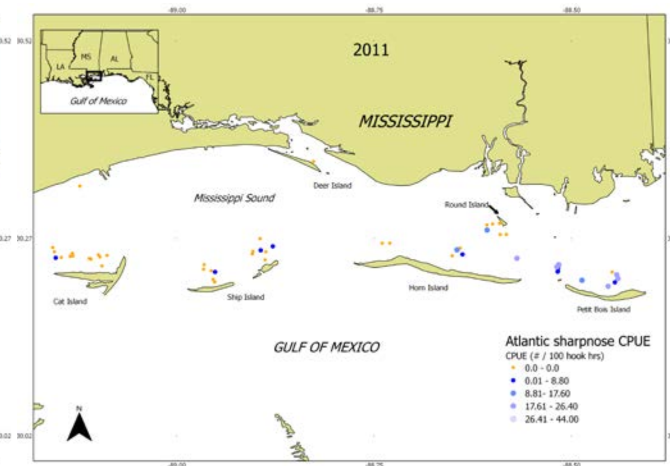
Appendix:

Annual Effort and Catch

Appendix Figure 1. Annual survey effort and catch of Atlantic sharpnose sharks from the Mississippi bottom longline survey from 2004-2011.




2010
MISSISSIPPI
Mississippi Sound
Deer Island
Round Island
Cat Island
Ship Island
Horn Island
Petit Bois Island
GULF OF MEXICO
Gulf of Mexico
LA
MS
AL
FL
Atlantic sharpnose CPUE
CPUE (# / 100 hook hrs)
0.0 - 0.0
0.01 - 8.80
8.81- 17.60
17.61 - 26.40
26.41 - 44.00
N


2011
MISSISSIPPI
Mississippi Sound
Deer Island
Round Island
Cat Island
Ship Island
Horn Island
Petit Bois Island
GULF OF MEXICO
Gulf of Mexico
LA
MS
AL
FL
Atlantic sharpnose CPUE
CPUE (# / 100 hook hrs)
0.0 - 0.0
0.01 - 8.80
8.81- 17.60
17.61 - 26.40
26.41 - 44.00
N