Relative abundance of Atlantic sharpnose and bonnethead shark from the northeastern Gulf of Mexico

John K. Carlson, Dana M. Bethea, Eric Hoffmayer, John Tyminski, Robert Hueter, R. Dean Grubbs, Matthew J. Ajemian, and George H. Burgess

SEDAR34-WP-29

Submitted: 17 June 2013
Updated: 3 July 2013

Please cite this document as:

Carlson, J.K., D.M. Bethea, E. Hoffmayer, J. Tyminski, R. Heuter, R.D. Grubbs, M.J. Ajemian, and G.H. Burgess. 2013. Relative abundance of Atlantic sharpnose and bonnethead shark from the northeastern Gulf of Mexico. SEDAR34-WP-29. SEDAR, North Charleston, SC. 17 pp.

Relative abundance of Atlantic sharpnose and bonnethead shark from the northeastern Gulf of Mexico

John K. Carlson[1]
Dana M. Bethea[1]
Eric Hoffmayer[2]
John Tyminski[3]
Robert Hueter[3]
R. Dean Grubbs[4]
Matthew J. Ajemian[5,6]
George H. Burgess[7]

[1]NOAA National Marine Fisheries Service, Southeast Fisheries Science Center, Panama City Laboratory, Panama City, FL USA
[2] NOAA National Marine Fisheries Service, Mississippi Laboratories, Pascagoula, MS USA
[3] Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway Sarasota, FL 34236
[4] Florida State University, Coastal and Marine Laboratory, St. Teresa, FL USA
[5] Texas A&M University, Fisheries and Ocean Health Lab, Harte Research Institute, Corpus Christi, TX USA
[6] The University of South Alabama, Dauphin Island Sea Lab, Dauphin Island, AL USA
[7] The University of Florida, Florida Museum of Natural History, Gainesville, FL USA The

SEDAR34-WP-29

ABSTRACT

Following recommendations at SEDAR29, fishery independent gillnet data sets from several surveys were combined to form a more spatially expansive inshore eastern Gulf of Mexico gillnet dataset. Since there were differences in the accessory data included with the data sets, several factors including temperature, salinity, year, month, location, depth, set time, and effort were used within a generalized linear model to standardize the series. Additionally, the factor "survey" was added to the dataset. A total of 3313 gillnet sets have been made throughout all areas since 1995. The majority of individuals captured were juveniles and the length distribution did not change significantly over the survey period for Atlantic sharpnose shark or bonnethead shark. The abundance trend was relatively stable for Atlantic sharpnose shark with some evidence for an increasing trend in later years. For bonnethead, outside one dip in the time series in 2005, the time series was relatively flat.

INTRODUCTION

Fishery-independent surveys of coastal shark populations have taken place since 1994 in the eastern and northern Gulf of Mexico. The cooperative Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) survey began in 1996 to examine the distribution and abundance of juvenile sharks in coastal areas. The ultimate intent of this survey is to continue to describe and further refine shark essential fish habitat as mandated by the Magnuson-Steven Fishery Conservation and Management Act. NOAA Fisheries Panama City Laboratory oversees the survey. In 2003, Gulf Coast Research Laboratory at the University of Southern Mississippi was added to the survey. In 2007, additional participants included the Florida Natural History Museum at the University of Florida and Dauphin Island Sea Laboratory at the University of South Alabama. In 2008, the Florida State University Coastal and Marine Laboratory became a collaborator. The Center for Shark Research (CSR) at Mote Marine Laboratory has been conducting routine surveys of juvenile sharks in Florida Gulf coast nursery areas since 1995 as part of a NMFS/MARFIN-funded project on shark nurseries to assess Florida's coastal areas as nurseries specifically for the blacktip shark (*Carcharhinus limbatus*). The project also documents nursery areas of other shark species, quantifies relative abundance of juvenile blacktips and other shark species, determines bycatch mortality of these small sharks and associated fishes in gill net fishing gear, and conducts basic biological studies. This paper determines a relative abundance index for Atlantic sharpnose and bonnethead sharks from both the GULFSPAN and Mote Marine Laboratory surveys. Data from all surveys were combined in an attempt to provide a single relative index of abundance for sharks from the northeastern Gulf of Mexico.

MATERIAL AND METHODS

GULFSPAN Survey Field Data Collection

From 1996-2005, a 186-m long gill net consisting of six different mesh size panels was used for sampling. Stretched mesh sizes (SM) ranged from 8.9 cm (3.5") to 14.0 cm (5.5") in steps of 1.27 cm (0.5"), with an additional size of 20.3 cm (8.0"). Panel depths when fishing were 3.1 m. Webbing for all panels, except for 20.3-cm, was of clear monofilament, double knotted and double selvaged. The 20.3-cm SM webbing was made of #28 multifilament nylon, single-knotted, and double selvage. In 2005, a panel of monofilament net with 7.6 cm (3.0”) mesh size was added to the sampling gear and the 20.3 cm mesh panel was removed.   Previous analysis has found the additional of the 7.6 cm SM panel and the removal of the 20.3 SM panel did not affect shark catch rates.

Surveys were conducted monthly from April-October, occasionally March-November. Depending on institution and area, gillnet set locations were either chosen randomly within each area based on depth strata and GPS location, based on a spatially-balanced sampling design, or randomly selected using Hawth’s Tools extension for ArcMap. The nets were checked and cleared of catch or pulled and reset every 1.0-2.0 hr. Sharks were measured to the nearest cm for body lengths (precaudal, fork, total, and stretch total length) and data for sex and life history stage (neonate, young-of-the-year, juvenile, adult) were recorded. Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged and released. Environmental data were collected prior to sampling. Mid-water temperature (°C), salinity (ppt), and dissolved oxygen (mg l^{-1}) was measured with a YSI Model 55 oxygen meter and light transmission (cm) was determined using a secchi disk. Further details can be found in Carlson and Brusher (1999).

Mote Marine Laboratory Field Data Collection

Monthly, random stratified, fishery-independent sampling by gill net was conducted in the three Florida Gulf bays from March through October (with sampling in summer months only during 1999-2004) in all years except 1998. In each area, two geographically fixed 10 km^2 grids were regularly sampled based upon previous exploratory surveys that revealed subareas with relatively high CPUE of juvenile blacktip sharks. For quantitative assessment of relative abundance, standardized sets were conducted each month in five of the ten 1 x 1 km blocks for each grid. Sets were made using 0.52 mm monofilament, 11.8 cm stretch mesh, 366 x 3 m weighted gill nets, used because of their relatively high selectivity for small sharks and relatively low bycatch of other species. The net was allowed to soak for one hour before being retrieved. All shark catch was identified, sexed, categorized by stage of maturity (neonate, young-of-the-year, older juvenile, or mature), measured and weighed, and live sharks were tagged and released. Physical data including depth, tide, salinity, temperature, dissolved oxygen, bottom type, and weather were collected for each set to characterize shark nursery habitat in the three areas.

Index Development

While these surveys were fishery-independent and factors were generally controlled, we applied a generalized linear model to correct for factors that could have influenced abundance. Several categorical variables were constructed for analysis of the survey data:

“Year” (17 levels): 1995-2011

“Area” (9 levels): locations of gillnet set major areas based on apparent zoogeographical breaks
Apalachee Bay
Appalachicola Bay
BARR_IN
BARR_OUT

Charlotte Harbor
CK-AK
HB-CK
St. Andrew Bay to St. Joe Bay
Tampa Bay

"Survey" (6 levels): Laboratory conducting the survey

"Season" (3 levels):
Spring=Mar-May
Summer=Jun-Aug
Fall=Sep-Nov

"Setdepth" (2 levels):
Shallow=less than 5 meters
Deep=greater than 5 meters

"Temperature" (3 levels)
<19.9° C
20.0-29.9° C
>30.0° C

"Salinity" (4 levels)
Fresh=0-5 ppt
Estuarine=6-30 ppt
Marine=30-39 ppt
Hypersaline=>40 ppt

Indices of abundance were estimated following the Delta method (Lo et al., 1992) by modeling the probability of the non-zero catch assuming a type-3 model with a binomial error distribution and a logit link. The distribution of the positive shark catches was modeled assuming a lognormal distribution. Catch per unit effort was the number of sharks caught per hour.

Following Ortiz and Arocha (2004), factors most likely to influence abundance were evaluated in a forward stepwise fashion. Initially, a null model was run with no factors entered into the model. Models were then fit in a stepwise forward manner adding one independent variable. Each factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant at $p<0.05$ based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. Regardless of its level of significance, year was kept in all models. This allows the estimation of the annual indices, which is the main objective of the standardization process, but also accounts for the variability associated with year-interactions. After selecting the set of factors for each error distribution, all factors that included the factor year were treated as random interactions (Ortiz and Arocha, 2004). We applied a Generalized Linear Mixed Modeling

(GLMM), approach because these models can predict CPUEs for un-fished fishing cells based on the estimated effects of the explanatory variables as long as these cells were fished in some of the years. The standardized CPUE values for the Delta models were calculated as the product of the expected probability of a non-zero catch and the expected conditional catch rate for sets that had a non- zero catch. The expected probability and expected conditional catch rate were the least square means of the factor year from each of the two analyses that constitute an analysis using the Delta model approach (Lo et al., 1992; Stefansson, 1996). All models were fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute Inc.) and the MIXED procedure in SAS statistical computer software (PROC GLIMMIX).

Final models were selected based on Akaike Information Criteria (AIC). Models of positive catches were checked for appropriate fit and diagnostics by examining the residuals plotted against the fitted values to check for systematic departures from the assumptions underlying the error distribution; the absolute values of the residuals plotted against the fitted values as a check of the assumed variance function; and the dependent variable was plotted against the linear predictor function as a check of the assumed link function (McCullagh and Nelder, 1989).

RESULTS AND DISCUSSION

A total of 3313 gillnet sets have been made throughout all areas since 1995 (Figure 1). The majority of individuals captured were juveniles and the length distribution did not change significantly over the survey period for Atlantic sharpnose shark ($p=0.4898$; Figure 2a) or bonnethead ($p=0.3319$; Figure 2b). However, significant differences in size of individuals captured was evident among institutions ($p<0.001$).

Figure 1. Location of study sites in the northeastern Gulf of Mexico.

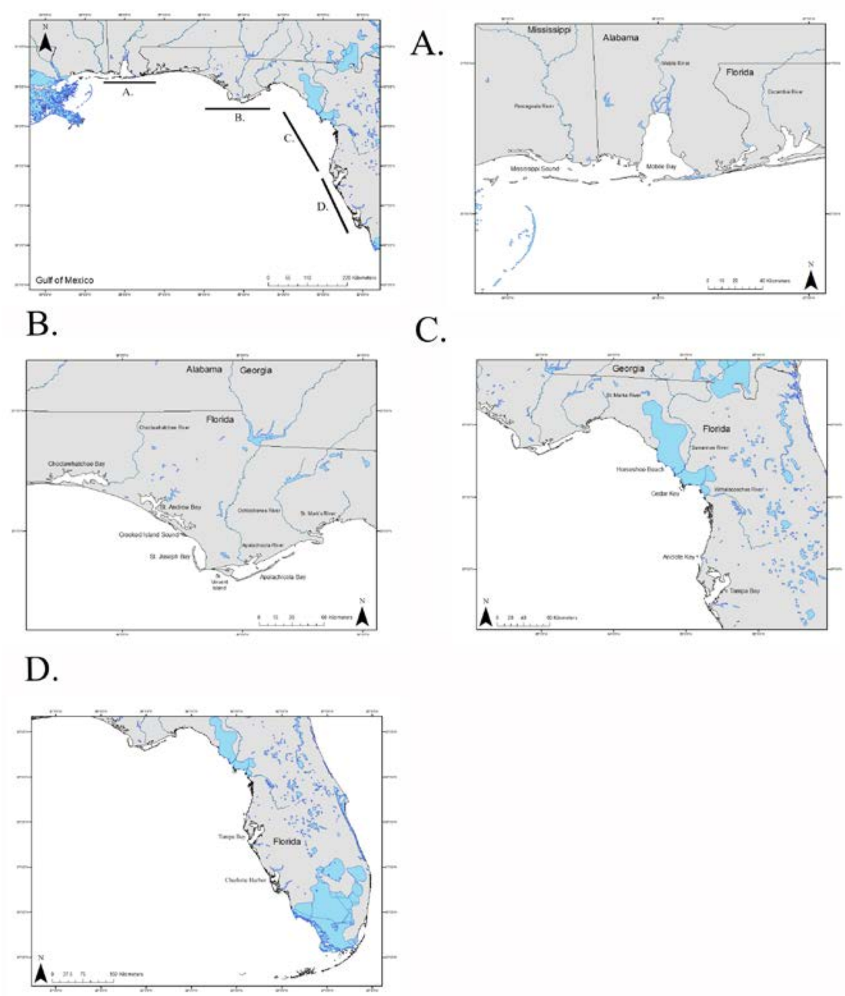


Figure 2a. Observed fork lengths (FL) by year for Age 1+ sharks captured by year and years combined for Atlantic sharpnose shark.

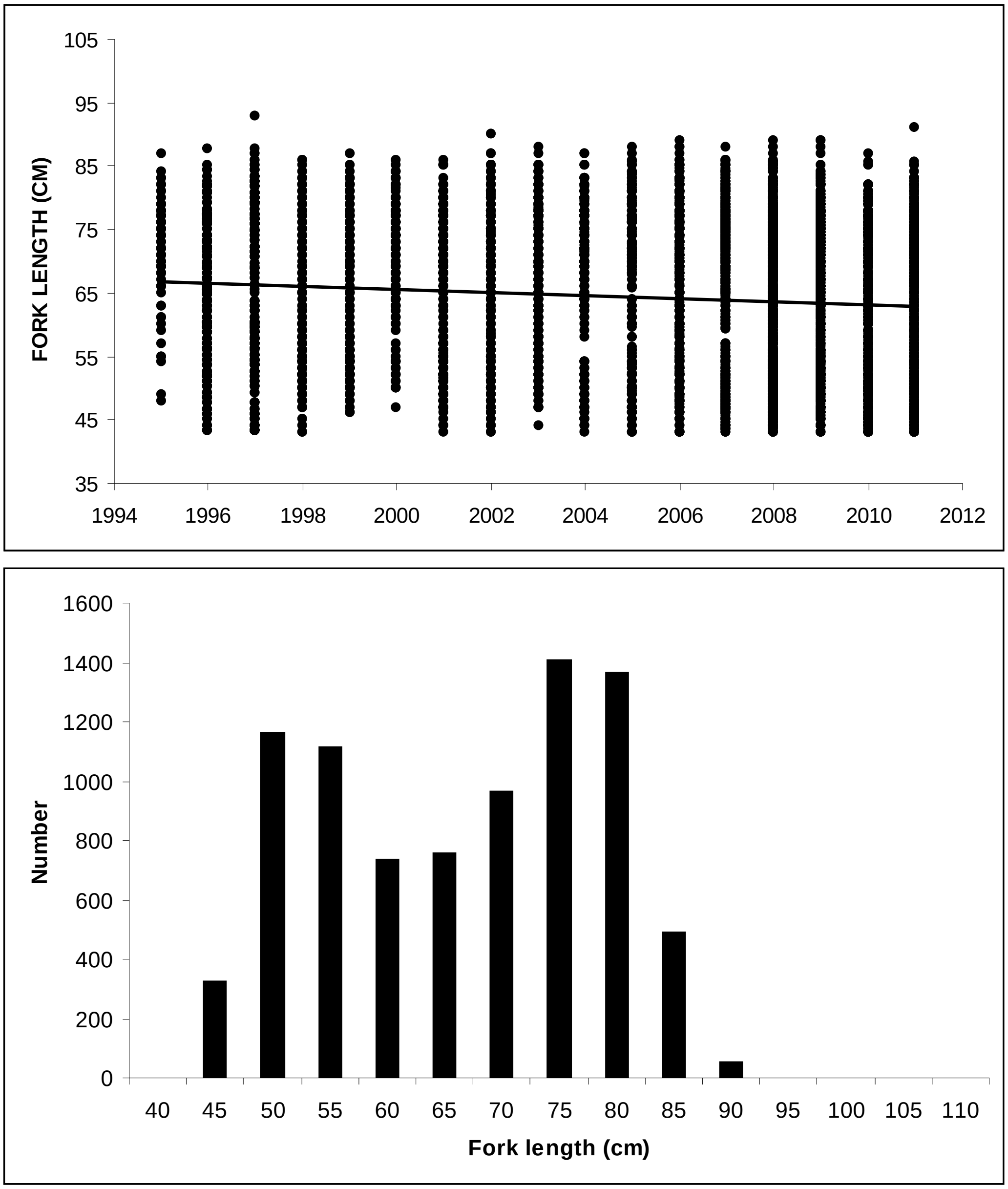
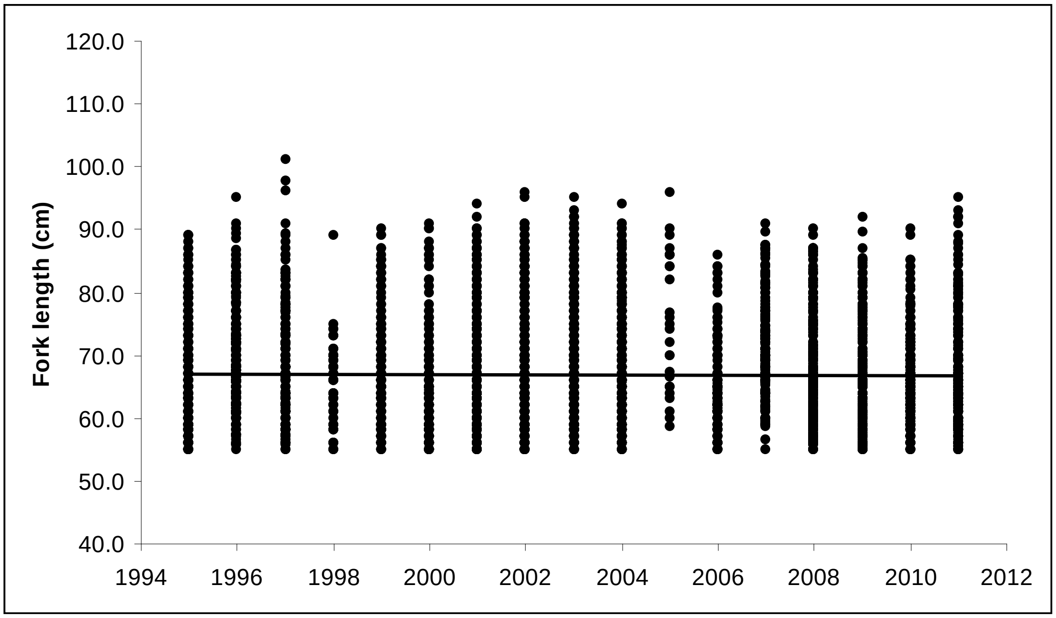
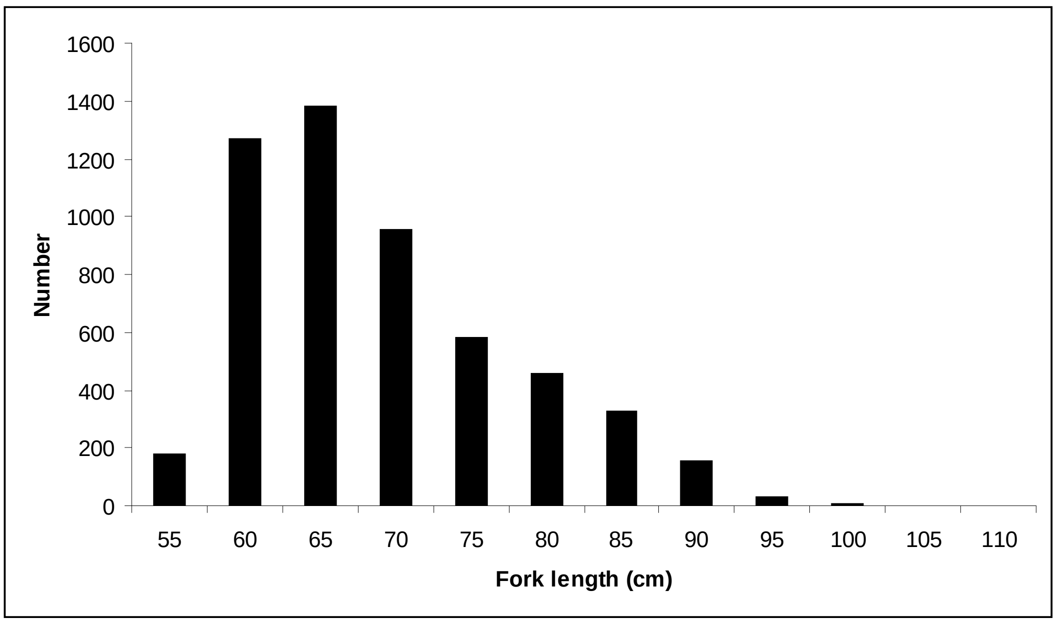


Figure 2b. Observed fork lengths (FL) by year for Age 1+ captured by year and years combined for bonnethead shark.


120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
Fork length (cm)
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012


1600
1400
1200
1000
800
600
400
200
0
Number
55
60
65
70
75
80
85
90
95
100
105
110
Fork length (cm)

Atlantic sharpnose shark

The proportion of positive sets (at least one shark was caught) was 41.3%. The stepwise construction of the model is summarized in Table 1 and the index statistics can be found in Table 2. Table 3 provides a table of the frequency of observations by factor and level. The standardized abundance index is shown in Figure 3 and the diagnostic plots assessing the fit of the models were deemed acceptable (Figure 4).

Table 1. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear and mixed model formulations of the proportion of positive and positive catches for Atlantic sharpnose sharks for combined surveys. Final models selected are in bold.

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	2.7875				
YEAR	2.3244	16.613	16.613	311.94	<.0001
YEAR+					
AREA	1.2137	56.459	39.846	187.59	<.0001
SALINITY	1.2721	54.364		Negative of Hessian not positive definite.	
SEASON	1.2754	54.246		19.76	<.0001
SETBEGIN	1.282	54.005		1.03	0.309
SURVEY	2.0373	26.913		226.73	<.0001
TEMPERATURE	2.3515	15.641		18.63	<.0001
SETDEPTH	2.3767	14.737		0.02	0.8753
YEAR+AREA+					
SURVEY	1.1603	58.375	1.916	143.54	<.0001
TEMPERATURE	1.208	56.682		18.68	<.0001
SEASON	1.2083	56.653		16.47	0.0003
YEAR+AREA+SURVEY+					
SEASON	1.1537	58.612	0.237	19.37	<.0001
TEMPERATURE	1.1539	58.604		18.85	<.0001
MODEL	**AIC**				
YEAR+AREA+SURVEY	231.7				
YEAR+AREA+SURVEY YEAR*AREA	231.9				
YEAR+AREA+SURVEY YEAR*SURVEY	**227.3**				
Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.087				
YEAR	1.0506	3.349	3.349	59.66	<.0001
YEAR+					
AREA	0.9971	8.270	4.922	74.88	<.0001
SURVEY	1.0145	6.670		49.66	<.0001
SALINITY	1.0209	6.081		37.6	<.0001

SEASON	1.0435	4.002		10.66	0.0048
TEMPERATURE	1.0446	3.901		9.31	0.0095
SETDEPTH	1.051	3.312		0.41	0.5222
SETBEGIN	1.0718	1.398		14.17	0.0002
YEAR+AREA+					
SALINITY	0.9837	9.503	1.233	18.27	<.0001
SEASON	0.9891	9.006		12.28	0.0022
SURVEY	0.9895	8.970		13.75	0.0081
TEMPERATURE	0.9927	8.675		7.62	0.0221
SETBEGIN	1.0286	5.373		0.53	0.4687
YEAR+AREA+SALINITY					
SURVEY	0.974	10.396	0.892	16.68	0.0022
SEASON	0.9773	10.092		10.32	0.0057
TEMPERATURE	0.9789	9.945		8.21	0.0165
MODEL	**AIC**				
YEAR+AREA+SALINITY	3810.2				
YEAR+AREA+SALINITY YEAR*AREA	3796.8				
YEAR+AREA+SALINITY YEAR*SALINITY	**3797.6**				

Table 2. The standardized and nominal index (number of sharks per net hour) of absolute abundance, and coefficients of variation (CV) for Atlantic sharpnose sharks. N=number of sets.

Year	Nominal index	CV	N	Standardized index	CV
1995	0.205	2.78	250	0.848	0.67
1996	0.381	0.90	186	0.816	0.42
1997	0.416	1.18	135	1.399	0.35
1998	1.149	0.45	83	0.968	0.53
1999	1.406	0.42	118	1.469	0.40
2000	1.599	0.43	128	1.962	0.35
2001	1.222	0.46	187	1.595	0.35
2002	1.349	0.45	235	1.772	0.34
2003	1.464	0.38	237	1.529	0.36
2004	1.039	0.53	209	1.509	0.37
2005	1.319	0.45	162	1.272	0.46
2006	2.868	0.26	167	2.007	0.38
2007	2.344	0.25	202	1.763	0.33
2008	2.184	0.30	278	1.979	0.33
2009	2.409	0.32	245	2.483	0.31
2010	3.221	0.26	189	2.785	0.30
2011	2.855	0.28	302	2.577	0.32

Figure 3. Nominal (obscpue) and standardized (STDCPUE) indices of abundance for Atlantic sharpnose sharks. The dashed lines are the 95% confidence limits (LCL, UCL) for the standardized index. Each index has been divided by the maximum of the index

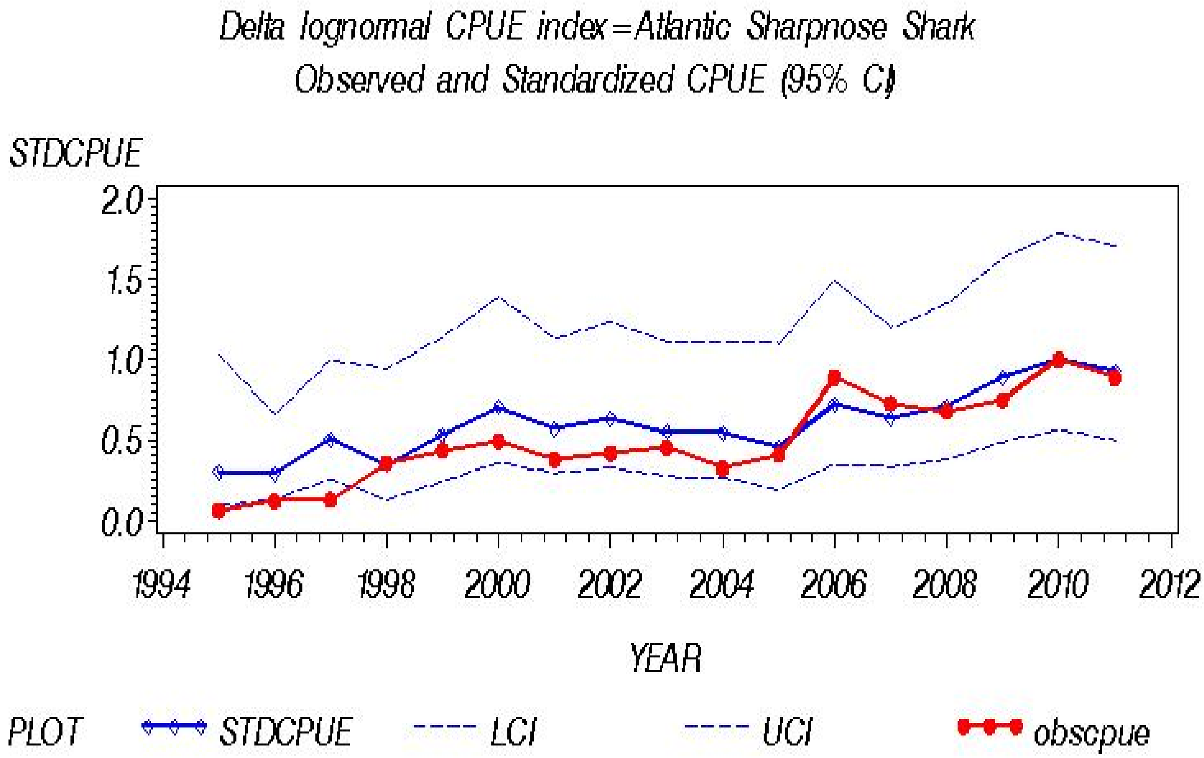
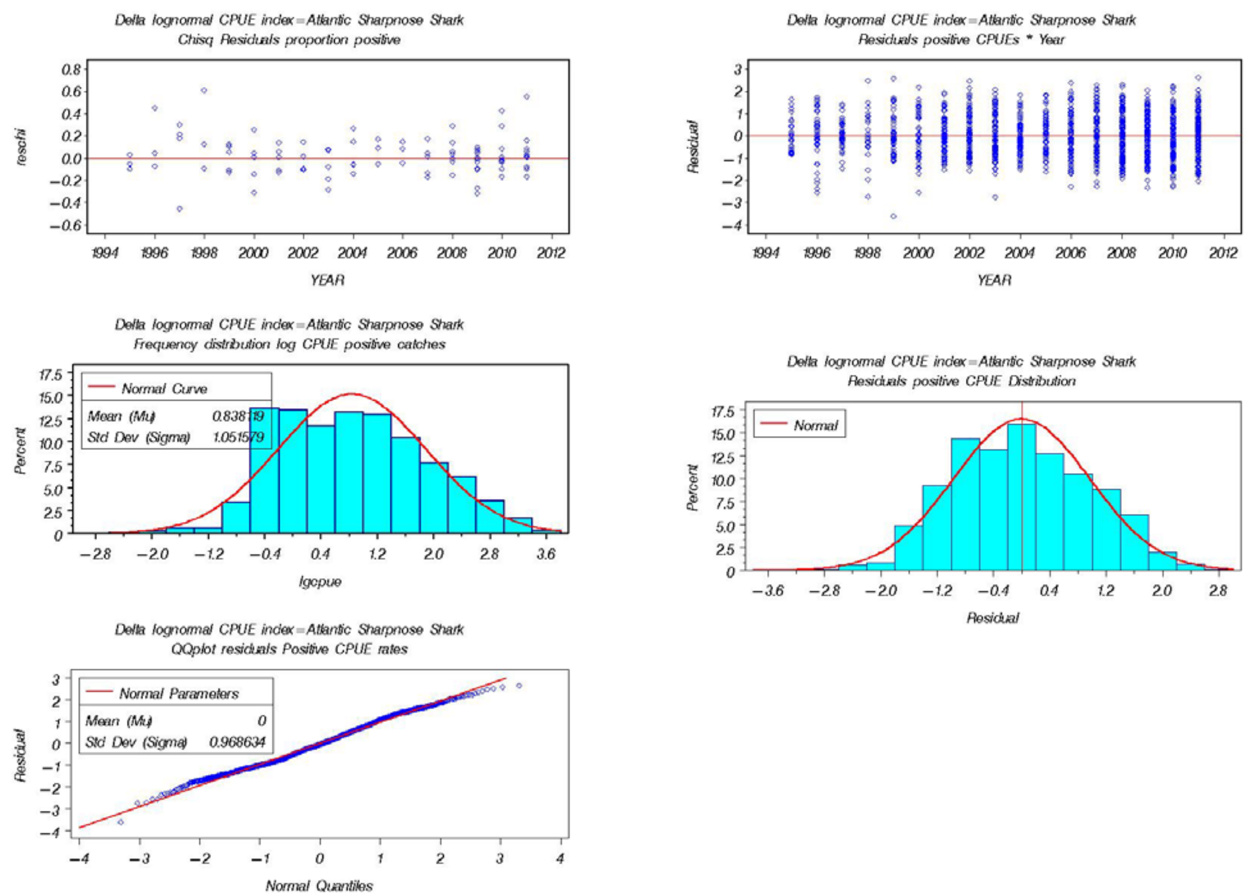


Table 3. Frequency of observations by factor and level used in the development of the standardized catch rate series.

FACTOR	LEVEL	FREQUENCY OF TOTAL
Year	1995	7.5
	1996	5.6
	1997	4.1
	1998	2.5
	1999	3.6
	2000	3.9
	2001	5.6
	2002	7.1
	2003	7.2
	2004	6.3
	2005	4.9
	2006	5.0
	2007	6.1
	2008	8.4
	2009	7.4
	2010	5.7
	2011	9.1
Survey	DISL	7.0
	FSU	5.6
	GCRL	8.1
	MOTE	29.3
	PC	46.2
	UF	3.8
Area	Apalachee Bay	1.4
	Appalachicola Bay	14.4
	BARR_IN	13.1
	BARR_OUT	1.1
	Charlotte Harbor	11.8
	CK-AK	17.7
	HB-CK	1.4
	St. Andrew Bay to St. Joe Bay	34.4
	Tampa Bay	4.7
Season	Fall	23.8
	Spring	25.5
	Summer	50.7
Setdepth	Shallow	43.7
	Deep	56.3
Temperature	<19.9	3.5
	20.0-29.9	26.4
	>30.0	70.1

Salinity	Fresh	0.5
	Estuarine	48.7
	Marine	50.8
	Hypersaline	<0.01

Figure 4. Diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year for Atlantic sharpnose shark



Bonnethead shark

The proportion of positive sets (at least one shark was caught) was 37.5%. The stepwise construction of the model is summarized in Table 4 and the index statistics can be found in Table 5. The standardized abundance index is shown in Figure 5 and the diagnostic plots assessing the fit of the models are in Figure 6.

Table 4. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear and mixed model formulations of the proportion of positive and positive catches for bonnethead sharks for combined surveys. Final models selected are in bold.

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.3304				
YEAR	1.2772	3.999	3.999	158.83	<.0001
YEAR+					
SURVEY	1.1679	12.214	8.216	290.8	<.0001
AREA	1.1688	12.147		291.94	<.0001
TEMPERATURE	1.264	4.991		36.79	<.0001
SEASON	1.2725	4.352		14.64	0.0007
SALINITY	1.2762	4.074		Negative of Hessian not positive definite.	
SETDEPTH	1.2773	3.991		1.02	0.3122
SETBEGIN	1.278	3.969		0.19	0.662
YEAR+SURVEY+					
AREA	1.1504	13.530	1.315	53.48	<.0001
TEMPERATURE	1.158	12.928		26.94	<.0001
SEASON	1.1671	12.275		4.41	0.1101
MODEL	**AIC**				
YEAR+SURVEY+AREA	201.2				
YEAR+SURVEY+AREA YEAR*SURVEY	**190.700**				
YEAR+SURVEY+AREA YEAR*AREA	201.200				

Proportion positive-Lognormal error distribution

FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.9098				
YEAR	0.8697	4.408	4.408	74.18	<.0001
YEAR+					
SURVEY	0.8056	11.453	7.046	103.78	<.0001
AREA	0.8204	9.826		83.4	<.0001
SEASON	0.8445	7.177		39.86	<.0001
SETBEGIN	0.8564	5.869		5.97	0.0145
TEMPERATURE	0.8597	5.507		16.95	0.0002
SETDEPTH	0.8613	5.331		13.54	0.0002
SALINITY	0.8664	4.770		5.83	0.0157

YEAR+SURVEY+					
SEASON	0.7945	12.673		19.96	<.0001
SETBEGIN	0.796	12.508		1.41	0.2344
SALINITY	0.8022	11.827		6.4	0.0114
SETDEPTH	0.806	11.409		0.28	0.5974
AREA	0.8075	11.244		4.07	0.772
MODEL	**AIC**				
YEAR+SURVEY+SEASON+	3686.5				
YEAR+SURVEY+SEASON YEAR*SURVEY	**3684.4**				
YEAR+SURVEY+SEASON YEAR*SEASON	3688.3				

Table 5. The standardized and nominal index (number of sharks per net hour) of absolute abundance, and coefficients of variation (CV) for bonnethead sharks. N=number of sets.

Year	Nominal index	CV	N	Standardized index	CV
1995	1.785	0.11	250	1.049	0.19
1996	0.792	0.16	186	0.467	0.27
1997	1.499	0.14	135	1.030	0.21
1998	0.769	0.41	83	1.178	0.27
1999	1.352	0.22	118	1.264	0.23
2000	1.376	0.17	128	0.903	0.26
2001	1.889	0.14	187	1.432	0.19
2002	1.418	0.14	235	1.107	0.18
2003	1.987	0.14	237	1.546	0.18
2004	1.835	0.16	209	1.399	0.20
2005	0.168	1.16	162	0.515	0.38
2006	0.938	0.39	167	1.495	0.24
2007	0.622	0.40	202	1.048	0.24
2008	0.559	0.43	278	1.033	0.23
2009	1.035	0.27	245	1.377	0.20
2010	1.080	0.28	189	1.333	0.23
2011	0.828	0.30	302	1.312	0.19

Figure 5. Nominal (obscpue) and standardized (STDCPUE) indices of abundance for bonnethead sharks. The dashed lines are the 95% confidence limits (LCL, UCL) for the standardized index. Each index has been divided by the maximum of the index

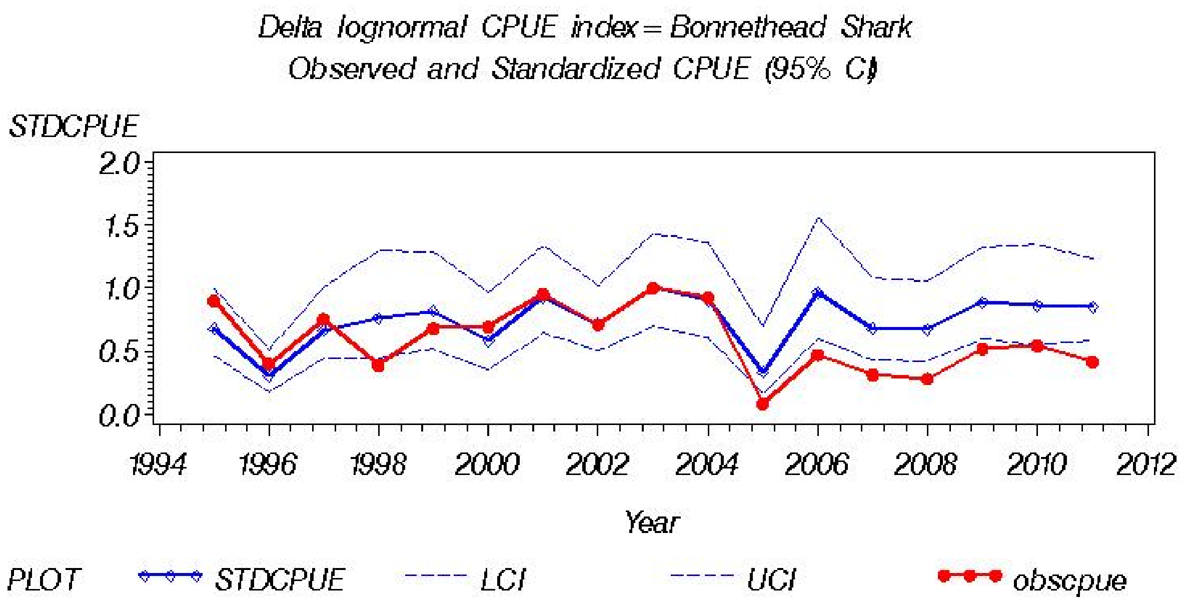


Figure 6. Diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year for bonnethead shark