Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Shark Drift Gillnet Fishery: 1993-2011

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Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Shark Drift Gillnet Fishery: 1993-2011

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Abstract

Catch rate standardization using the Delta lognormal approach for data from the directed shark drift gillnet fishery was developed based on observer programs from 1993-1995 and 1998-2011. For Atlantic sharpnose shark, initial selection of factors indicated the negative of hessian not positive definite for the binomial model when only year was considered as a factor. Given that year is a factor in all model selection no further analysis was performed. For bonnethead shark, year and meshsize were significant as a main effect in the binomial model and year and area in the lognormal model. The relative abundance index was unstable with random peaks throughout the time series likely related to low sample size or missing observations (years with no data) throughout the time series.

Introduction

The shark drift gillnet fishery developed off the east coast of Florida and Georgia in the late 1980's (Trent el. al 1997). Observer coverage of the Florida-Georgia shark gillnet fishery began in 1992, and has since documented the many changes to effort, gear characteristics, and target species the fishery has undergone following the implementation of multiple fisheries regulations (e.g., Passerotti et al. 2010 and references therein). Most recently, the directed large coastal shark (LCS) gillnet fishery has been significantly reduced since the implementation of Amendment 2 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2007). The 33-head LCS trip limit implemented by Amendment 2 has essentially ended the strike net fishery and limited the number of fishers targeting LCS with drift gillnet gear. Additionally, Amendment 3 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2010) has limited the small coastal shark (SCS) gillnet fishery by significantly reducing SCS quota and linking SCS fishery closure to fulfillment of the newly established quota for blacknose shark *Carcharhinus acronotus*. Currently, there are a total of 222 directed and 276 incidental shark permits issued to fishers in the US Atlantic and Gulf of Mexico, of which only a small portion use gillnet gear. Many gillnet fishers have now begun targeting coastal teleost species with varying types of gillnet gear. As such, the southeast gillnet observer program currently covers all anchored (sink, stab, set), strike, or drift gillnet fishing by vessels that fish from Florida to North Carolina and in the Gulf of Mexico year-round. Current protocols for selection of vessels for observer coverage and collection of data are found in Passerotti et al. (2010). Herein, we develop a catch rate series for bonnethead and Atlantic sharpnose shark based on data collected by on-board observers from 1993-1995 and 1998-2011.

I. Fishery description

Vessels, fishing gear, and fishing techniques have been previously described in Trent et al. (1997). Generally, shark driftnet vessels operate between 4.8 and 14.4 km from shore in areas north of Key West, FL (~24° 37-24° 58' N) and between West Palm Beach, FL (~26° 46'N) and Altamaha Sound, GA (~31° 45' N) and in the northern Gulf of Mexico. Vessels fish gillnets (both multi and monofilament) ranging in length from 547.2-2,736 m; depths from 9.1-13.7 m and stretched mesh sizes from 12.7-25.4 cm (Passerotti et al. 2010 and references therein). Nets are normally set in a straight line off the stern at night, allowed to drift at the surface for a period of time and then hauled onto the vessel when the catch is adequate. The number of drift gillnet vessels has decreased from about 12 in 1990 to about 3-6, depending on the market value of sharks and the level of activity in other fisheries.

Information on this fishery was collected using on-board NMFS-approved contract observers. The observer normally left port with the vessel between 1500-1700 hrs; depending on distance to the fishing grounds. Trips are normally 1-3 days in duration. For each set and haul of the net observers recorded: beginning and ending times of setting and hauling; estimated length of net set; latitude and longitude coordinates; and water depth. During haul back, the observer remained about 3-8 m forward of the net reel in an unobstructed view and recorded species, numbers and estimated lengths (±30 cm) of sharks and other species caught as they were suspended in the net just after passing over the power roller.

Catch rates analysis

A combined data set was developed based on observer programs from Trent el al. (1997) and Passerotti et al. (2010 and references therein). Catch rates were standardized in a two-part generalized linear model analysis using the PROC GENMOD procedure in SAS (SAS Inst., Inc.). For the purposes of analysis, several categorical variables were constructed:
-“Year” (17 levels)=1993-1995, 1998-2011

- “Area” (2 levels)=location of net set (Figure 1).
South Atlantic=North Carolina to Miami, FL
Gulf of Mexico=All sets within the eastern Gulf of Mexico from -88.0 W longitude east.

- “SetBegin” (4 levels)
Dawn=0401-1000 hrs
Day=1001-1600 hrs
Dusk=1601-2200 hrs
Night=2201-0400 hrs

-“Season” (4 levels): corresponds to the level of observer coverage as it pertains to the right whale calving season.
Rightwhale1=Jan-Mar
Nonrightwhale1=Apr-Jun
Nonrightwhale2=Jul-Sep
Rightwhale2=Oct-Dec

-“Meshsize” (3 levels): corresponds to the principal mesh size used in the fishing gear. Small mesh=4”-6” stretched mesh; Medium mesh=7”-9” stretched mesh; Large mesh=>10” stretched mesh.

The proportion of sets that caught a shark (when at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. The positive catches were modeled assuming a lognormal distribution with a normal link function. Positive catches were modeled using a dependent variable of the natural logarithm of the number of sharks caught per 10^{-7} net area hours, i.e.:

$$CPUE=\log [(\text{shark kept}+\text{shark released})/(\text{net length}*\text{net depth}*\text{soak time}/10000000)]$$

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 plotted against the linear predictor function as a check of the assumed link function (McCullagh and Nelder, 1989).

Results and Discussion

Bonnethead

The proportion of positive sets (i.e. at least one bonnethead was caught) was 53.1%. The stepwise construction of the model is summarized in Table 1 and the index statistics can be found in Table 2. Table 3 provides the frequency of observations by factor and level. Figure 1 provides a map of shark drift gillnet fishery effort for all years. The standardized abundance index is shown in Figure 2, and the diagnostic plots assessing the fit of the models that were deemed acceptable are shown in Figure 3. Average lengths of bonnethead sharks caught in drift gillnet gear are not available, as no direct measurements were recorded by observers through 2011.

Table 1. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear formulations of the proportion of positive and positive catches for bonnethead shark. Model in bold is the final selected model.

Proportion positive-Binomial error distribution						
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**	
NULL	2.476					
YEAR	2.175	12.142	12.142	72.3	<.0001	
YEAR+						
MESHSIZE	2.001	19.191	7.049	40.92	<.0001	
AREA	2.207	10.858		19.11	<.0001	
SEASON	2.362	4.605		Negative of Hessian not positive definite.		
SETBEGIN	2.390	3.462		6.31	0.0973	
YEAR+MESHSIZE						
AREA	1.856	25.035		Negative of Hessian not positive definite		
SETBEGIN	1.963	20.721		Negative of Hessian not positive definite		
MIXED MODEL	**AIC**					
YEAR+MESHSIZE	**56.8**					
YEAR+MESHSIZE YEAR*MESHSSIZE	model unable to converge					
Positive catches-Lognormal error distribution						
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**	
NULL	3.839					
YEAR	3.430	10.652		41.19	0.0002	
YEAR+						
AREA	3.164	17.571	6.919	20.17	<.0001	
MESHSIZE	3.427	10.728		2.34	0.3096	
SEASON	3.309	13.804		11.74	0.0083	
SETBEGIN	3.424	10.801		3.62	0.3054	
YEAR+AREA						
MESHSIZE	3.173	17.339		1.49	0.4738	
SEASON	3.1308	18.441		5.76	0.124	
MIXED MODEL	**AIC**					
YEAR+AREA	**918.0**					
YEAR+AREA YEAR*AREA	model unable to converge					

Table 2. The absolute standardized and nominal index of abundance for bonnethead shark with the associated coefficients of variation (CV) and number of sets observed (N). A dash (-) indicates no observations were made in that year.

Year	Absolute Standardized index	CV	N	Absolute Nominal index	CV
1993	0.00		5	275.15	0.00
1994	513.63	0.38	39	439.55	0.45
1995	143.99	1.31	7	144.94	1.31
1996			-		
1997			-		
1998	95.49	0.77	9	63.13	1.17
1999	175.65	0.35	50	101.83	0.60
2000	640.20	0.42	53	909.99	0.29
2001	156.81	0.38	90	728.10	0.08
2002	110.61	0.39	70	207.38	0.21
2003	170.18	0.70	24	192.71	0.62
2004	30.15	0.71	32	10.68	2.00
2005	121.20	0.49	31	74.08	0.80
2006	12.69	0.87	4	5.43	2.02
2007	21.20	1.57	4	15.59	2.14
2008	0.00		16	0.00	0.00
2009	55.60	1.09	7	31.30	1.94
2010	28.69	1.64	5	20.36	2.31
2011			-		

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	1993	1.1
	1994	8.7
	1995	1.6
	1996	-
	1997	-
	1998	2.0
	1999	11.2
	2000	11.9
	2001	20.2
	2002	15.7
	2003	5.4
	2004	7.2

	2005	7.0
	2006	0.9
	2007	0.9
	2008	3.6
	2009	1.6
	2010	1.1
	2011	-
AREA	South Atlantic	89.9
	Gulf of Mexico	10.1
SETBEGIN	Dawn	4.7
	Day	2.7
	Dusk	62.3
	Night	30.3
SEASON	Rightwhale1=Jan	24.4
	Nonrightwhale1=Apr	32.7
	Nonrightwhale2=Jul	41.3
	Rightwhale2=Oct	1.6
MESHSIZE	Large	20.2
	Medium	36.1
	Small	43.7

Figure 1. Distribution of fishing effort in the directed shark drift gillnet fishery 1998-2011. Individual plots by year and in some locations were not possible because of vessel confidentiality.

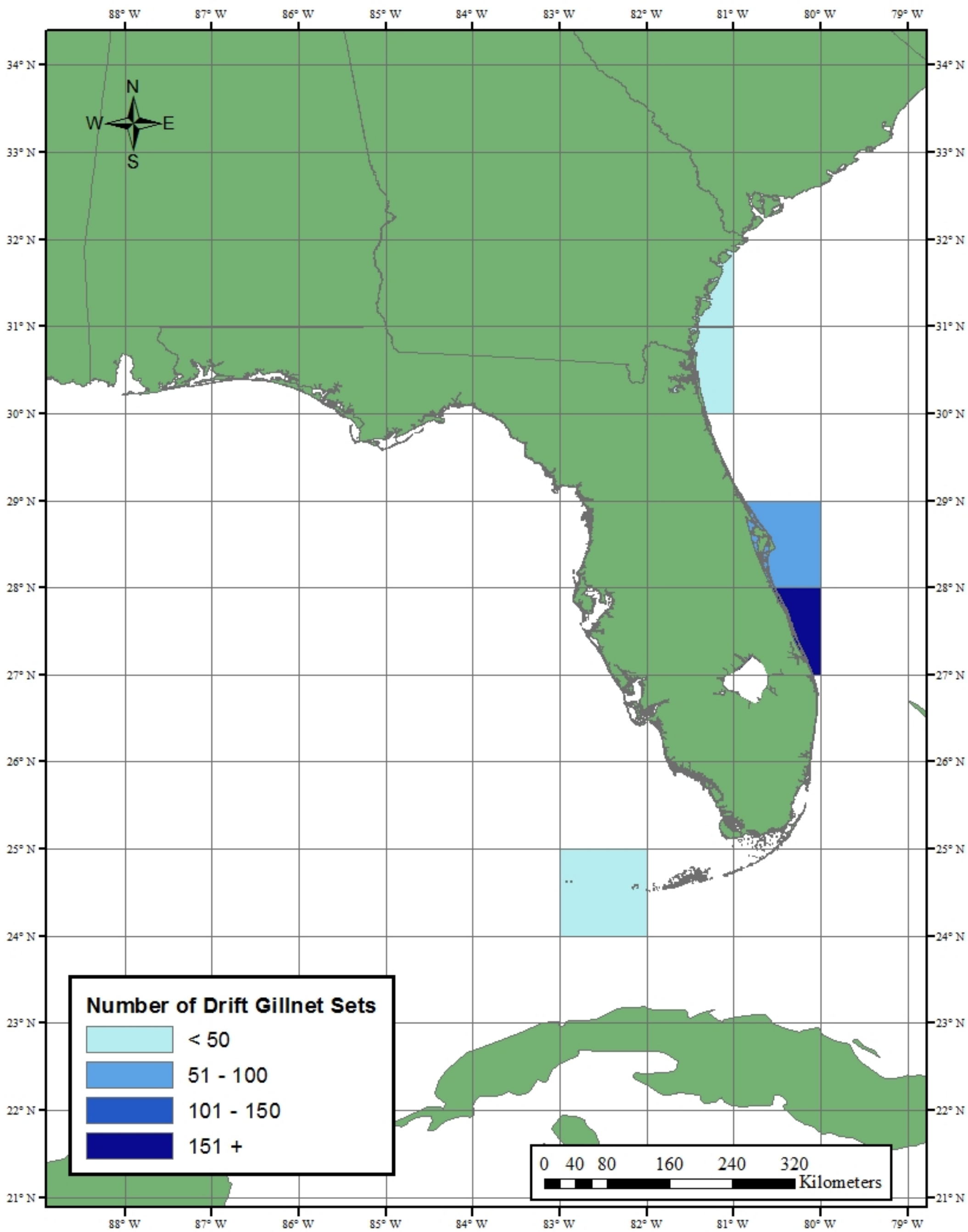
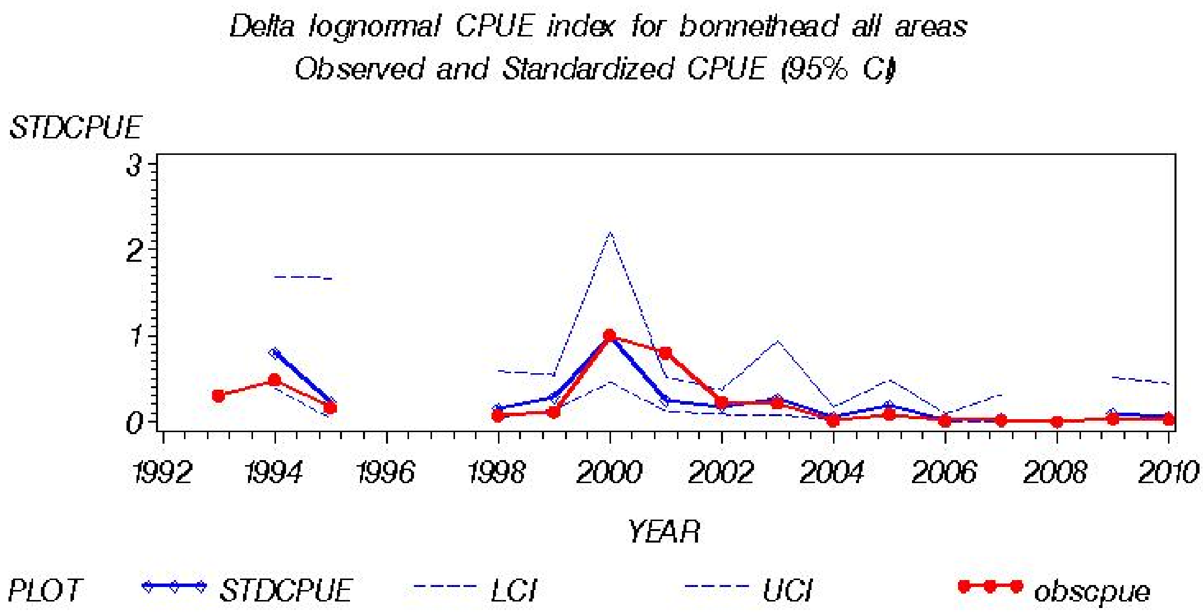


Figure 2. Nominal and standardized indices of abundance for bonnethead shark. The dashed lines are the 95% confidence limits for the standardized index. Each index has been divided by the maximum of the index.



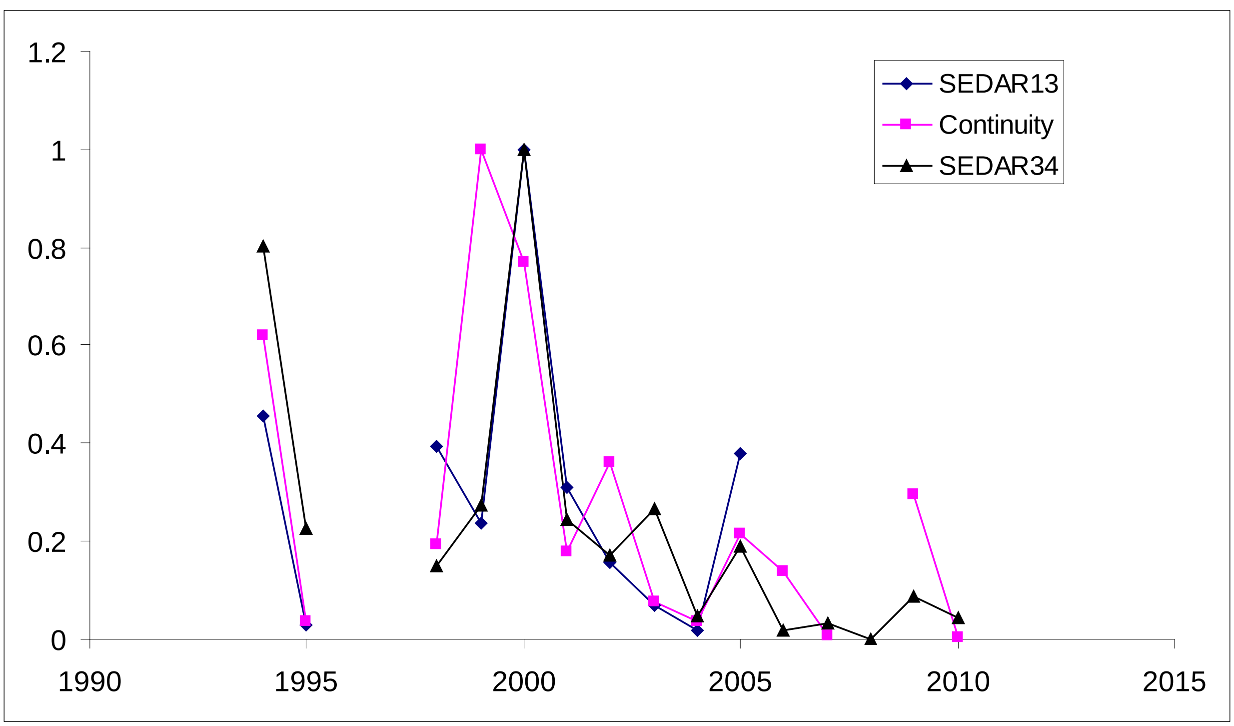
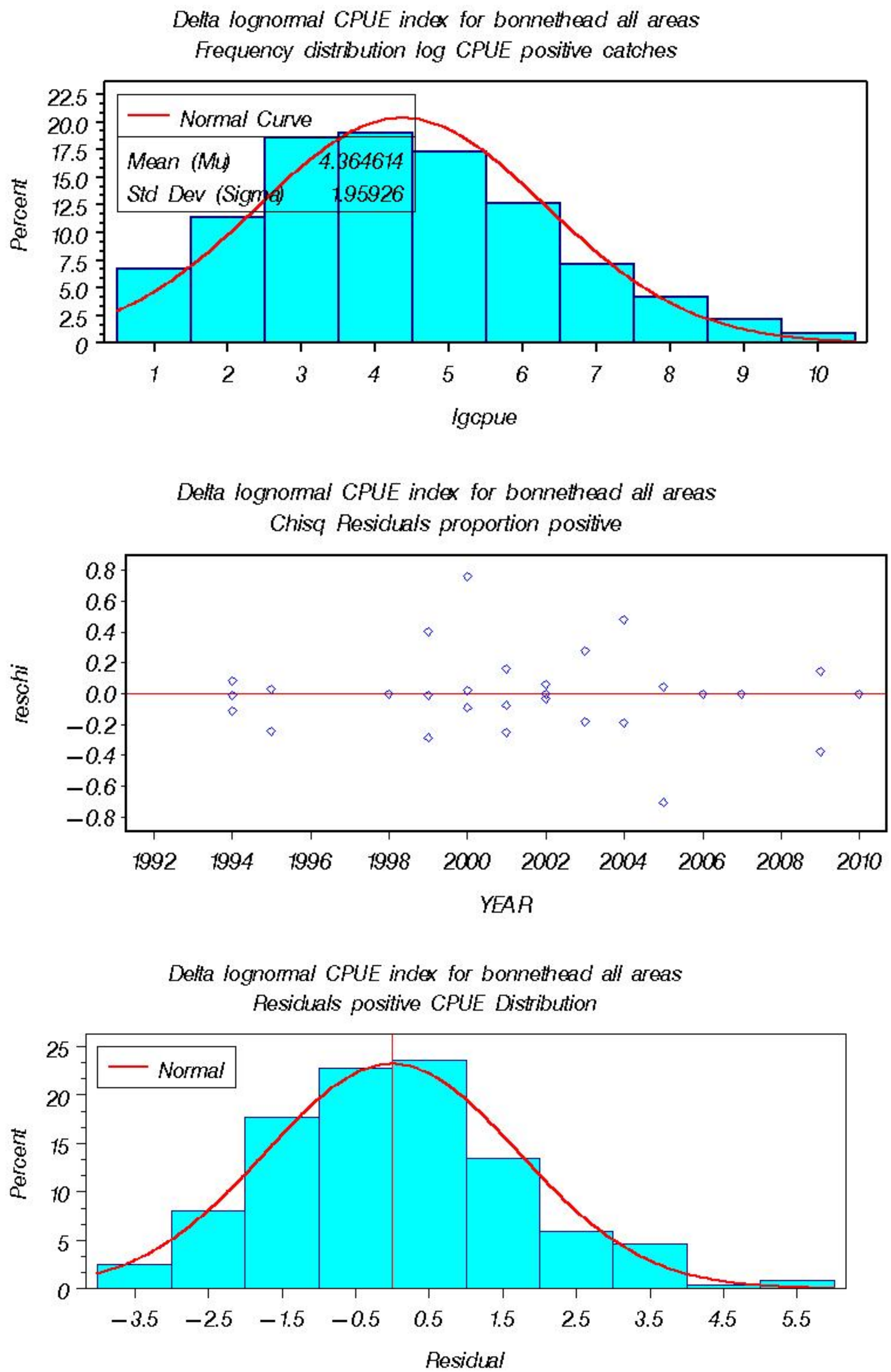
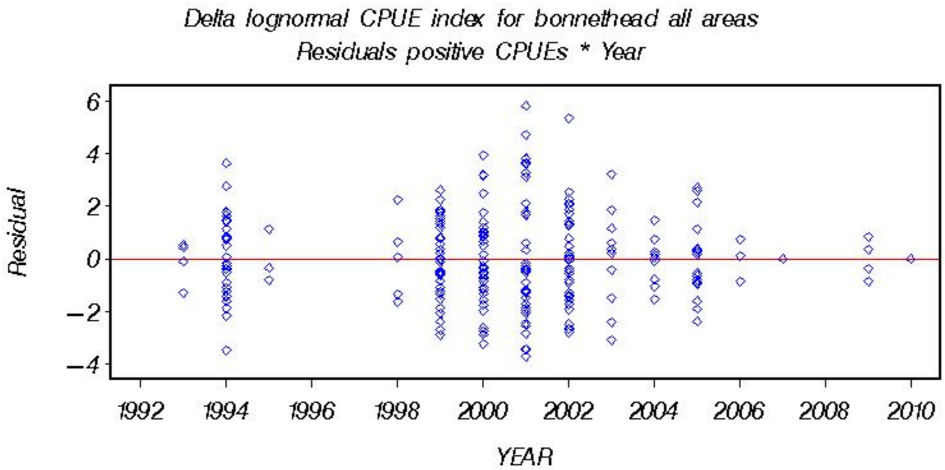
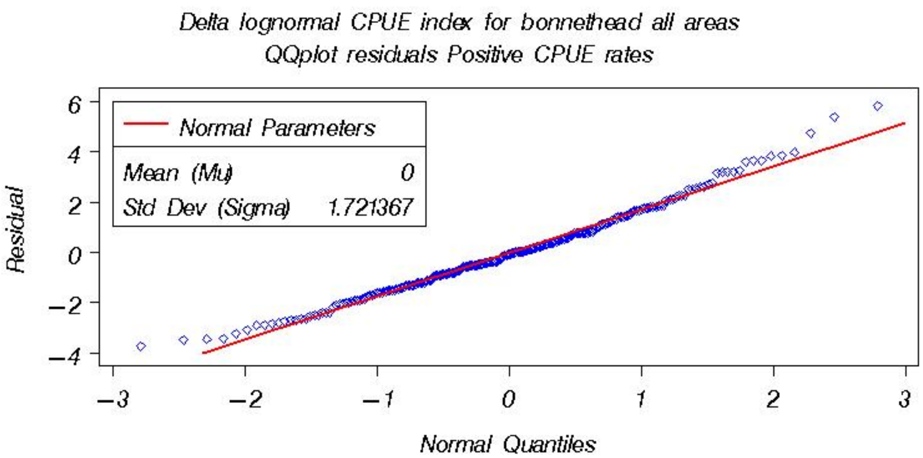


Figure 3. Diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year from the lognormal model for bonnethead shark.




Delta lognormal CPUE index for bonnethead all areas
Residuals positive CPUEs * Year
Residual
YEAR


Delta lognormal CPUE index for bonnethead all areas
QQplot residuals Positive CPUE rates
Normal Parameters
Mean (Mu) 0
Std Dev (Sigma) 1.721367
Residual
Normal Quantiles

Results and Discussion

Atlantic sharpnose shark

Initial selection of factors indicated the negative of hessian not positive definite for the binomial model when only year was considered as a factor. Given that year is a factor in all model selection no further analysis was performed. A continuity analysis was attempted using factors selected at SEDAR13 (Table 5) but the model was unable to converge.

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