Relative abundance index for young-of-the-year scalloped hammerhead shark based on a fishery-independent gillnet survey off Texas, 1982-2019

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Relative abundance index for young-of-the-year scalloped hammerhead shark based on a fishery-independent gillnet survey off Texas, 1982-2019

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INTRODUCTION

This paper determines a relative abundance index for young-of-the-year scalloped hammerhead sharks utilizing a fishery independent gillnet survey by the Texas Parks and Wildlife Department, Coastal Fisheries Division. The protocol for the survey, as it is constituted today, has been standardized since 1982 with the purpose of monitoring relative abundance and size of organisms, their spatial and temporal distribution, and species composition of the community and selected environmental parameters known to influence their distribution and abundance (Martinez-Andrade et al. 2010).

MATERIAL AND METHODS

Field Data Collection

Surveys were conducted in 10 major bay systems along the Texas coast in the north- western Gulf of Mexico from 1982 to 2019 (Figure 1). Barrier islands separate these bays from the Gulf of Mexico along the majority of the coastline, and saltwater exchange occurs via 6 major tidal inlets. Texas bays are shallow subtropical estuaries that are physically dynamic, and most are located near large human population centers. Coastal fisheries resource monitoring data were collected as a stratified cluster sampling design; each bay system serves as non-overlapping strata with a fixed number of samples. Gillnets were deployed each spring (April, May, June) and fall (September, October, November; Martinez-Andrade et al. 2010). Sample locations were drawn independently and without replacement for each season (Martinez- Andrade et al. 2010). Sharks were sampled using standardized 183 m gill-nets perpendicular to shore. Nets were constructed of 4 panels with stretched mesh sizes of 76, 102, 127, and 152 mm with the smallest mesh on the shoreward end. Gillnets were deployed 1 h before sunset, fished overnight, and retrieved within 4 h of sunrise the following day, and a total set time was calculated for each sample. Each captured shark was identified to species, measured, and released. Abundance data were converted to catch per unit effort (CPUE) by dividing the number of sharks captured by 'soak time', in hours, of each net in the sample.

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" (37 levels): 1982-2019

"Area" (10 levels): locations of gillnet set with a major bay system (Figure 1).

"Season" (3 levels):
Spring=Apr-Jul
Other=Outside these periods
Fall=Sep-Nov

"Temperature"-continuous variable

“Salinity” - continuous variable

“Dissolved oxygen” - continuous variable

“Turbidity”- continuous variable

The proportion of sets that caught a hammerhead (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 hammerheads caught per hook/hour.

Following previous methods in multiple SEDARs, factors most likely to influence the probability of capturing a scalloped hammerhead were evaluated in a forward stepwise fashion (e.g. Ortiz and Arocha 2004, Cortés et al. 2007, Brodziak and Walsh 2013). 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 factor. Each factor was ranked from the relative greatest to least reduction in deviance per degree of freedom when compared to the null model:

$$\%Dev_t = 100*(Dev_{null} - Dev_f) / Dev_{null}$$

where $\%Dev_t$ = the percentage of reduction in deviance explained by the addition of each factor, Dev_{null} =the deviance per degree of freedom from the null model, and Dev_f =the deviance per degree of freedom due to the addition of a factor.
The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant ($p \leq 0.05$) 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. All analysis was conducted using the SAS statistical computer software (version 9.4) with the PROC GENMOD procedure.
After selecting the set of fixed factors and interactions for each error distribution, all interactions that included the factor year were treated as random interactions (Ortiz and Arocha, 2004). This process converted the basic models from generalized linear models into generalized linear mixed models. The final model determination was evaluated using the Akaike Information Criteria (AIC). These 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). Relative indices of abundance were calculated as the product of the year effect least square means from the two independent models.

RESULTS AND DISCUSSION

Results and Discussion

The proportion of positive sets (i.e. at least one shark was caught) was 1.1% for the scalloped hammerhead. The stepwise construction of the models is summarized in Table 1. Analyses of Delta-lognormal mixed model formulations are in Table 2. The index values can be found in

Table 3. The delta-lognormal abundance index is shown in Figure 2. To allow for visual comparison with the nominal values, both series were scaled to the average of their respective index. Diagnostic plots assessing the fit of the models were deemed acceptable (Figure 3).

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 scalloped hammerhead.

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.1192				
YEAR	0.1115	6.460	6.460	223.91	<.0001
YEAR+					
AREA	0.1026	13.926	7.466	253.56	<.0001
SALINITY	0.1083	9.144		90.24	<.0001
TEMP	0.1097	7.970		51.45	<.0001
SEASON	0.11	7.718		Negative of Hessian not positive definite	
DO	0.1104	7.383		30.7	<.0001
TURBIDITY	0.1111	6.795		11.58	0.0007
YEAR+AREA+					
SALINITY	0.0976	18.121	4.195	144.54	<.0001
TEMP	0.1009	15.352		48.45	<.0001
DO	0.1018	14.597		23.97	<.0001
TURBIDITY	0.1023	14.178		10.61	0.0011
YEAR+AREA+SALINITY+					
TEMP	0.0964	19.128	1.007	34.48	<.0001
DO	0.097	18.624		16.58	<.0001
TURBIDITY	0.0975	18.205		3.02	0.0824
PROPORTION POSITIVE	**AIC**				
YEAR+AREA+SALINITY	110083.5				
YEAR*AREA	105191.7				
YEAR*SALINITY	125671.4				

Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.3874				
YEAR	0.3764	2.839	2.839	47.31	0.0983
YEAR+					
DO	0.375	3.201	0.361	3.4	0.0652
SEASON	0.3773	2.607		0.38	0.535
TEMP	0.3776	2.530		0.18	0.6753
TURBIDITY	0.3776	2.530		0.2	0.6534
AREA	0.3782	2.375		7.77	0.4563
SALINITY	0.3784	2.323		0.58	0.4461
POSITIVE	**AIC**				
YEAR	576.5				

Table 3. The absolute standardized and nominal index of abundance for scalloped hammerhead with the associated coefficients of variation (CV) and number of sets observed (N).

Year	Nominal	Standard error	N	Standardized Index	LCL	UCL	CV
1982	0.000		654	0.000			
1983	0.001	0.000	666	0.000	0.000	0.002	0.912
1984	0.000		671				
1985	0.000		670	0.000			
1986	0.000	0.000	760	0.000	0.000	0.001	0.732
1987	0.000		760				
1988	0.001	0.000	760	0.001	0.000	0.002	0.618
1989	0.000		760	0.000			
1990	0.001	0.001	760	0.001	0.000	0.003	0.603
1991	0.000	0.000	760	0.001	0.000	0.002	0.749
1992	0.000		760				
1993	0.000	0.000	760	0.000	0.000	0.001	0.819
1994	0.000	0.000	760	0.000	0.000	0.001	0.848
1995	0.000	0.000	760	0.000	0.000	0.001	1.165
1996	0.002	0.000	800	0.001	0.000	0.003	0.536
1997	0.001	0.001	800	0.002	0.001	0.006	0.666
1998	0.000	0.000	800	0.000	0.000	0.001	0.842
1999	0.001	0.000	800	0.000	0.000	0.001	0.781
2000	0.001	0.000	780	0.000	0.000	0.001	0.589
2001	0.003	0.001	780	0.001	0.000	0.005	0.603
2002	0.000	0.000	780	0.000	0.000	0.001	0.822
2003	0.002	0.001	780	0.002	0.001	0.005	0.577
2004	0.001	0.001	780	0.001	0.000	0.003	0.689
2005	0.002	0.001	780	0.003	0.001	0.007	0.517
2006	0.001	0.000	780	0.001	0.000	0.002	0.630
2007	0.000	0.001	780	0.001	0.000	0.003	0.778
2008	0.001	0.001	780	0.001	0.000	0.003	0.703
2009	0.002	0.001	780	0.001	0.000	0.003	0.560
2010	0.002	0.001	780	0.002	0.001	0.006	0.598
2011	0.004	0.001	780	0.001	0.000	0.003	0.563
2012	0.002	0.001	780	0.001	0.000	0.003	0.540
2013	0.009	0.002	780	0.005	0.002	0.011	0.428
2014	0.004	0.001	780	0.002	0.001	0.005	0.477
2015	0.001	0.002	780	0.003	0.001	0.008	0.565
2016	0.002	0.001	780	0.002	0.001	0.006	0.590
2017	0.000	0.000	780	0.000	0.000	0.002	0.775

2018	0.007	0.002	780	0.005	0.002	0.012	0.499
2019	0.002	0.001	780	0.002	0.001	0.007	0.514

Figure 1. Distribution of gillnet sampling effort along the Texas coast. From SEDAR (2013)

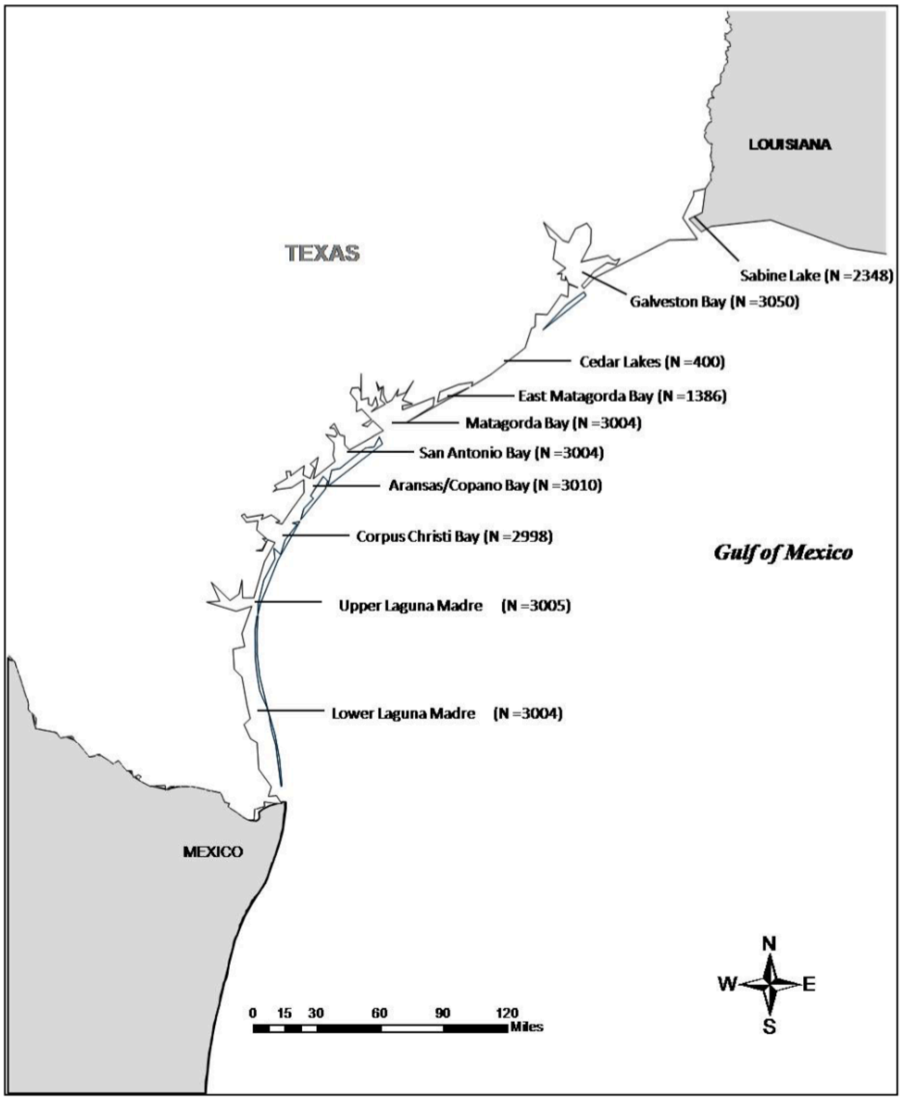


Figure 2. Nominal and standardized indices of abundance for scalloped hammerhead. The dashed lines are the 95% confidence limits for the standardized index. Each index has been divided by the mean of the index.

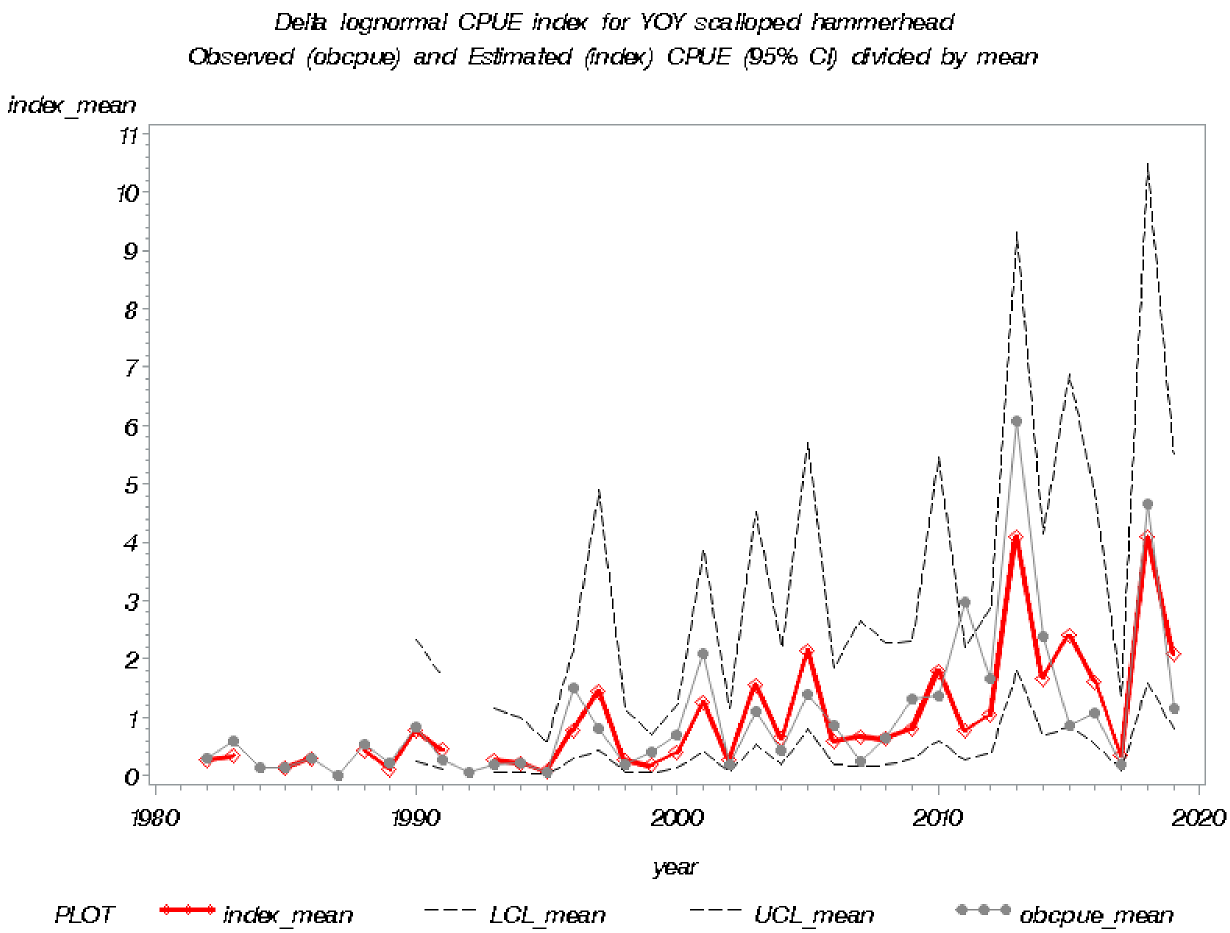
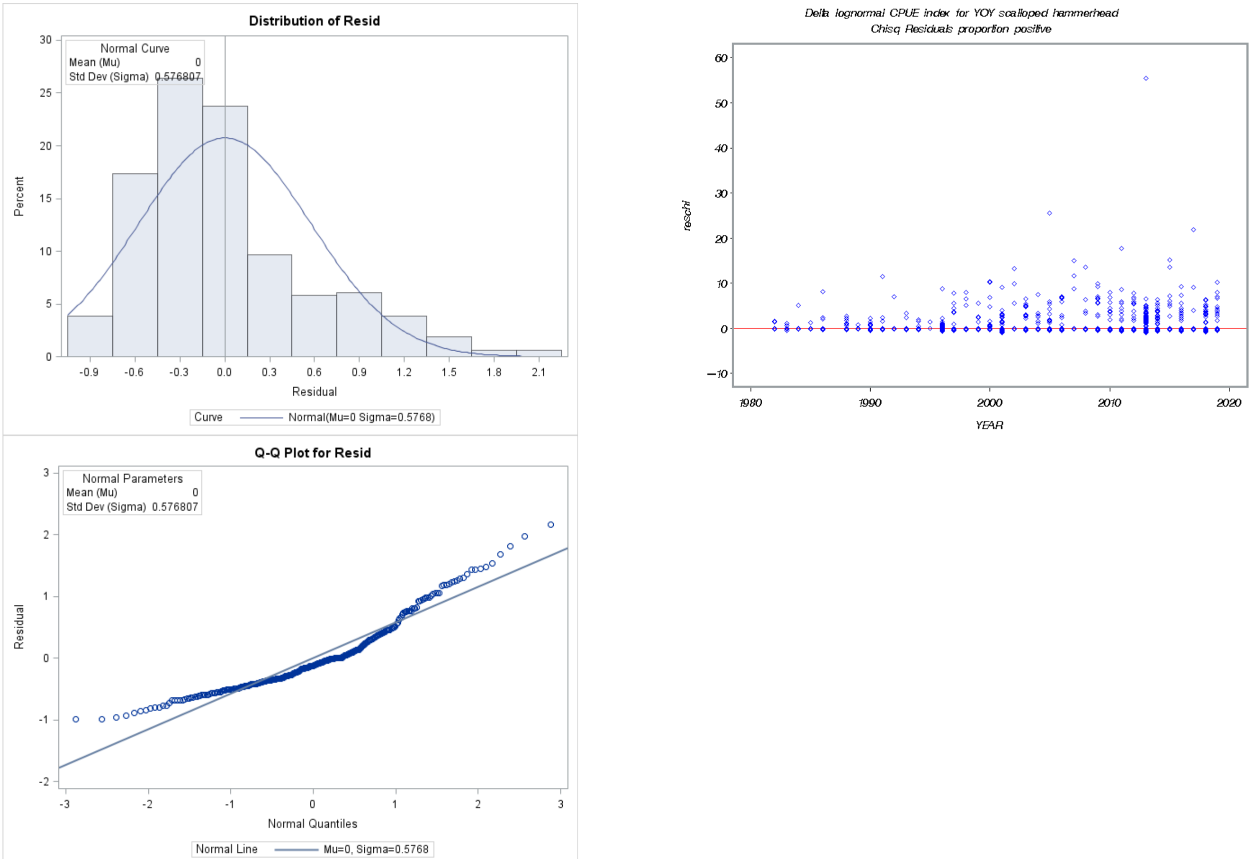


Figure 3. Diagnostic plots of the model outputs for scalloped hammerhead.



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