Standardized Abundance Indices for Great Hammerhead from the Florida State University Longline Survey - With Addendum

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SEDAR77-DW14

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Standardized Abundance Indices for Great Hammerhead from the Florida State University Longline Survey - with Addendum

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SEDAR77-DW14

Introduction

The Florida State University longline survey was expanded in 2011 to include regular sampling in southwest Florida in an effort to capture smalltooth sawfish for research directed at promoting recovery of this endangered species. This work is concentrated in two areas, in Everglades National Park, mostly in northern Florida Bay, along the middle to lower Florida Keys, primarily along the shelf break. Along the Florida Keys, scalloped and great hammerhead sharks are among the most frequently encountered species in this survey (only Atlantic sharpnose, blacknose and blacktip sharks are more frequently captured). As a result, this survey was used to assess the effects of time on hook on physiological stress, release condition and likely mortality in scalloped and great hammerheads (see Prohaska et al. SEDAR 77). In this paper, FSU longline survey data are analyzed to examine relative abundance of great hammerhead sharks from 2011 to 2019.

Methods

The FSU survey targets coastal sharks and smalltooth sawfish using fishery-independent longlines consisting of a 4.0 mm monofilament main line that is anchored on each end and marked with a surface buoy bearing the permit numbers. Each mainline set was approximately 750 m long. A standard set included 50 or 100 gangions consisting of a stainless steel tuna clip with an 8/0 stainless steel swivel attached to 2.5 m of 300 kg monofilament that was doubled in the terminal 25 cm and attached to 16/0 non-offset circle hook. Hooks were baited with ladyfish *Elops saurus* or Spanish mackerel *Scomberomorus maculatus*. Depth (m), turbidity (cm), water temperature (°C), salinity, and dissolved oxygen (mg l^{-1}) were recorded from the surface to the bottom for all sets made in depths of less than 10 m, and bottom water temperature (°C) was recorded for those greater than 10 m deep. Targeted soak times were 1 h to minimize mortality, and all lines were set during daylight hours. The line was hauled in the order and direction it was set and teleosts and elasmobranchs were sampled as they were caught during retrieval. Areas sampled included the Atlantic side of the Florida Keys from Key West to Islamorada and inside ENP from Florida Bay north to Ponce de Leon Bay (Figure 1).

<u>Catch rates analysis</u>

Catch rates were standardized in a two-part generalized linear model analysis (Lo et al. 1992) using the PROC GENMOD procedure in SAS (SAS Inst., Inc.). Covariates considered in the analysis include both categorical and continuous variables:

<u>Categorical</u>

-"Year" (9 levels)=2011-2019
- "Region" (5 levels)=location of longline set
-"Survey" (2 levels)=Whether the longline set was made at a fixed station or randomly set based on depth
- "Season" (2 levels)=Wet = Jul-Nov; Dry = Dec-Jun
-"Bait type" (2 levels)=Ladyfish; Other
-"Set Depth" (2 levels)=<10.0 m=Shallow; >10 m=Deep

<u>Continuous</u>

-"Bottom temperature"

-" Bottom salinity"
-"Bottom dissolved oxygen"

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

The proportion of positive sets (i.e. at least one shark was caught) was 13.2% for great hammerhead and 1.9% for the scalloped hammerhead. Due to the low proportion positive for scalloped hammerhead and the inability of the model to converge when only year was a covariate, an abundance index was not developed. 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 great hammerhead.

Proc Genmod-BINOMIAL					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.777				
YEAR	0.7282	6.281		26.11	0.001
YEAR+					
SALINITY	0.6964	10.373	4.093	13.61	0.0002
DEPTH	0.7004	9.858		11.99	0.0005
REGION	0.7071	8.996		11.39	0.0225
TEMPERATURE	0.7167	7.761		5.38	0.0204
SEASON	0.7228	6.976		2.9	0.0888
SURVEY	0.7293	6.139		0.24	0.6212
BAIT	0.7299	6.062		0.02	0.8854
YEAR+SALINITY+					
DEPTH	0.6677	14.067	3.694	12.35	0.0004
REGION	0.6817	12.265		8.7	0.069
TEMPERATURE	0.6924	10.888		2.32	0.1275

Proc Genmod-LOGNORMAL					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.33				
YEAR	0.2184	33.818		43.72	<.0001
YEAR+					
SALINITY	0.1919	41.848	8.030	3.3	0.0692
REGION	0.196	100.000		14.05	0.0071
SURVEY	0.2113	35.970		4.01	0.0453
SEASON	0.2181	33.909		1.22	0.2686
BAIT	0.2209	33.061		0.12	0.734
DEPTH	0.2211	33.000		0	0.9762
TEMPERATURE	0.2212	32.970		1.19	0.2753
YEAR+SALINITY+					
REGION	0.1784	45.939	4.091	7.83	0.0496
SURVEY	0.1759	46.697		6.23	0.0125

Table 2. Analyses of Delta-lognormal mixed model formulations for scalloped hammerhead. An asterisk indicates that the iteration limit was exceeded or the negative of the Hessian was not positive definite and the model output was deemed questionable. AIC= Akaike's information criterion. Final model selected is in bold.

PROPORTION POSITIVE	**AIC**		**POSITIVE**	**AIC**
YEAR+SALINITY+DEPTH	**377.1**		**YEAR+SALINITY+REGION**	**75.2**
YEAR*SALINITY	377.1		YEAR*SALINITY	73.8
YEAR*DEPTH	597.4		YEAR*REGION	75.8

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

Year	Nominal	N	Standardized Index	LCL	UCL	CV
2011	0.0008	91	0.0004	0.0000	0.0495	17.3159
2012	0.0000	21				
2013	0.0005	72	0.0019	0.0000	0.1349	9.5081
2014	0.0015	41	0.0020	0.0000	0.1106	7.3475
2015	0.0010	37				
2016	0.0027	102	0.0061	0.0005	0.0713	1.8831
2017	0.0033	87	0.0092	0.0009	0.0916	1.6515
2018	0.0033	76	0.0065	0.0006	0.0722	1.8071
2019	0.0043	65	0.0027	0.0001	0.0860	4.3246

Figure 1. Distribution of sampling effort in the FSU Longline Survey

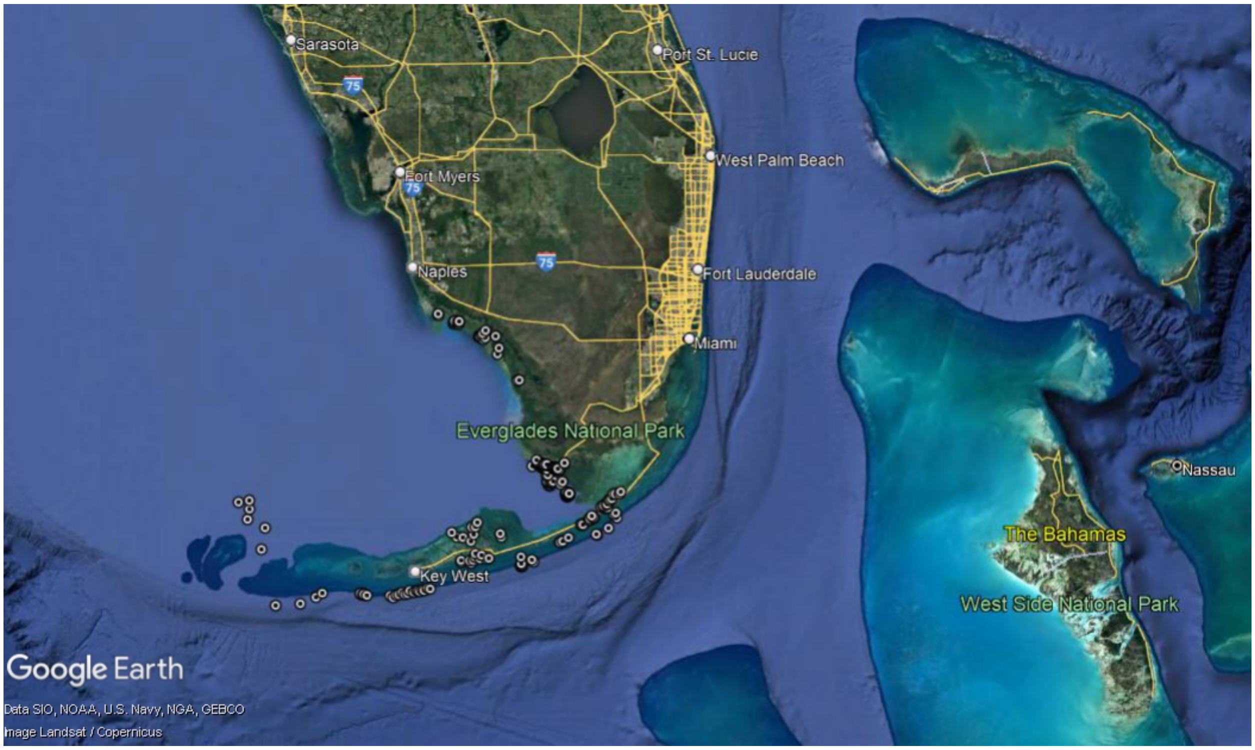


Figure 2. Nominal and standardized indices of abundance for great hammerhead. The dashed lines are the 95% confidence limits for the standardized index. Each index has been divided by the mean of the index.

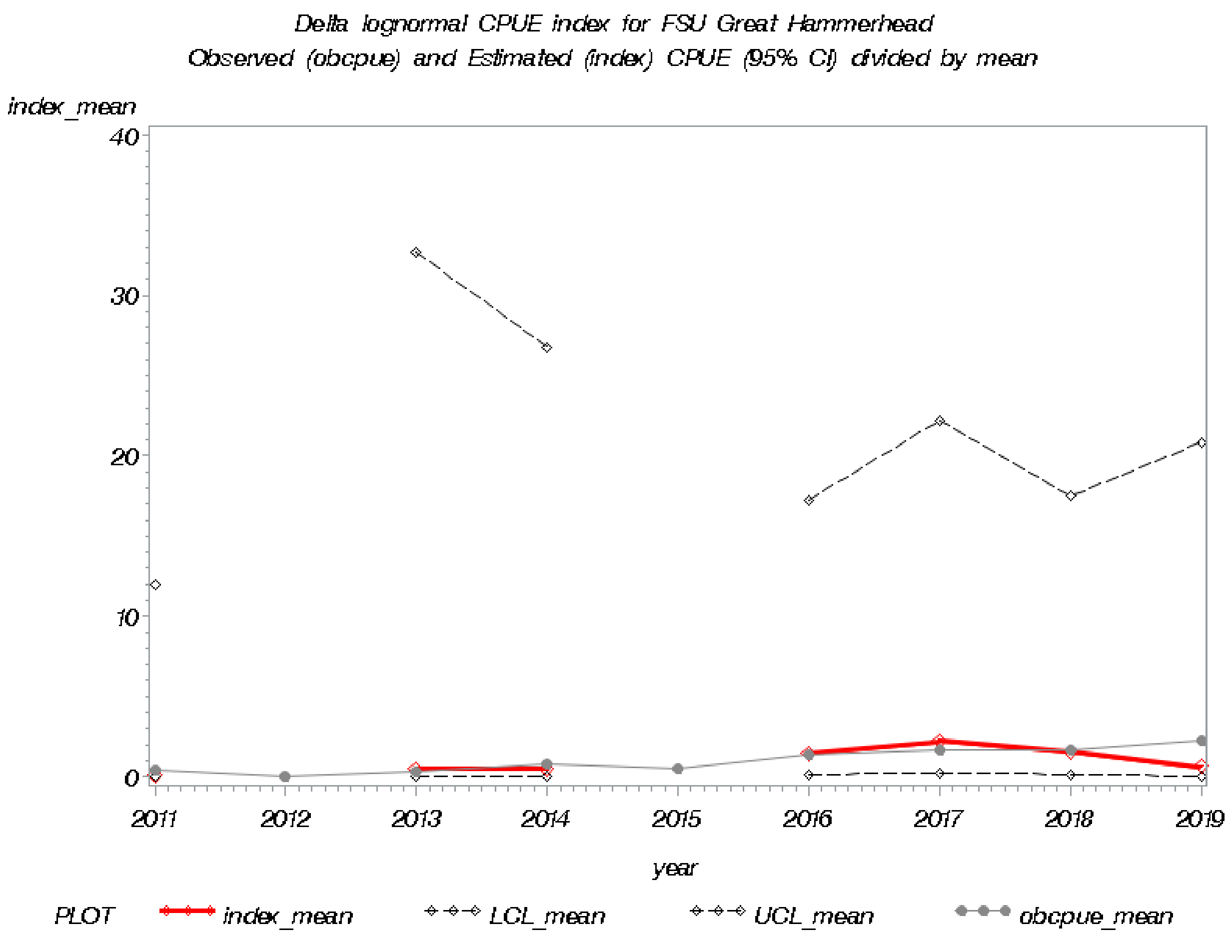
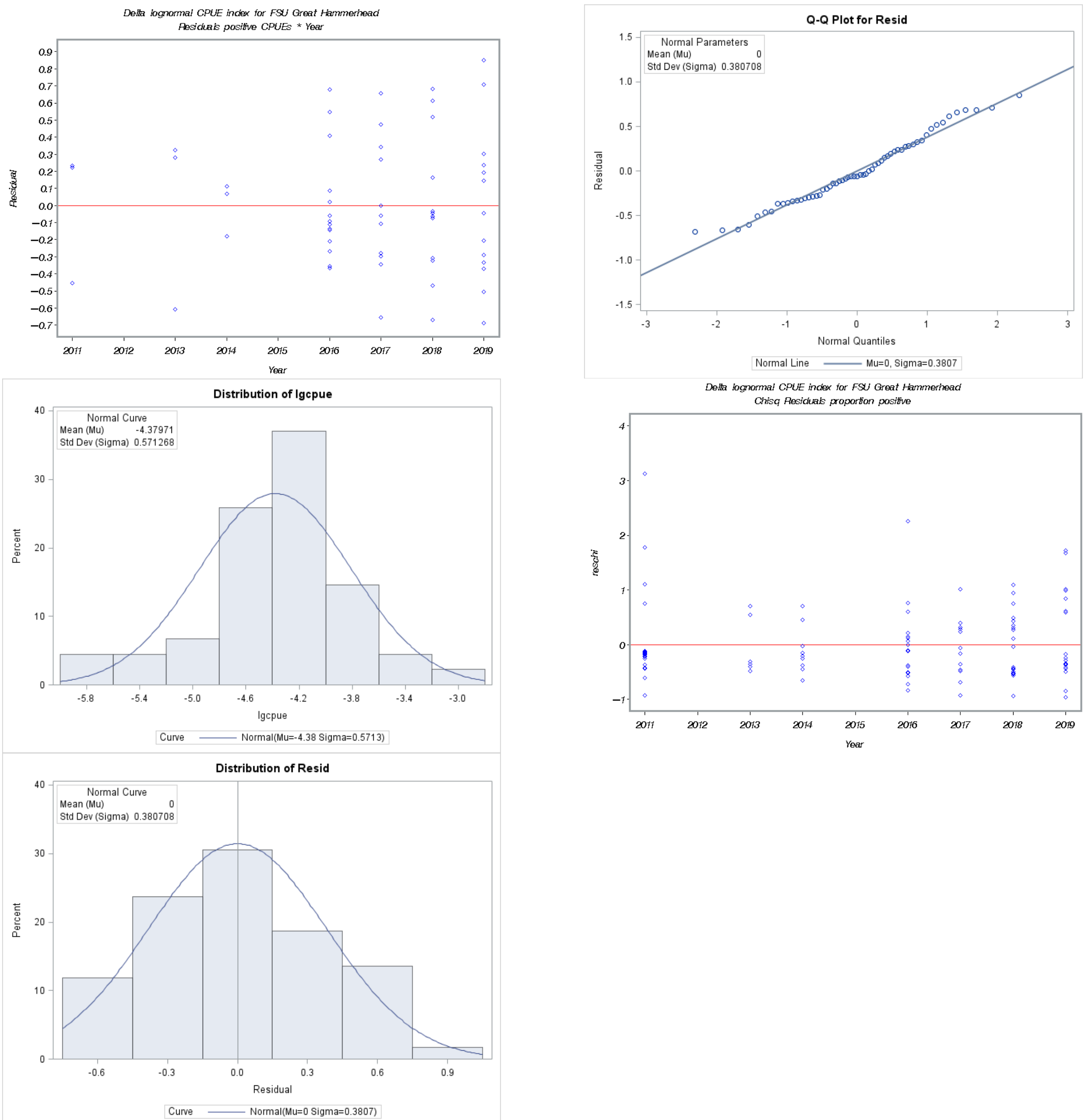


Figure 3. Diagnostic plots of the model outputs for great hammerhead.



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ADDENDUM TO SEDAR77-DW14 (Standardized Abundance Indices for Great Hammerhead from the Florida State University Longline Survey).

During discussions during SEDAR77, the Indices Working Group noted that the initial analysis of these data resulted in high CVs and a low proportion positive. The Working Group recome Working Group recomended that a post-analysis be conducted on a subset of data based on habitat. Data was refined and post-analysis conducted on a subset of data to reduce true zeros from areas where hammerheads would never or rarely be available. The revised indices for scalloped and great hammerhead are in Tables 1 and 2, respectively.

Table 1. Revised indices of scalloped hammerhead shark abundance developed using the delta-lognormal model. The nominal frequency of occurrence, the number of samples (N), the DL Index (number per sharks per 100 hook 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.

SurveyYear	*NominalFrequency*	*N*	*LoIndex*	*ScaledLoIndex*	*CV*	*LCL*	*UCL*
2011	0.26190	42	.002502520	0.66221	0.33274	0.34636	1.26606
2014	0.09091	11	.000853606	0.22588	1.14653	0.03616	1.41115
2015	0.35714	14	.005611364	1.48485	0.46765	0.61010	3.61385
2016	0.22222	9	.003969819	1.05048	0.77734	0.26560	4.15472
2017	0.52000	25	.009096064	2.40696	0.27058	1.41443	4.09596
2018	0.15789	19	.002530397	0.66958	0.65567	0.20248	2.21424
2019	0.16667	12	.001889713	0.50005	0.79598	0.12317	2.03004

Table 2. Revised indices of great hammerhead shark abundance developed using the delta-lognormal model. The nominal frequency of occurrence, the number of samples (N), the DL Index (number per sharks per 100 hook 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.

SurveyYear	*NominalFrequency*	*N*	*LoIndex*	*ScaledLoIndex*	*CV*	*LCL*	*UCL*
2011	0.15663	83	.001027728	0.39977	0.29131	0.22590	0.70745
2013	0.16667	12	.001415426	0.55057	0.73405	0.14810	2.04674
2014	0.18182	11	.002094389	0.81468	0.72873	0.22085	3.00517
2015	0.17647	17	.002469014	0.96040	0.59772	0.31797	2.90081
2016	0.20339	59	.003464370	1.34757	0.29643	0.75418	2.40785
2017	0.22642	53	.004452870	1.73208	0.29309	0.97548	3.07551
2018	0.25581	43	.003374469	1.31260	0.30150	0.72766	2.36777
2019	0.17391	23	.002268287	0.88232	0.51885	0.33230	2.34272