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Standardized Abundance Indices for Scalloped Hammerhead from the Southeast Coastal Gillnet Fishery

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Introduction

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). In 2005, the gillnet observer program was expanded to include all vessels that have an active directed shark permit and fish with sink gillnet gear. These vessels were not previously subject to observer coverage because they either were targeting non-highly migratory species or were not fishing gillnets in a drift or strike fashion. These vessels were selected for observer coverage in an effort to determine their impact on finetooth shark, *Carcharhinus isodon*, landings and their overall fishing impact on shark resources when the gear is not targeting sharks. In 2006, the National Marine Fisheries Service Southeast Regional Office requested further expansion of the scope of the gillnet observer program to include all vessels fishing gillnets regardless of target, and for coverage to be extended to cover the full geographic range of gillnet fishing effort in the southeast United States. This was requested because of the need to monitor (at statistically adequate levels) all gillnet fishing effort to assess risks to right whales and other protected species. Further, in 2007 the regulations implementing the Atlantic Large Whale Take Reduction Plan were amended and included the removal of the mandatory 100% observer coverage for drift gillnet vessels during the right whale calving season but now prohibit all gillnets in an expanded southeast U.S. restricted area that covers an area from Cape Canaveral, FL, to the North Carolina/South Carolina border, from November 15 - April 15. The rule does posses limited exemptions, only in waters south of 29 degrees N latitude, for shark strikenet fishing during this same period and for Spanish mackerel gillnet fishing in the months of December and March. Based on these regulations and on current funding levels, the gillnet observer program now covers all anchored (sink, stab, set), strike, or drift gillnet fishing by vessels that fish from Florida to North Carolina and the Gulf of Mexico year-round. Current protocols for selection of vessels for observer coverage and collection of data are found in Mathers et al. (2014). Herein, we develop a catch rate series for scalloped hammerhead based on data collected by on-board observers from 1998-2019.

Methods

Following the definition of the south Atlantic and Gulf of Mexico by the Highly Migratory Species Division, abundance trends were developed for the Atlantic Ocean and all areas. Abundance trends were not developed specific to the Gulf of Mexico due to low proportion positives. Similarly, abundance trends were not developed for great hammerhead due to low sample size.

I. Fishery description

Vessel and gear descriptions are provided in detail in Mathers et al. (2018 and references therein).

Catch rates analysis

A data set was developed based from Mathers et al. (2018 and references therein). 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.). For the purposes of analysis, several categorical variables were constructed:

-“Year” (21 levels)=1998-2019

- “Area” (5 levels)=location of net set
South Florida=South of 27°51’ N Latitude
Central Florida=27°51’ N to 30°00’N Latitude
Florida/Georgia=30°00’ N Latitude to 32°00’N Latitude
North Carolina= North of 32°00’ N Latitude
Gulf of Mexico

-‘Target” (4 levels)
Shark
Mackerel (Spanish or King Mackerel)
Teleost
Dogfish
Mixed

- “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=2”-6” stretched mesh
Medium mesh=7”-9” stretched mesh
Large mesh=>10” stretched mesh

-Gear Type: corresponds to how the net was fished
Drift-The net is allowed to float at the surface
Strike-The net is actively encircled around a school of fish
Sink-The net is anchored on both ends

The proportion of sets that caught a scalloped 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 mackerel caught per 10^{-7} net area hours, i.e.:

CPUE=log [(sharks kept+ sharks released)/(net length*net depth*soak time/10000000)]

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 8.7% for all areas and 8.7% for the Atlantic. The stepwise construction of the models is summarized in Table 1. Analyses of Delta-lognormal mixed model formulations for scalloped hammerhead are in Table 2. The index statistics 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 maximum 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 for all areas.

All areas

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.9788				
YEAR	1.6038	18.951	18.951	258.4	<.0001
YEAR+					
TARGET	1.4361	27.426	8.475	101.83	<.0001
SEASON	1.4851	24.949		72.5	<.0001
GEAR_TYPE	1.5039	23.999		60.23	<.0001
SETBEGIN	1.5236	23.004		50.56	<.0001
MESHSIZE	1.5856	19.871		13.61	0.0011
AREA	1.605	18.890		2.51	0.2855
YEAR+TARGET+					
GEAR_TYPE	1.3053	34.036	6.610	77.02	<.0001
SEASON	1.3231	33.136		68.3	<.0001
SETBEGIN	1.3758	30.473		38.42	<.0001
MESHSIZE	1.392	29.654		27.88	<.0001
YEAR+TARGET+GEAR_TYPE+					
SEASON	1.2494	36.861	2.825	35.48	<.0001
SETBEGIN	1.2936	34.627		10.54	0.0145
MESHSIZE	1.2977	34.420		6.9	0.0317
YEAR+TARGET+GEAR_TYPE+SEASON+					
SETBEGIN	1.2341	37.634	0.773	12.33	0.0063
MESHSIZE	1.2453	37.068		4.79	0.0913

Positive catches-Lognormal error distribution					
FACTOR	**DEVIANCE/ DF**	**%DIFF**	**DELTA%**	**CHISQUA RE**	**PR>CHI**
NULL	4.0664				
YEAR	1.8345	54.886	54.886	291.86	<.0001
YEAR+					
SETBEGIN	1.4532	64.263	9.377	82	<.0001
SEASON	1.6948	58.322		29.99	<.0001
GEAR_TYPE	1.7007	58.177		27.75	<.0001
TARGET	1.7528	56.896		19.71	0.0006
MESHSIZE	1.8391	54.773		1.3	0.5208
AREA	1.8423	54.695		0.71	0.6999

YEAR+SETBEGIN+					
SEASON	1.4025	65.510	1.247	15.25	0.0016
GEAR_TYPE	1.4298	64.839		7.64	0.0219
TARGET	1.4525	64.280		4.51	0.3416

Atlantic Ocean

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	2.0641				
YEAR	1.6903	18.110	18.110	233.45	<.0001
YEAR+					
TARGET	1.493	27.668	9.559	105.17	<.0001
AREA	1.5219	26.268		89.25	<.0001
GEAR_TYPE	1.5587	24.485		69.3	<.0001
SEASON	1.5643	24.214		68.05	<.0001
SETBEGIN	1.6045	22.266		47.93	<.0001
MESHSIZE	1.6738	18.909		11.64	0.003
YEAR+TARGET+					
GEAR_TYPE	1.3195	36.074	8.406	89.21	<.0001
AREA	1.365	33.869		67.97	<.0001
SEASON	1.3746	33.404		63.21	<.0001
SETBEGIN	1.4247	30.977		38.38	<.0001
MESHSIZE	1.4466	29.916		26.08	<.0001
YEAR+TARGET+GEAR_TYPE+					
AREA	1.1957	42.072	5.998	65.15	<.0001
SEASON	1.2712	38.414		27.83	<.0001
SETBEGIN	1.3128	36.398		7.27	0.0638
MESHSIZE	1.3177	36.161		3.56	0.1683
YEAR+TARGET+GEAR_TYPE+AREA+					
SEASON	1.1828	42.697	0.625	9.93	0.0192

Positive catches-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	4.141				
YEAR	1.7556	57.604	57.604	298.33	<.0001
YEAR+					
SETBEGIN	1.3554	67.269	9.664	86.3	<.0001
AREA	1.5557	62.432		42.05	<.0001
GEAR_TYPE	1.6182	60.922		28.31	<.0001

SEASON	1.6231	60.804		28.44	<.0001
TARGET	1.6886	59.222		16.82	0.0021
MESHSIZE	1.7597	57.505		1.41	0.4943
YEAR+SETBEGIN+					
AREA	1.2608	69.553	2.284	26.49	<.0001
SEASON	1.3094	68.380		26.08	<.0001
GEAR_TYPE	1.3411	67.614		5.57	0.0616
TARGET	1.3528	67.332		5	0.2876
YEAR+SETBEGIN+AREA+					
SEASON	1.2727	69.266		0.31	0.9577

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

ALL AREAS					
PROPORTION POSITIVE	*AIC*			*POSITIVE*	**AIC**
YEAR*GEAR_TYPE	**2078.4**			**YEAR*SEASON**	**1076.7**
YEAR*SEASON	2087.7			YEAR+SETBEGIN+SEASON	1083.3
YEAR+TARGET+GEAR_TYPE+SEASON+SET BEGIN	2126.3			YEAR*SETBEGIN	1084.7
YEAR*TARGET	2126.3				
YEAR*SETBEGIN	2126.3				
ATLANTIC					
YEAR*GEAR TYPE	**652.3**			**YEAR*AREA**	**983.7**
YEAR*AREA	655.9			YEAR+SETBEGIN+AREA	988.5
YEAR+TARGET+GEAR_TYPE+AREA	658.9			YEAR*SETBEGIN	988.6
YEAR*TARGET	658.9				

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).

All Areas

Year	Nominal	N	Standardized Index	LCL	UCL	CV
1998	37.95	9	28.90	4.61	181.08	1.15
1999	3.32	52	3.90	0.95	16.07	0.81
2000	15.41	54	24.64	6.78	89.51	0.72
2001	6.43	106	6.99	1.93	25.23	0.71

2002	9.24	107	6.31	1.62	24.53	0.77
2003	5.52	65	3.67	0.77	17.49	0.92
2004	26.39	56	23.65	6.47	86.50	0.72
2005	81.43	152	22.09	7.58	64.37	0.58
2006	48.43	213	37.38	12.40	112.69	0.60
2007	20.30	168	11.08	2.31	53.18	0.92
2008	23.92	204	11.25	3.20	39.51	0.70
2009	43.82	418	18.62	5.58	62.18	0.66
2010	19.79	305	18.80	4.43	79.85	0.83
2011	25.01	420	23.34	5.66	96.29	0.81
2012	34.94	331	27.01	7.85	92.95	0.68
2013	59.29	230	41.61	10.22	169.46	0.80
2014	14.23	241	25.51	4.62	140.94	1.04
2015	15.49	220	18.62	3.66	94.66	0.97
2016	16.86	207	21.46	4.74	97.19	0.88
2017	0.31	75	0.70	0.08	5.90	1.45
2018	122.70	89	124.26	31.54	489.57	0.77
2019	43.56	94	54.63	12.98	229.89	0.82

Atlantic Ocean

Year	Nominal	N	Standardized Index	LCL	UCL	CV
1998	37.95	9	17.26	2.52	118.34	1.24
1999	3.32	52	3.36	0.85	13.31	0.78
2000	5.30	45	13.96	3.62	53.74	0.76
2001	4.71	93	10.13	2.95	34.76	0.68
2002	11.32	86	7.09	1.81	27.81	0.77
2003	5.52	65	4.84	1.07	21.92	0.88
2004	26.39	56	27.60	8.17	93.24	0.67
2005	81.43	152	31.28	11.15	87.75	0.55
2006	49.27	204	36.88	12.02	113.17	0.61
2007	20.30	168	7.14	1.53	33.37	0.90
2008	24.25	201	19.19	5.46	67.40	0.70
2009	44.90	390	26.40	8.65	80.51	0.60
2010	19.79	305	21.26	4.97	90.99	0.83
2011	25.25	416	29.71	7.93	111.27	0.74
2012	37.92	305	22.21	7.13	69.24	0.62
2013	63.72	214	50.39	12.87	197.27	0.77
2014	14.66	234	42.72	8.32	219.28	0.98
2015	18.52	184	13.23	2.84	61.73	0.90
2016	17.54	199	25.72	6.26	105.69	0.80

2017	0.07	66	0.46	0.04	5.58	1.93
2018	136.51	80	83.66	21.04	332.67	0.78
2019	44.02	93	33.38	7.30	152.72	0.88

Figure 1. Distribution of fishing effort in the southeast gillnet fishery 1998-2019. An individual plot by year and in some locations was not possible because of vessel confidentiality.

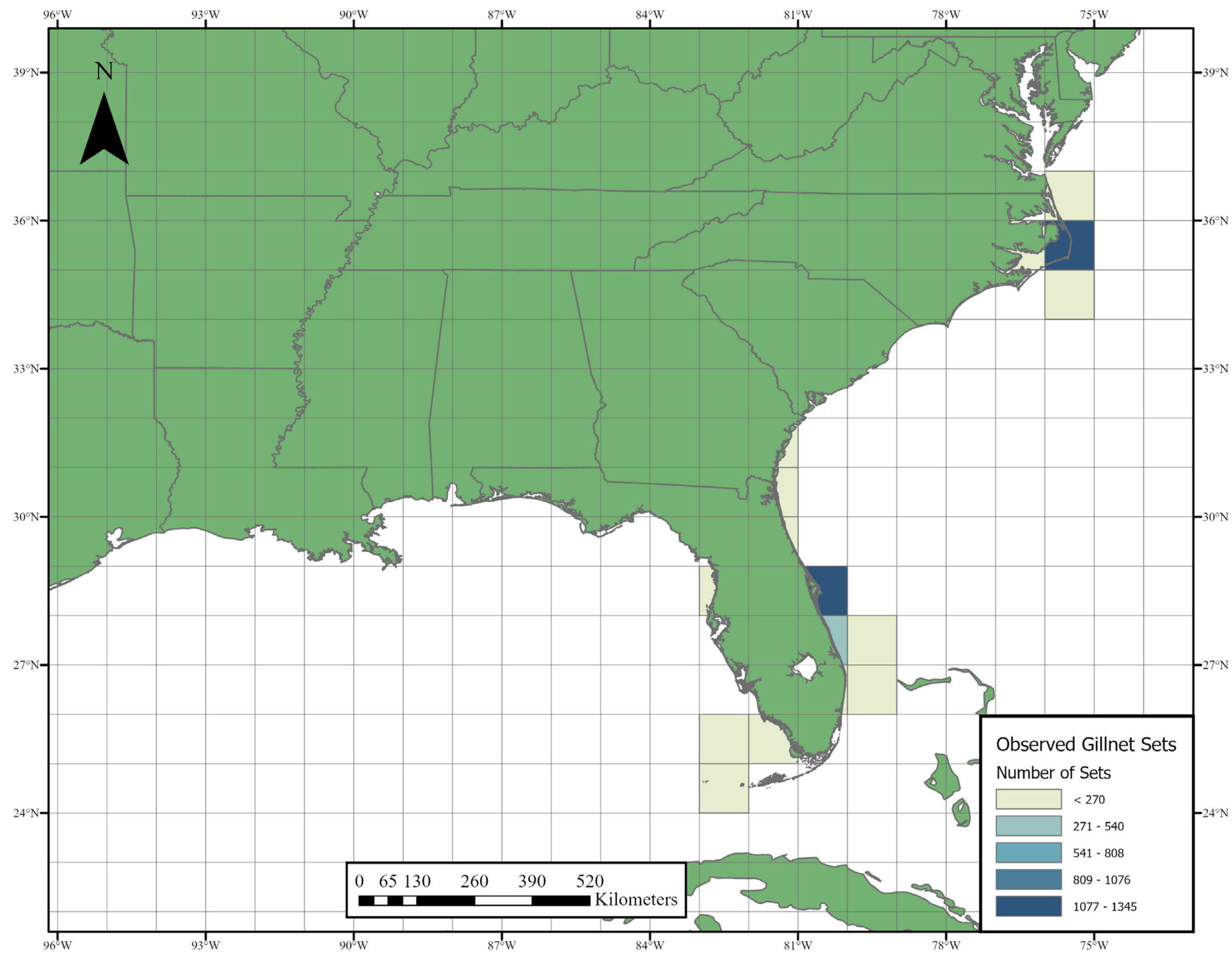
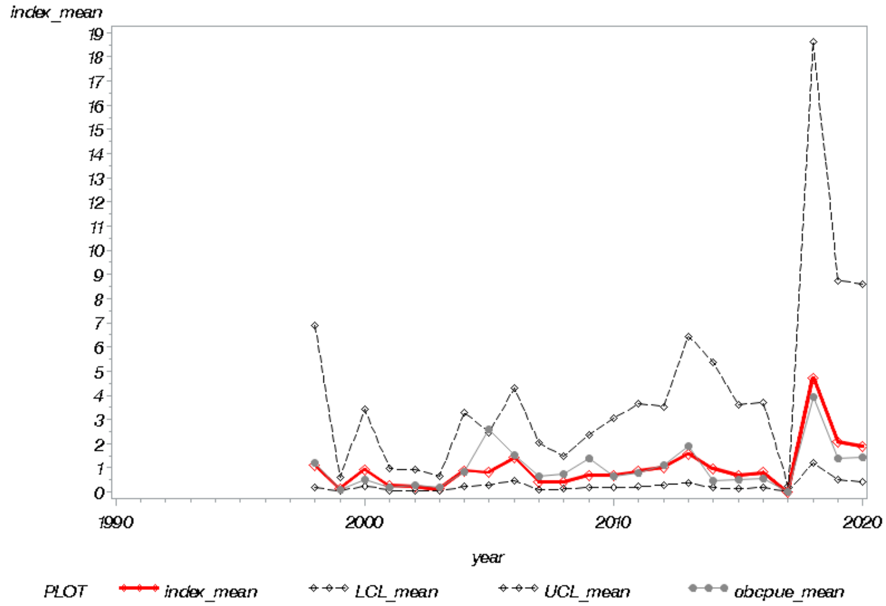


Figure 2. Nominal and standardized indices of abundance for scalloped hammerhead. The dashed lines are the 95% confidence limits for the standardized index. Each index has been divided by the maximum of the index.

Delta lognormal CPUE index for Scalloped Hammerhead_All Areas
Observed (obcpue) and Estimated (index) CPUE (95% CI) divided by mean



Delta lognormal CPUE index for Scalloped Hammerhead_Atlantic Ocean
Observed (obcpue) and Estimated (index) CPUE (95% CI) divided by mean

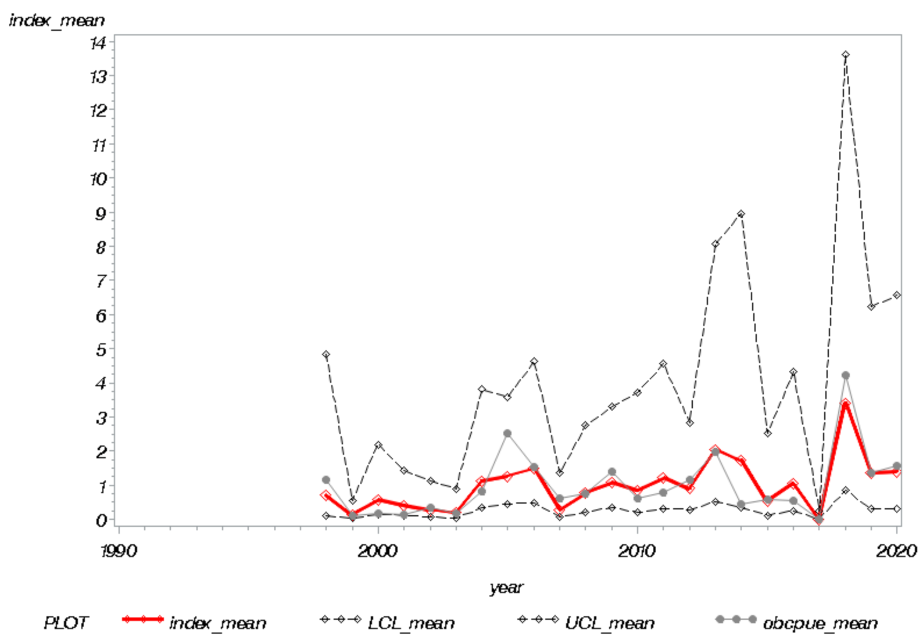
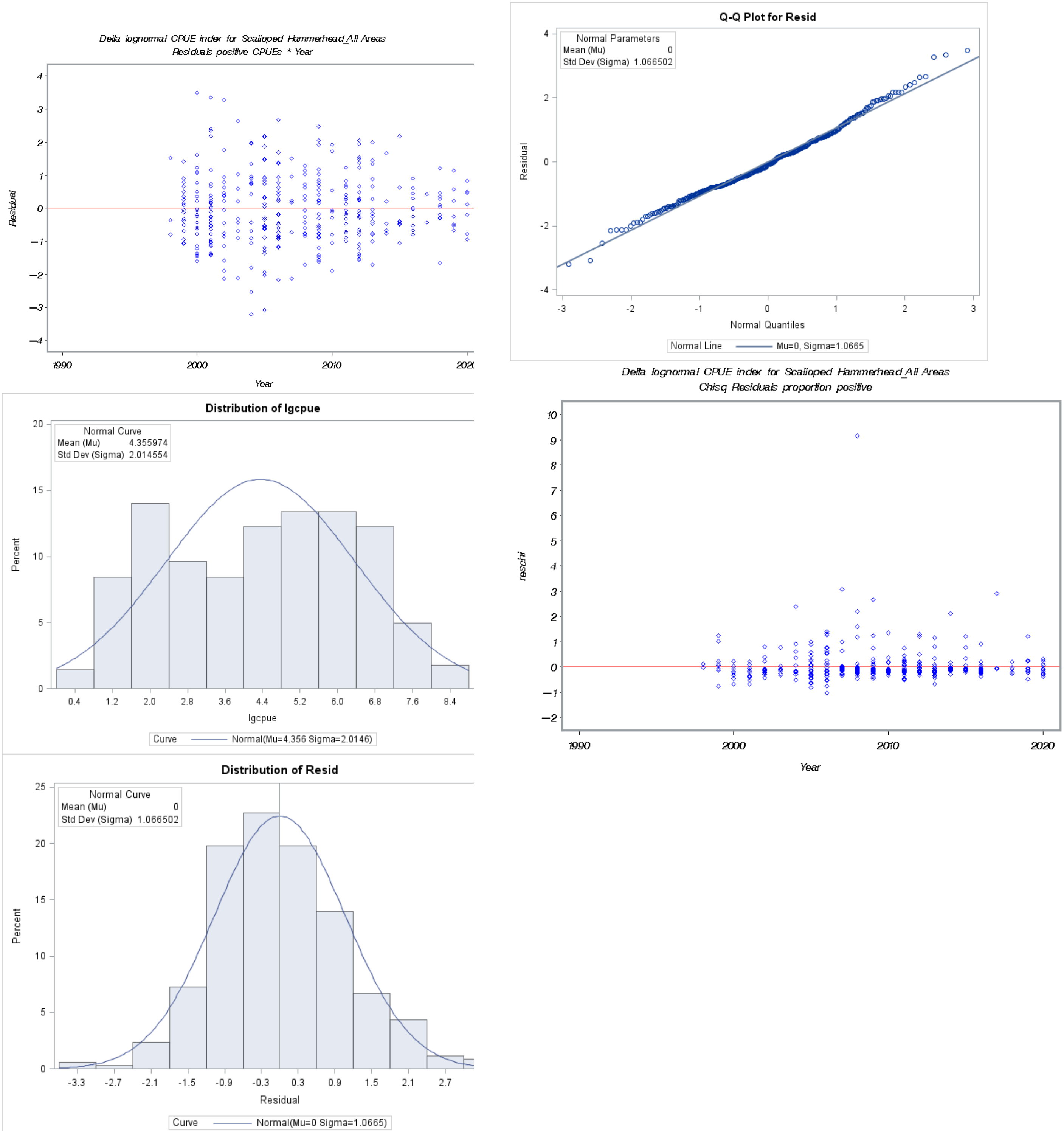
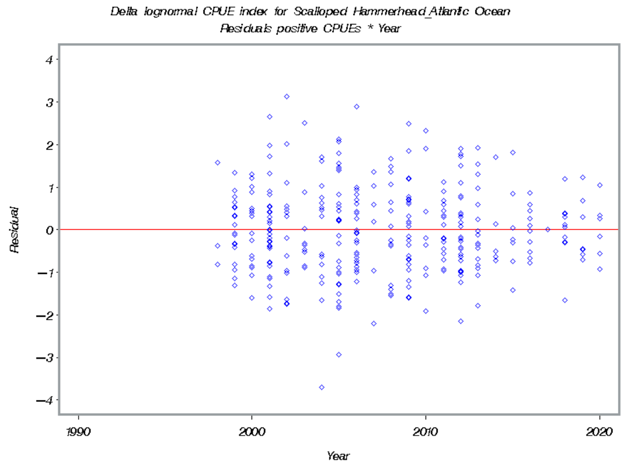
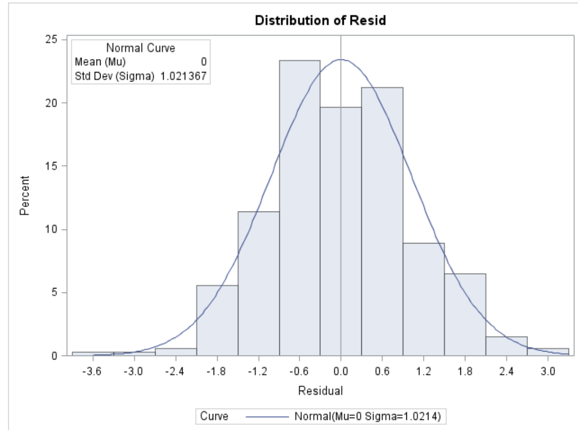
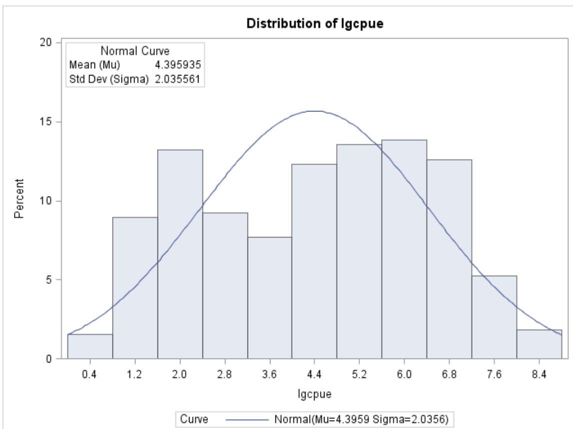


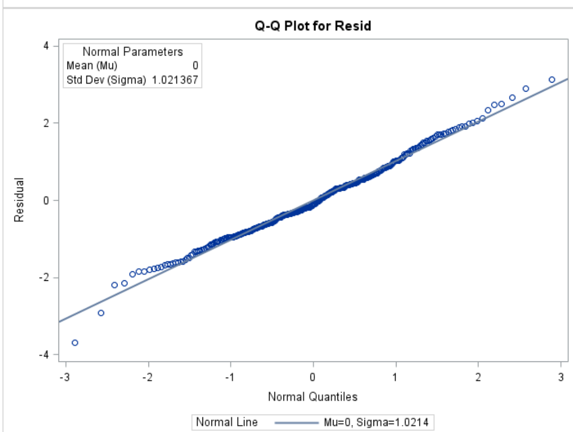
Figure 3. Diagnostic plots of the model outputs for scalloped hammerhead.

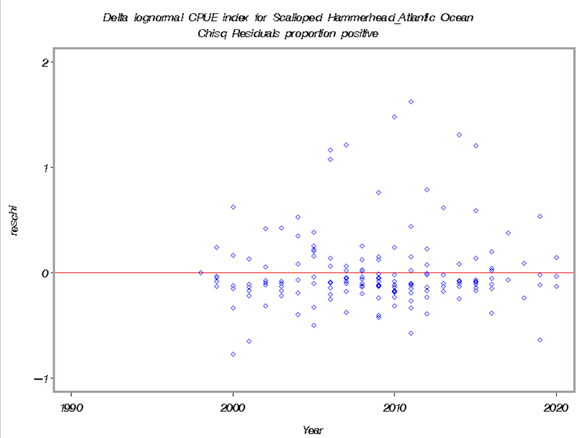



Delta lognormal CPUE index for Scalloped Hammerhead_Atlantic Ocean
Residuals positive CPUEs * Year
Residual
Year
1990
2000
2010
2020


Distribution of Resid
Normal Curve
Mean (Mu) 0
Std Dev (Sigma) 1.021367
Percent
Residual
Curve
Normal(Mu=0 Sigma=1.0214)


Distribution of lgcpue
Normal Curve
Mean (Mu) 4.395935
Std Dev (Sigma) 2.035561
Percent
lgcpue
Curve
Normal(Mu=4.3959 Sigma=2.0356)


Q-Q Plot for Resid
Normal Parameters
Mean (Mu) 0
Std Dev (Sigma) 1.021367
Residual
Normal Quantiles
Normal Line
Mu=0, Sigma=1.0214


Delta lognormal CPUE index for Scalloped Hammerhead_Atlantic Ocean
Chisq Residuals proportion positive
reschi
Year
1990
2000
2010
2020

Literature Cited

Brodziak, J. and Walsh, W.A., 2013. Model selection and multimodel inference for standardizing catch rates of bycatch species: a case study of oceanic whitetip shark in the Hawaii-based longline fishery. Canadian Journal of Fisheries and Aquatic Sciences, 70(12), pp.1723-1740.

Cortes, E., Brown, C.A. and Beerkircher, L.R., 2007. Relative Abundance of Pelagic Sharks in the Western North Atlantic Ocean, Including the Gulf of Mexico and Caribbean Sea. Gulf and Caribbean Research, 19(2), pp.37-52.

Lo, N.C.H., Jacobson, L.D. and Squire, J.L., 1992. Indices of relative abundance from fish spotter data based on delta-lognornial models. Canadian Journal of Fisheries and Aquatic Sciences, 49(12), pp.2515-2526.

Ortiz, M. and Arocha, F., 2004. Alternative error distribution models for standardization of catch rates of non-target species from a pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery. Fisheries Research, 70(2-3), pp.275-297
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