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Standardized Catch Rates of Spanish mackerel 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 Spanish mackerel based on data collected by on-board observers from 1998-2020.

I. Fishery description

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

Catch rates analysis

A combined 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 using the PROC GENMOD procedure in SAS (SAS Inst., Inc.). For the purposes of analysis, several categorical variables were constructed:

-"Year" (22 levels)=1998-2020

- "Area" (4 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

-"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 Spanish mackerel (when at least one mackerel 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 [(mackerel kept+ mackerel released)/(net length*net depth*soak time/10000000)]

Following previous methods in multiple SEDARs, factors most likely to influence the probability of capturing a Spanish mackerel 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 mackerel was caught) was 47.9%. The stepwise construction of the models is summarized in Table 1. The index statistics can be found in Table 2. 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 Spanish mackerel.

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/ DF**	**%DIFF**	**DELTA %**	**CHISQUARE**	**PR>CHI**
NULL	6.0666				
YEAR	5.1424	15.234	15.234	579.85	<.0001
YEAR+					
TARGET	2.0282	66.568	51.334	Negative of Hessian not positive definite	
SEASON	4.0204	33.729		486.72	<.0001
MESHSIZE	4.6288	23.700		175.45	<.0001
GEAR_TYPE	4.7686	21.396		104.87	<.0001
AREA	4.8266	20.440		166.99	<.0001
SETBEGIN	4.9329	18.688		26.82	<.0001

YEAR+SEASON+					
MESHSIZE	3.7555	38.095	4.367	141.05	<.0001
AREA	3.8127	37.153		116.14	<.0001
SETBEGIN	3.8938	35.816		75.53	<.0001
GEAR_TYPE	3.9669	34.611		34.91	<.0001
YEAR+SEASON+MESHSIZE+					
SETBEGIN	3.6274	40.207	2.112	75.17	<.0001
AREA	3.6518	39.805		62.98	<.0001
GEAR_TYPE	3.7624	37.982		4.06	0.1314
YEAR+SEASON+MESHSIZE+SETBEGIN					
AREA	3.5401	41.646	1.439	54.21	<.0001
GEAR_TYPE	3.6235	40.271		9.22	0.01

Positive catches-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	3.4898				
YEAR	2.1043	39.701	39.701	911.92	<.0001
YEAR+					
TARGET	1.8902	45.836	6.135	192.08	<.0001
AREA	1.9097	45.278		173.96	<.0001
SETBEGIN	2.0184	42.163		76.49	<.0001
SEASON	2.027	41.916		68.99	<.0001
MESHSIZE	2.0901	40.108		14.01	0.0009
GEAR_TYPE	2.0999	39.827		5.73	0.0571
YEAR+TARGET+					
AREA	1.6659	52.264	6.427	225.43	<.0001
SETBEGIN	1.8356	47.401		54.6	<.0001
SEASON	1.8414	47.235		49.11	<.0001
GEAR_TYPE	1.8629	46.619		27.6	<.0001
MESHSIZE	1.8918	45.791		0.49	0.7821
YEAR+TARGET+AREA+					
SEASON	1.6391	53.032	**0.768**	31.68	<.0001
SETBEGIN	1.6472	52.800		22.92	<.0001
GEAR_TYPE	1.6666	52.244		1.3	0.522

Table 2. The absolute standardized and nominal index of abundance for Spanish mackerel with the associated coefficients of variation (CV) and number of sets observed (N).

YEAR	LO INDEX	CV	N	RELATIVE INDEX (INDEX/MAX)	LCI	UCI
1998			9			
1999	1033.451	0.433	52	0.044	0.019	0.101
2000	420.036	0.514	45	0.018	0.007	0.047
2001	300.230	0.805	93	0.013	0.003	0.053
2002	165.527	1.003	86	0.007	0.001	0.037
2003	300.382	1.779	65	0.013	0.001	0.140
2004	263.992	1.309	56	0.011	0.002	0.083
2005	5099.396	0.465	152	0.218	0.090	0.527
2006	4341.447	0.352	204	0.185	0.093	0.367
2007	10580.427	0.226	168	0.452	0.289	0.706
2008	5264.853	0.198	201	0.225	0.152	0.333
2009	18480.408	0.126	390	0.789	0.613	1.014
2010	7163.481	0.217	305	0.306	0.199	0.470
2011	3993.649	0.153	416	0.170	0.126	0.231
2012	6475.301	0.160	305	0.276	0.201	0.380
2013	6356.031	0.244	214	0.271	0.168	0.438
2014	9111.125	0.218	234	0.389	0.253	0.598
2015	8451.095	0.269	184	0.361	0.212	0.612
2016	10895.285	0.226	199	0.465	0.298	0.727
2017	3563.076	0.459	66	0.152	0.063	0.365
2018	7962.722	0.247	80	0.340	0.209	0.553
2019	8690.920	0.256	93	0.371	0.224	0.614
2020	23433.800	0.331	62	1.000	0.525	1.907

Figure 1. Distribution of fishing effort in the southeast gillnet fishery 1998-2020. An individual plot by year and in some locations was not possible because of vessel confidentiality.

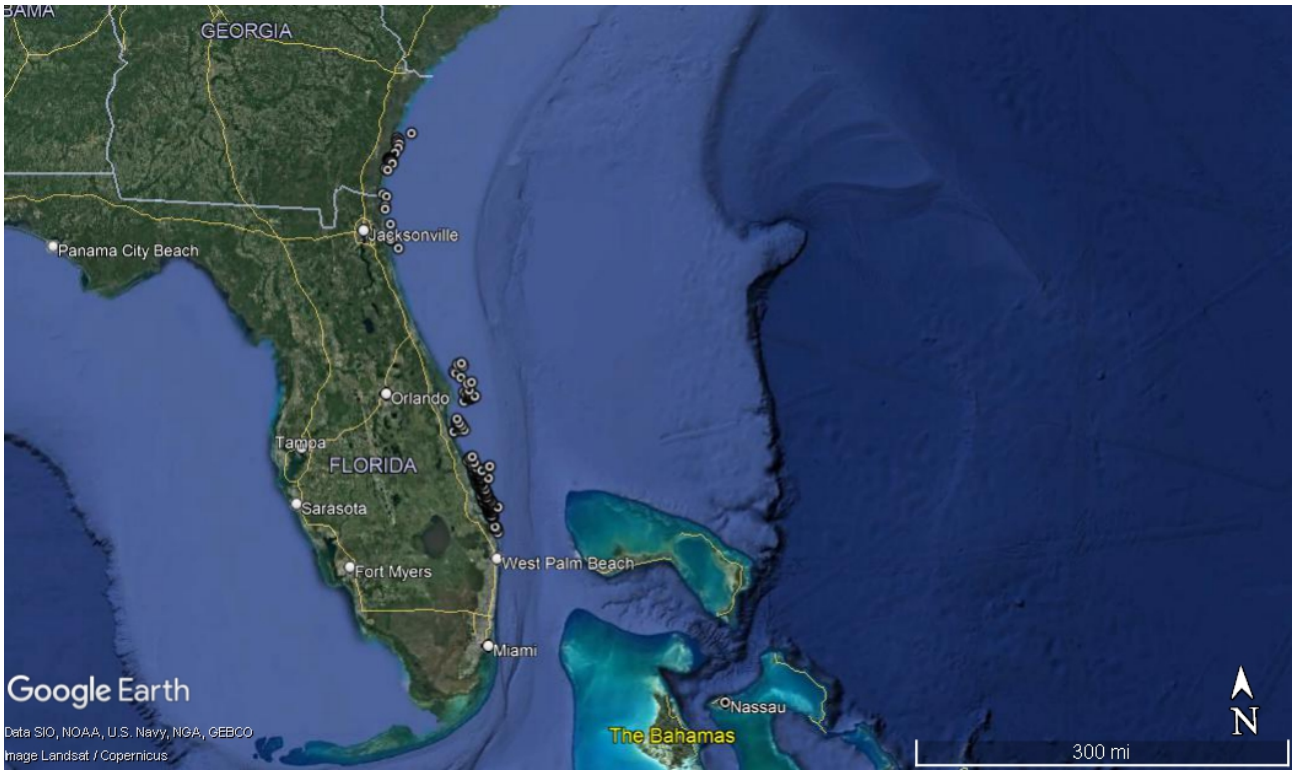


Figure 2. Nominal and standardized indices of abundance for Spanish mackerel. The dashed lines are the 95% confidence limits for the standardized index. Each index has been divided by the maximum of the index.

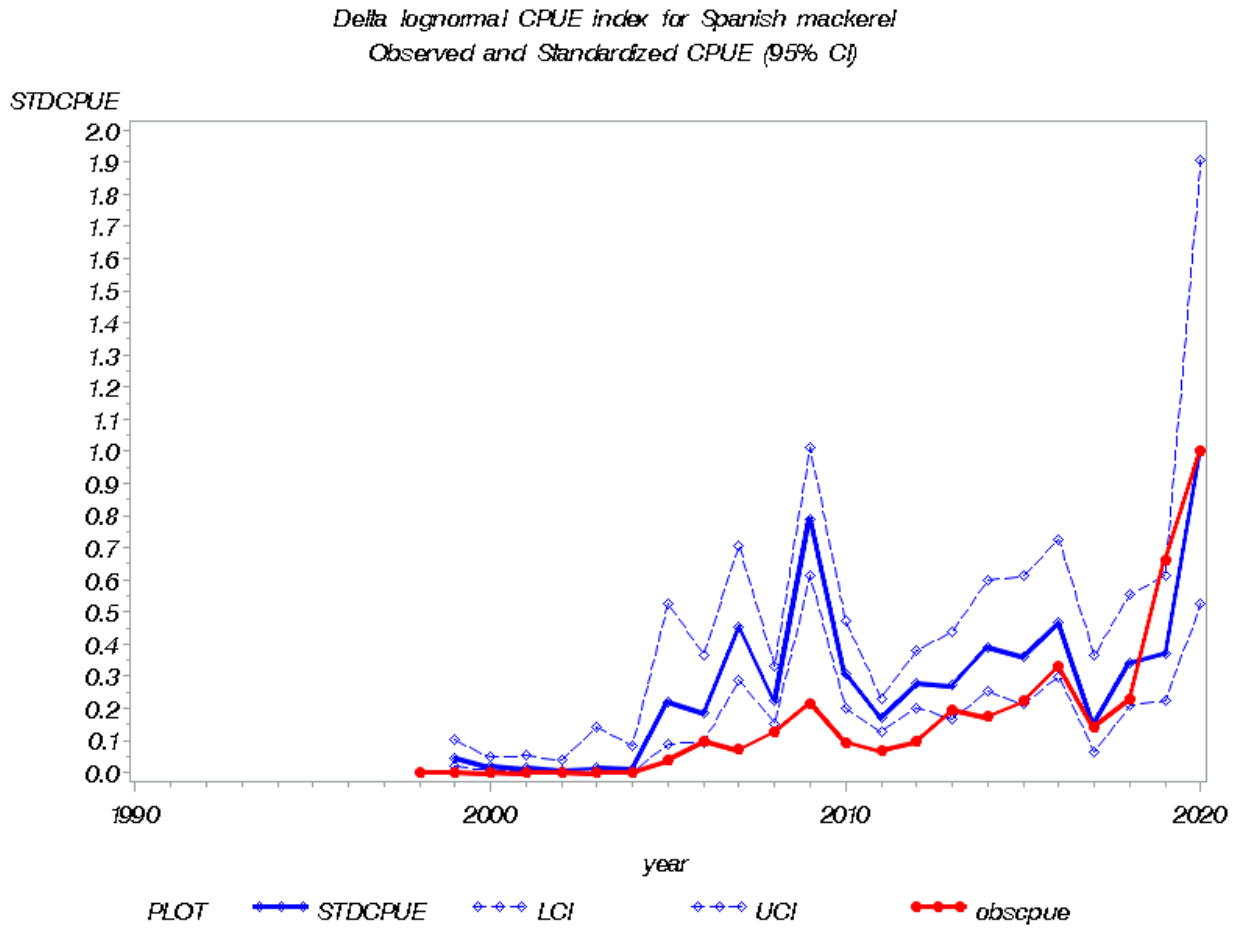
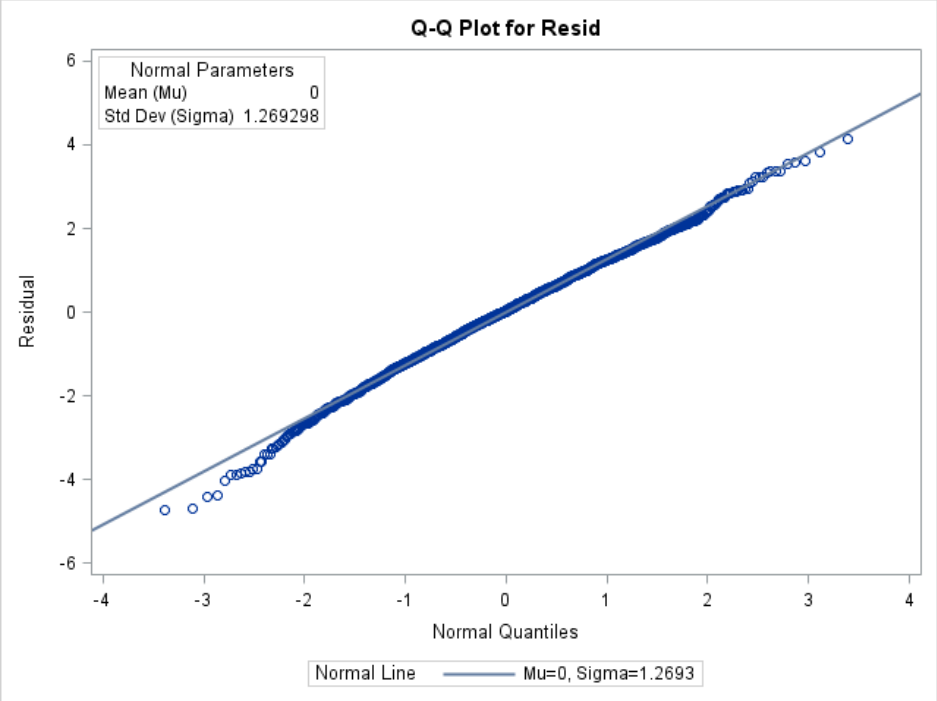
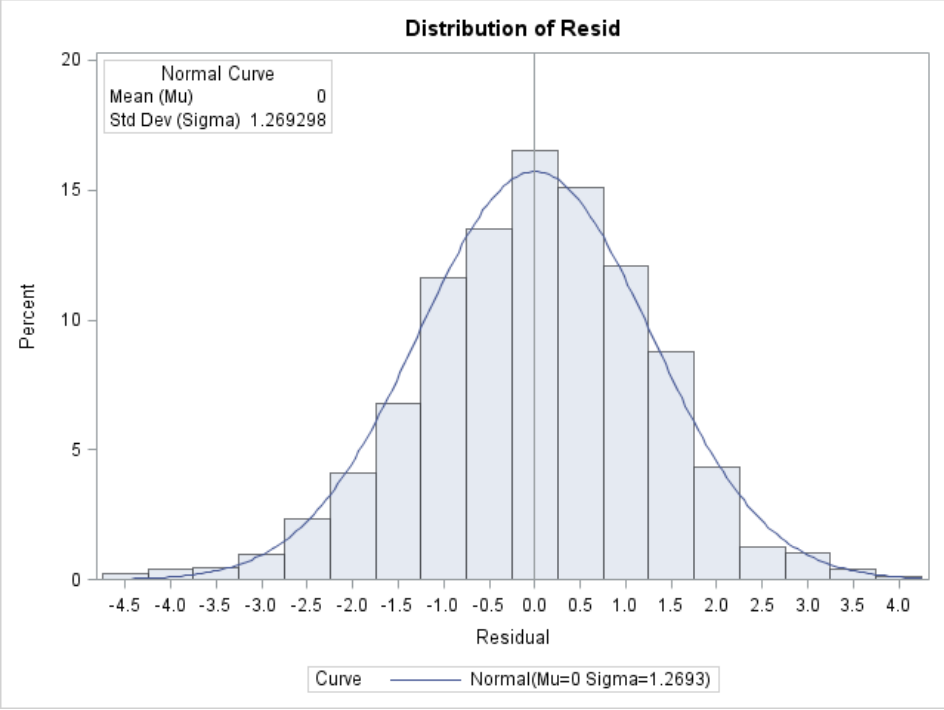
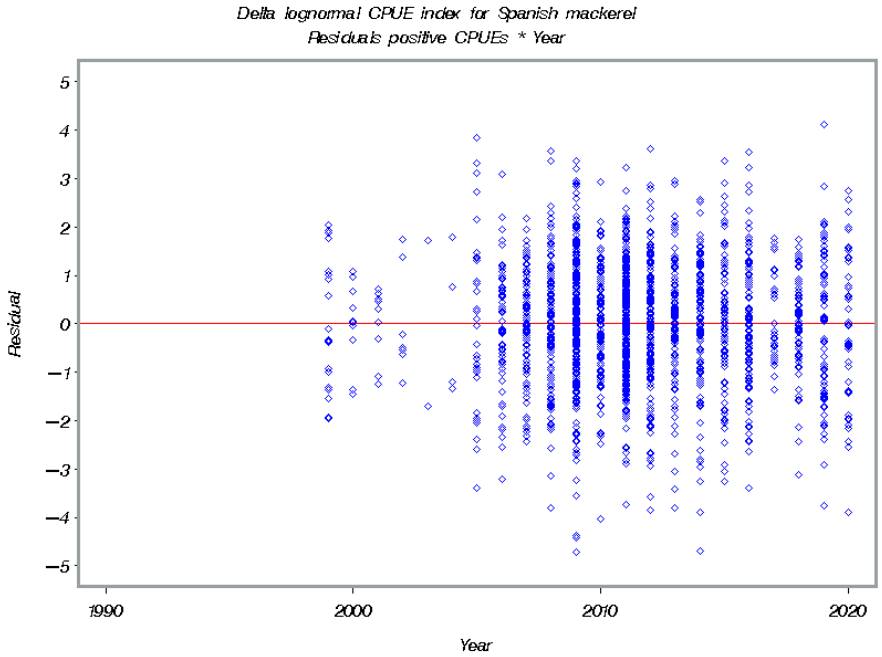
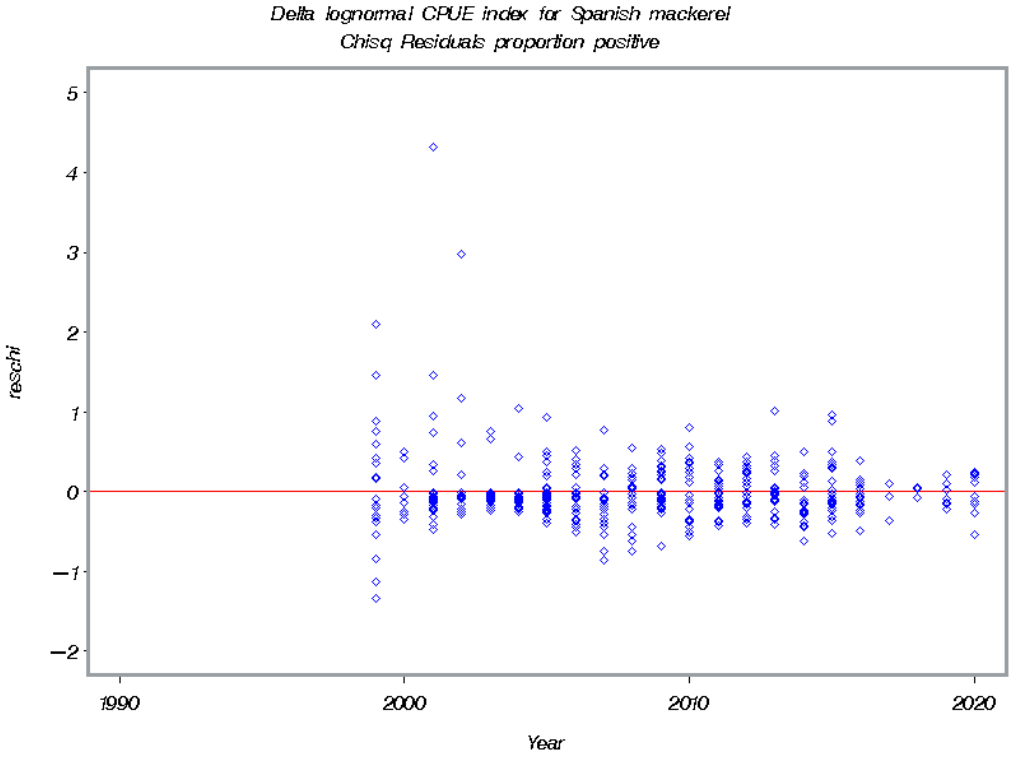


Figure 3. Diagnostic plots of the model outputs for Spanish mackerel.






Delta lognormal CPUE index for Spanish mackerel
Residuals positive CPUEs * Year
Residual
Year
1990
2000
2010
2020


Delta lognormal CPUE index for Spanish mackerel
Chisq Residuals proportion positive
reschi
Year
1990
2000
2010
2020