Standardized index of abundance for scalloped hammerhead sharks from the NOAA Northeast Fisheries Science Center coastal shark bottom longline survey

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Standardized index of abundance for scalloped and great hammerhead sharks from the NOAA Northeast Fisheries Science Center coastal shark bottom longline survey

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Summary

This document details scalloped hammerhead shark catches from the Northeast Fisheries Science Center (NEFSC) coastal shark bottom longline survey conducted by the Apex Predators Program from 1996-2018. Data from this survey were used to examine the trends in relative abundance in the waters off the east coast of the United States. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were examined for each year of the bottom longline survey, 1996, 1998, 2001, 2004, 2007, 2009, 2012, 2015, and 2018. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized CPUE results from the NEFSC longline survey show an increasing trend in scalloped hammerhead shark relative abundance across the survey years from 1996 to 2018.

Introduction

The Northeast Fisheries Science Center (NEFSC) coastal shark bottom longline survey is conducted by the Apex Predators Program, Narragansett Laboratory, Narragansett, RI. The primary objective of this survey is to conduct a standardized, systematic survey of the shark populations off the US Atlantic coast to provide unbiased indices of the relative abundance for species inhabiting the waters from Florida to the Mid-Atlantic. It also provides an opportunity to tag sharks as part of the NEFSC Cooperative Shark Tagging Program and to collect biological samples and data used in analyses of life history characteristics (age, growth, reproductive biology, trophic ecology, etc.) and other research of sharks in US coastal waters.

Methods

Sampling Gear and Data Collection

The NEFSC coastal shark survey (1996-2018) covers the US continental shelf waters from Florida to Delaware in depths of 9-80 m. The survey uses a fixed station design with stations generally located approximately 30 nm apart except where the continental shelf narrows off Cape Hatteras, NC (Figure 1). Standard sampling gear consists of a 300 hook 'Florida' commercial style bottom longline. This gear consists of a 940 lb test monofilament mainline with 12 foot (3.6 m) gangions composed of 730 lb test monofilament with a longline clip at one end and a 3/0 shark hook at the other. Gangions (referred to hereafter simply as 'hooks') baited with chunks of spiny dogfish are attached to the mainline at 60-70 ft (21 m) intervals; 5 lb (2.3 kg) weights are attached every 15 hooks and a bullet float and 15 lb (6.8 kg) weights are placed at 50 hook intervals. A 20 ft (6 m) staff buoy ('high flyer') equipped with radar reflectors and flashers (at night) is attached to a poly ('tag') buoy by a 12 ft (3.6 m) line. The poly buoy is then attached to the mainline and there is a set of these to mark each end of the mainline. To ensure that the gear fishes on the bottom, 20 lb (9.1 kg) weights are placed at the beginning and end of the mainline after a length of line 2-3 times the water depth is deployed.

Once set, the gear is fished for three hours with approximately six hours from start of setting to completion of haulback. The mainline covers from 2.0 to 5.5 nm, with an average of 3.7 nm. Fishing takes place at all times of the day. Number of sets completed per day varies from one to three with an average of 2.5 sets per day. The number of sets is dependent on distance between stations, weather conditions, and the length of time to complete previous sets during the day.

Data is recorded at the beginning and end of each set and haul, when available these data consist of: number of hooks, time, location, surface and bottom temperature and salinity, depth, air temperature, wind direction and strength, and sea state. For all surveys, catch data recorded at each station include, at a minimum: species, sex and length.

Data Analysis

Catch per unit effort (CPUE) for each set is defined as the number of sharks per 100 hook hours. The CPUE was standardized using a delta-lognormal generalized linear model, which models the proportion of positive sets separately from the positive catch. Factors considered as potential influences on CPUE were: year (1996, 1998, 2001, 2004, 2007, 2009, 2012, 2015, 2018), month (April, May), area (1 = <30.75 ^{o} latitude, 2 = 30.75 to 33.77 ^{o} latitude, 3 = > 33.75 ^{o} latitude), depth (<20, 20-29, 30-39, 40+ m), and bottom water temperature (<18, 18.0-19.9, 20.0-21.9, 22+ ^{o}C). The proportion of sets with positive catch values was modeled assuming a binomial distribution with a logit link function and the positive catch sets were modeled assuming a lognormal distribution.

Models were fit in a stepwise forward manner adding one potential factor at a time after initially running a null model with no factors included. Each potential factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor resulting in the greatest reduction in deviance was then incorporated into the model provided the effect was significant at $\alpha = 0.05$ based on a Chi-Square test, and the deviance per degree freedom was reduced by at least 1% from the less complex model. This process was continued until no additional factors met the criteria for incorporation into the final model. The factor "year" was kept in all final models, regardless of its significance, to allow for calculation of indices. All models in the stepwise approach were fitted using the SAS GENMOD procedure (SAS Institute, Inc.). The final models were then run through the SAS GLIMMIX macro to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Institute, Inc), in which all interactions including the "year" factor were treated as a random effect. The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and lognormal components.

Results

Scalloped Hammerhead

A total of 258 scalloped hammerhead sharks were caught during 557 longline sets from 1996 to 2018. The size range of scalloped hammerhead sharks caught by year is displayed in Figure 2 with the majority (70%) of the catch as mature males. The proportion of sets with positive catch (at least one scalloped hammerhead shark caught) was 22%. The stepwise construction of each model and the resulting statistics are detailed in Table 1. For the scalloped hammerhead, the proportion of positive catch sets was influenced by year, depth, area, month and year*month and the positive catch sets were influenced by year. Diagnostic plots for the binomial and lognormal model components are in Figures 3 and 4, respectively. The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices for the final model are reported in Table 2 and plotted by year in Figure 5.

Table 1. Results of the stepwise procedure for development of the catch rate model for scalloped hammerhead. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	220	393.4283	1.7883				
YEAR	212	294.6326	1.3898	22.2837	22.2837	98.80	<.0001
AREA	218	358.4819	1.6444	8.0467		34.95	<.0001
MONTH	219	361.153	1.6491	7.7839		32.28	<.0001
TEMP	217	362.4358	1.6702	6.6040		30.99	<.0001
DEPTH	217	378.6749	1.7450	2.4213		14.75	0.0020
YEAR +							
DEPTH	209	261.1857	1.2497	30.1180	7.8343	33.45	<.0001
AREA	210	264.4558	1.2593	29.5812	7.2974	54.37	<.0001
MONTH	211	270.6289	1.2826	28.2783	5.9945	24.00	<.0001
TEMP	209	279.4766	1.3372	25.2251	2.9413	15.16	0.0017
YEAR + DEPTH +							
AREA	207	237.0446	1.1451	35.9671	5.8491	24.14	<.0001
MONTH	208	277.4194	1.1895	33.4843	3.3663	13.77	0.0002
TEMP	206	246.0032	1.1942	33.2215	3.1035	15.18	0.0017
YEAR + DEPTH + AREA +							
MONTH	206	231.0009	1.1214	37.2924	1.3253	6.04	0.0140
TEMP	204	230.9991	1.1323	36.6829	0.7158	6.05	0.1094
YEAR + DEPTH + AREA + MONTH +							
YEAR*MONTH	198	208.4903	1.0530	41.1173	3.8249	28.55	0.0008
YEAR*AREA	191	188.6880	0.9879	44.7576	7.4652	Negative of hessian	
YEAR*DEPTH	183	208.2438	1.1379	36.3697	-0.9227	Negative of hessian	

MIXED MODELS	AIC	BIC	(-2) Res Log Likelihood
YEAR + DEPTH + AREA + MONTH	484.5	487.1	482.5
YEAR + DEPTH + AREA + MONTH + YEAR*MONTH	480.6	482.4	476.6

FINAL MODEL: YEAR + DEPTH + AREA + MONTH + YEAR*MONTH

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	119	47.6664	0.4006				
YEAR	111	37.0813	0.3341	16.6001	16.6001	30.13	0.0002
AREA	117	45.5698	0.3895	2.7708		5.40	0.0673
TEMP	116	45.6741	0.3937	1.7224		5.12	0.1630
DEPTH	116	46.3797	0.3998	0.1997		3.28	0.3499
MONTH	118	47.5655	0.4031	-0.6241		0.25	0.6142

FINAL MODEL: YEAR

Table 2. Scalloped hammerhead proportion positive (binomial) = year + area + depth, and positive catch (lognormal) = year + depth. Scalloped hammerhead number of sets per year (n obs), number of positive sets per year (obs pos), proportion of positive sets per year (obs ppos), nominal cpue as sharks per hook (obs cpue), resulting estimated cpue from the delta-lognormal model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCL	UCL	CV
1996	89	2	0.0225	0.0011	0.0009	0.0001	0.0069	1.3060
1997								
1998	88	5	0.0568	0.0042	0.0045	0.0009	0.0218	0.9363
1999								
2000								
2001	84	17	0.2024	0.0261	0.0257	0.0083	0.0797	0.6152
2002								
2003								
2004	68	13	0.1912	0.0207	0.0294	0.0094	0.0920	0.6195
2005								
2006								
2007	22	4	0.1818	0.0089	0.0066	0.0011	0.0413	1.1470
2008								
2009	49	11	0.2245	0.0153	0.0153	0.0044	0.0537	0.6934
2010								
2011								
2012	48	14	0.2917	0.0211	0.0284	0.0101	0.0798	0.5535
2013								
2014								
2015	50	23	0.4600	0.0478	0.0545	0.0246	0.1206	0.4133
2016								
2017								
2018	53	32	0.6038	0.1105	0.1126	0.0654	0.1939	0.2769

Figure 1. Survey stations along the US East Coast from Florida to North Carolina.

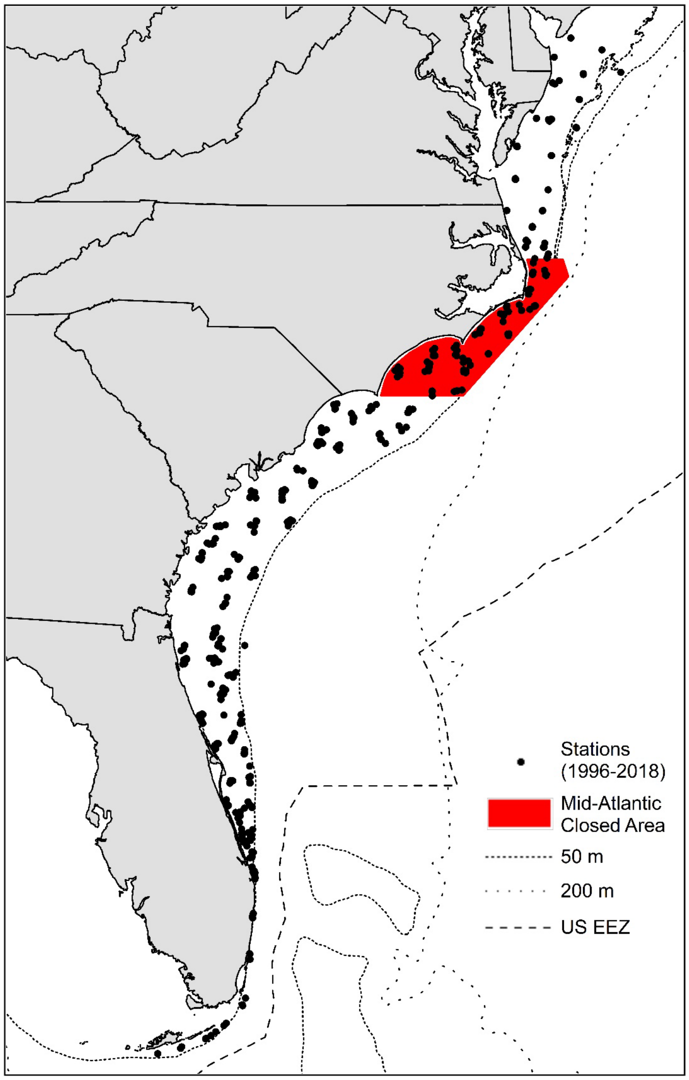


Figure 2. Fork lengths (cm) of scalloped hammerhead sharks caught by year

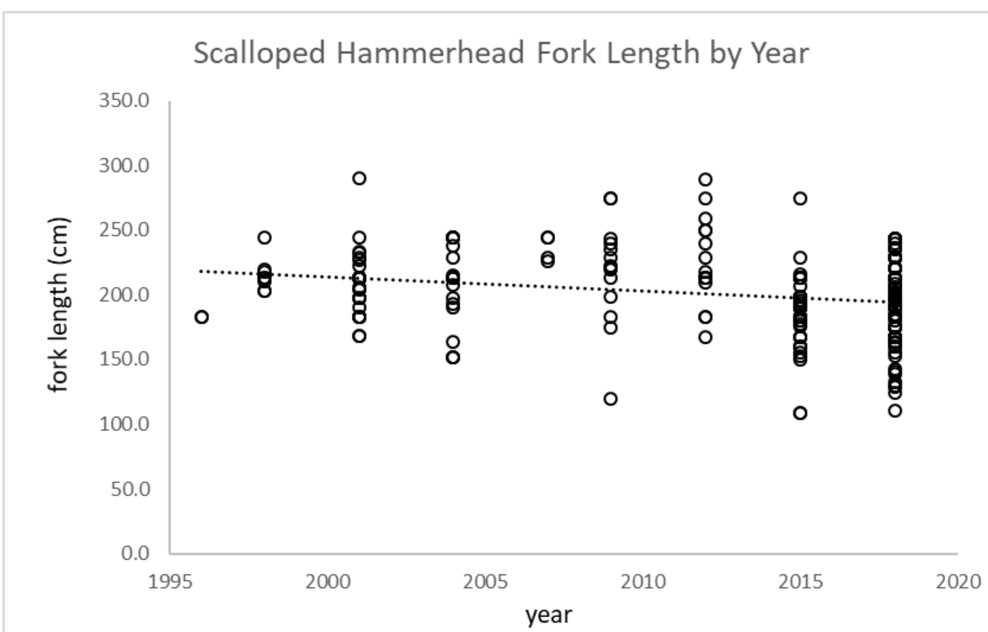


Figure 3. Scalloped hammerhead model diagnostic plots for the binomial component. Final model: proportion positive catch = year + depth + area + month. + year*month

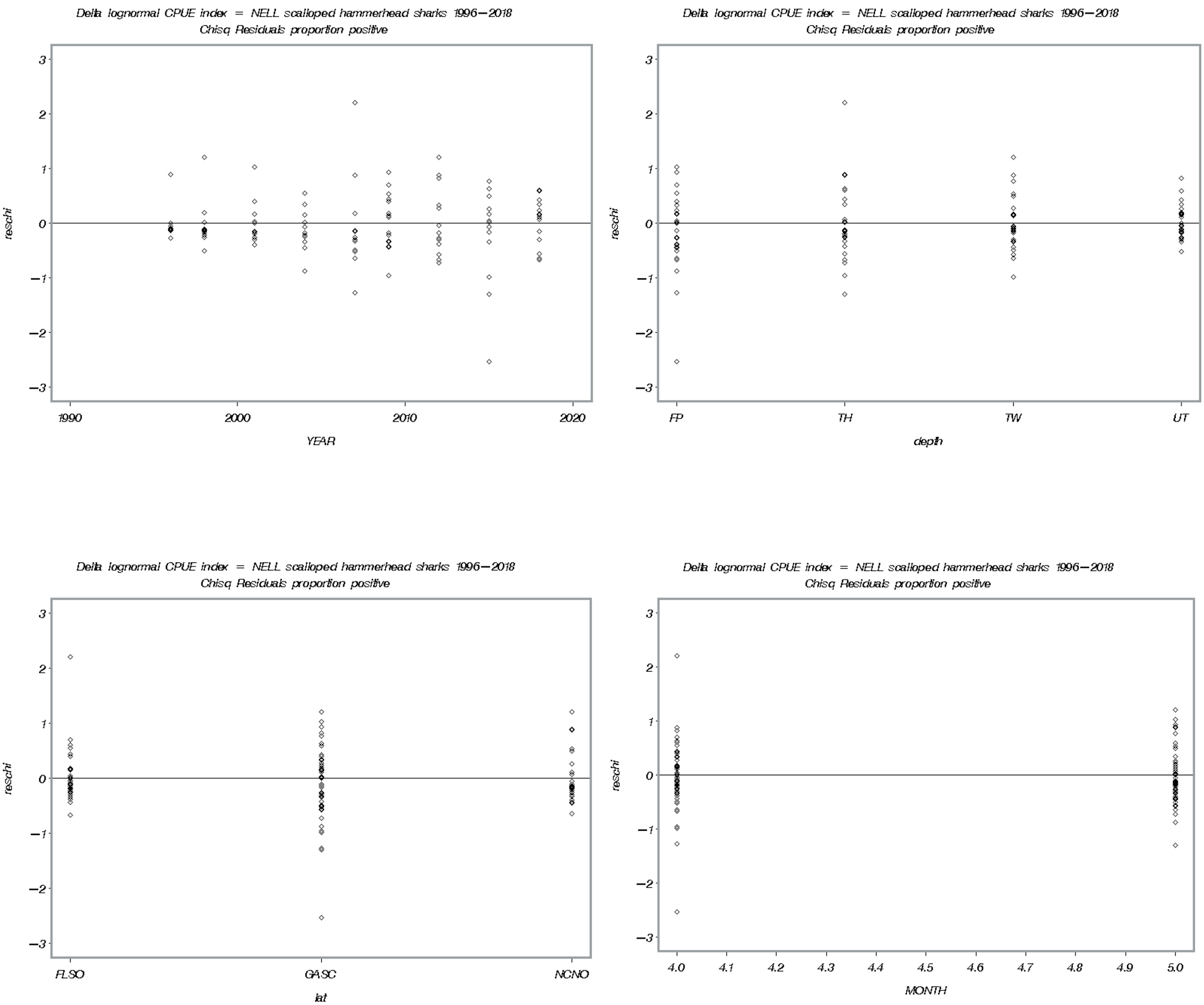
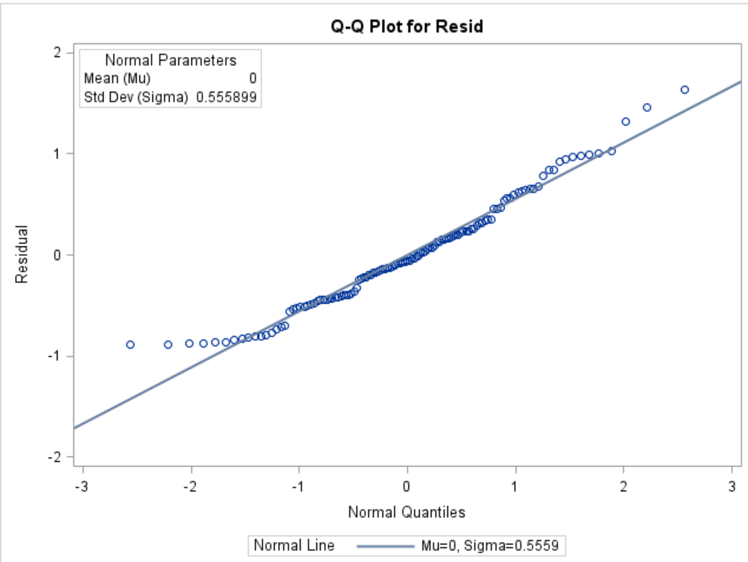
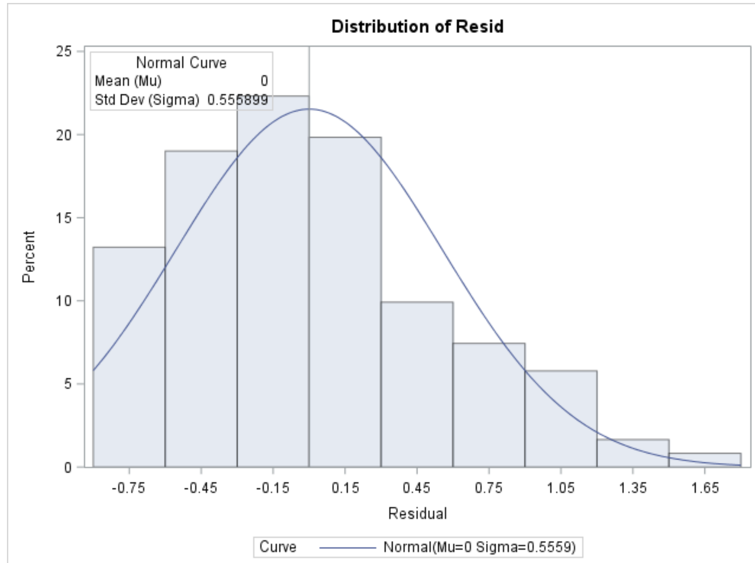


Figure 4. Scalloped hammerhead model diagnostic plots for the lognormal component. Final model: positive catch = year.





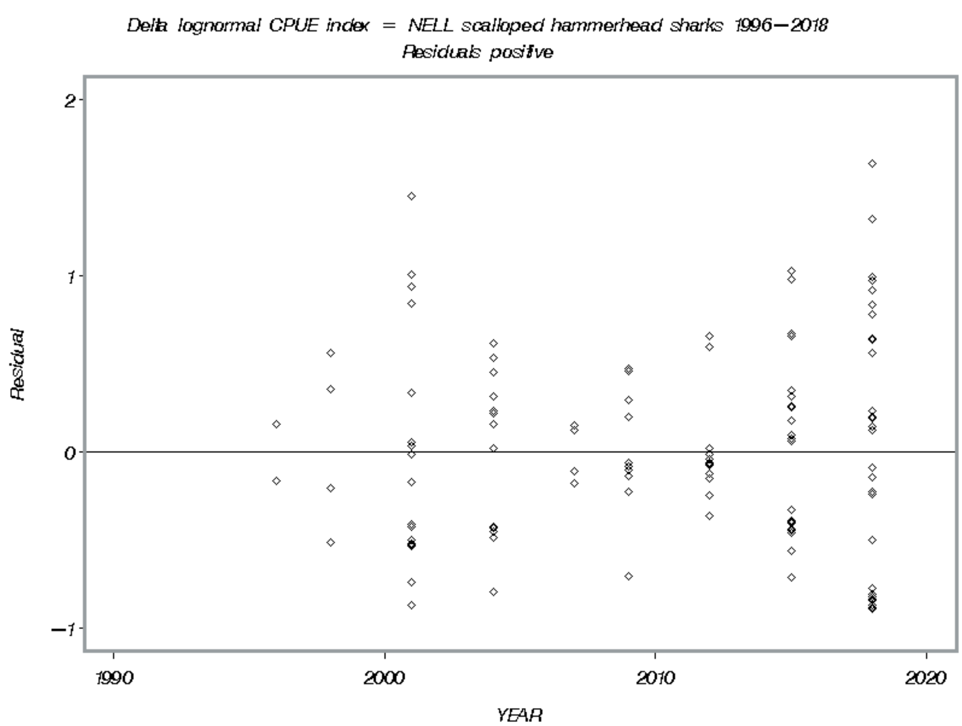


Figure 5. Scalloped hammerhead proportion positive (binomial) = year + depth + area + month + year*month and positive catch (lognormal) = year. NEFSC longline survey scalloped hammerhead shark observed (obscpue1) and standardized (stdcpue1) indices with 95% confidence limits (LCI1 and UCI1).