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ANALYSIS OF CATCH RATE SERIES FOR LARGE COASTAL SHARKS

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Summary

This document examines catch rate series of large coastal sharks that became available for this evaluation. The series include data from three fishery-independent surveys and two fishery-dependent programs: the NMFS longline survey in the northeast region, the South Carolina Department of Natural Resources longline survey, the NEFSC bottom trawl survey, the directed shark longline observer program, and the MRFSS recreational survey. A total of 41 series for large coastal sharks were examined: 8 series for the large coastal shark complex, 8 for sandbar shark, 7 for blacktip shark, 6 for dusky shark, 4 for the hammerhead shark genus, 4 for bull shark, 2 for tiger shark, 1 for scalloped hammerhead, and 1 for silky shark. Five of the series were subjected to the same Generalized Linear Model (GLM) standardization methodology to adjust for factors that affect relative abundance. The approach used to estimate relative abundance indices was a Generalized Linear Mixed Model that treats separately the proportion of sets with positive catches (i.e., where at least one shark was caught) assuming a binomial error distribution with a logit link function, and the catch rates of sets with positive catches assuming a Poisson error distribution with a log link function. Statistical analysis of trends in CPUE series revealed that there were eight significantly negative slopes and four significantly positive slopes for large coastal sharks and individual species, all of which were nominal, except for one.

ANALYSIS OF CATCH RATE SERIES AND TRENDS

Data Sources

A total of 41 catch rate series for large coastal sharks were examined. The series include data from three fishery-independent surveys and two fishery-dependent programs: the NMFS longline survey in the northeast region (NMFS LL NE), the South Carolina Department of Natural Resources longline survey (SC LL), the NEFSC bottom trawl survey (NEFSC Bottom Trawl), the directed shark bottom longline observer program (Shark Observer), and the MRFSS recreational survey (MRFSS1 and MRFSS2). Of the 41 series examined, 8 were for the large coastal shark complex, 8 for sandbar shark, 7 for blacktip shark, 6 for dusky shark, 4 for the hammerhead shark genus, 4 for bull shark, 2 for tiger shark, 1 for scalloped hammerhead, and 1 for silky shark. Several of the series (SC LL and NEFSC Bottom Trawl) were subjected to a Generalized Linear Model (GLM) standardization methodology to adjust for factors that affect relative abundance.

Fishery-independent Series

South Carolina Department of Natural Resources Longline Survey (SC LL). Three short series from this survey were presented in NMFS (1998). They are augmented herein to include the period 1995-2001. This survey utilizes monofilament longlines set in coastal waters of South Carolina monthly from January to December. The target species for this survey is red drum, although sharks of several species are commonly caught. Data were available for the large coastal shark complex and sandbar shark. Catch rates are expressed on a set basis, which consists of 120 hooks on 6000 feet of mainline, with an average soak time of 0.75 hours (Glenn Ulrich, South Carolina Department of Natural Resources, pers. comm.). The data set received allowed the series to be subjected to GLM analysis to account for spatio-temporal factors that can affect relative abundance.

CPUE Standardization Methodology

Standardized catch rates for the large coastal shark complex or individual species were developed using generalized linear mixed models for the SC LL and NEFSC Bottom Trawl data sets. Because these data sets are from fishery-independent sources, where the methodology is standardized, many of the fishery operational variables that affect relative abundance estimates in analyses of fishery-dependent data sets needed not be included in the present analysis. Explanatory variables included in the data sets received for the present analysis included season and area (geographical or depth) only. Note that these surveys do not target sharks specifically and, in the case of the NEFSC Bottom Trawl survey, contain a large proportion of sets with 0 catches. For this latter survey, the data set had to be truncated by eliminating levels of the explanatory variables (e.g., specific years) from the analysis to avoid over-parameterization of the model and lack of convergence of the algorithm. Final models thus typically contained few variables and no interaction terms were included because of the reasons given above.

The approach used to estimate relative abundance indices was a Generalized Linear Mixed Model that treats separately the proportion of sets with positive catches (i.e., where at least one shark was caught) assuming a binomial error distribution with a logit link function, and the catch rates of sets with positive catches assuming a Poisson error distribution with a log link

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function. The models were fitted with the SAS GENMOD procedure (SAS Institute Inc. 1999) using a forward stepwise approach in which each potential factor was tested one at a time. Initially, a null model was run with no explanatory variables (factors). Factors were then entered one at a time and the results ranked from greatest to smallest reduction in deviance per degree of freedom when compared to the null model. The factor which resulted in the greatest reduction in deviance per degree of freedom was then incorporated into the model if two conditions were met: 1) the effect of the factor was significant at least at the 5% level based on the results of a Chi-Square statistic of a Type III likelihood ratio test, and 2) the deviance per degree of freedom was reduced by at least 1% with respect to the less complex model. The year factor was always included because it is required for developing a time series.

Results were summarized in the form of deviance analysis tables including the deviance for proportion of positive observations and the deviance for the positive catch rates. Once the final model was selected, it was run with a computer program that utilizes the SAS GLIMMIX macro (which fits generalized linear mixed models using the SAS MIXED procedure; Wolfinger, SAS Institute Inc.). Goodness-of-fit criteria for the final model included Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion, and –2* the residual log likelihood (-2Res L). The significance of each individual factor was tested with a Type III test of fixed effects, which examines the significance of an effect with all the other effects in the model (SAS Institute Inc. 1999). The final mixed model calculated relative indices as the product of the year effect least squares means (LSMeans) from the binomial and Poisson components using bias correction terms to calculate confidence intervals.

Trend Analysis

Linear regressions were fitted to the CPUE series. The dependent variable (catch rate) was sometimes log-transformed to improve the fit between CPUE and time (independent variable). The positive or negative trend of the slope and whether it was significant was noted.

Results and Discussion

Standardized Catch Rates

SC LL Indices. Months were pooled into seasons (winter, spring, summer, and fall) and sampling locations, which were originally too numerous to include in the analysis, were pooled into four major areas. About 38%, 16%, and 11% of the sets analyzed encountered large coastal sharks, sandbar shark, and blacktip shark, respectively. The proportion of positive catches for the large coastal complex, sandbar, and blacktip shark was explained in each case by the season and year, area and year, and year and season factors, respectively (Tables 2-4). The mean catch rates for positive catches were explained by the area and season factors for the large coastal complex (Table 2), season and area for sandbar shark (Table 3), and year for blacktip (Table 4). Despite not being significant (P=0.0774 for the large coastal complex, Table 2; P=0.4922 for sandbar shark, Table 3), the year factor was included to develop the time series. Factors in the final model for the large coastal complex were significant, except for the year factor for both proportion positive and positive catches (Table 2). For sandbar shark, only the year factor in the positive catches was not significant (P=0.2979; Table 3), whereas for blacktip shark all factors

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were significant (Table 4). The relative standardized catch rates showed very similar trends to those of the nominal values for the three series, with all nominal values falling inside the 95% confidence limits of the standardized series (Figure 7).

Trend Analysis

Four of the eight series available for the large coastal shark complex showed a declining trend in catch rates, all statistically significant at the 1% and 5% levels (Table 7). Of the four series that showed a positive trend, only the Shark Observer series was statistically significant (1% level). This series had also the steepest slope (11%), whereas the largest statistically significant annual rate of decrease was about 6% (NEFSC Bottom Trawl survey).

Four of the eight series for sandbar shark also exhibited a declining trend, but only two had a significantly negative slope (5% and 1% level). Of the four series showing a positive trend, none had a significantly positive slope. For blacktip, three of the seven series exhibited negative slopes, but none was statistically significant. Of the six series available for dusky shark, three had negative slopes and three had positive slopes, one of which (NMFS LL NE) was very steep and significant (5% level; but keep in mind that this series consists only of 3 points). For tiger shark, both series examined had positive slopes, but only one was significant (5% level; Shark Observer). For sharks of the hammerhead genus all four series (MRFSS) showed declining trends: the two MRFSS2 series (type A+B1+B2 catch) had statistically significant slopes at the 1% (for the 1981-1993 series) and 5% (1994-2000) level, respectively. All four recreational series for bull shark had negative slopes, but none was statistically significant. The NMFS LL NE series for scalloped hammerhead had a steep, significant (5% level) positive slope, and the NMFS LL NE series for silky was positive, but not significant.

In all, there were eight significantly negative slopes and four significantly positive slopes for large coastal sharks and individual species. It must be noted that all of the statistically significant series were nominal, except for the NEFSC Bottom Trawl series, which showed a negative slope for the large coastal complex. Two of the four series with significantly positive—and steep—slopes were from the NMFS LL NE survey, which consisted of only 3 points for the present analysis. The other two significantly positive series were from the Shark Observer program, but this fishery-dependent data set has not been standardized.

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References

SAS Institute Inc. 1999. SAS/STAT User's Guide, version 8. Carey, NC: SAS Institute Inc., 1999. 3884pp.

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Table 2. Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the**large coastal shark** aggregate in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

SCDNR LL

Proportion positive

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	727	967.23	1.3304			-483.61		
SEASON	725	945.07	1.3036	2.01	2.01	-472.54	22.15	<0.0001
AREA	724	958.86	1.3244	0.45		-479.44	8.34	0.0394
YEAR	721	957.12	1.3275	0.22		-478.56	10.11	0.1203
SEASON +								
YEAR	719	934.31	1.2995	2.32	0.31	-467.16	10.76	0.0961
AREA	722	941.87	1.3045	1.95		-470.94	3.20	0.3614
SEASON+YEAR+								
AREA	716	932.16	1.3019	2.14	-0.18	-466.08	2.15	0.5419

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON	YEAR
SEASON+YEAR	3172	3176	3170	<0.0001	0.1055

Positive catches

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	276	218.55	0.7918			-199.92		
AREA	273	195.83	0.7173	9.41	9.41	-188.56	22.72	<0.0001
SEASON	274	198.11	0.7230	8.69		-189.7	20.44	<0.0001
YEAR	270	210.48	0.7795	1.55		-195.88	8.07	0.2328
AREA +								
SEASON	271	182.48	0.6734	14.95	5.54	-181.88	13.35	0.0013
YEAR	267	184.45	0.6908	12.76		-182.87	11.38	0.0774
AREA+SEASON+								
YEAR	265	176.36	0.6655	15.95	1.00	-178.82	6.12	0.4096

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA	SEASON	YEAR
AREA+SEASON+YEAR	579	582	577	0.0001	0.0058	0.2496

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

Table 3. Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the **sandbar shark** in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

SCDNR LL

Proportion positive

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	725	627.82	0.8660			-313.91		
AREA	722	599.07	0.8297	4.19	4.19	-299.53	28.75	<0.0001
YEAR	719	597.62	0.8312	4.02		-298.81	30.20	<0.0001
SEASON	723	614.39	0.8498	1.87		-307.20	13.42	0.0012
AREA+								
YEAR	716	573.78	0.8014	7.46	3.27	-286.89	25.28	0.0003
SEASON	720	592.76	0.8233	4.93		-296.38	6.31	0.0427
AREA+YEAR+								
SEASON	714	570.16	0.7986	7.78	0.32	-285.08	3.62	0.1639

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA	YEAR
AREA+YEAR	3661	3666	3659	<0.0001	0.0004

Positive catches

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	112	126.85	1.1326			-79.24		
SEASON	110	91.23	0.8294	26.77	26.77	-61.43	35.62	<0.0001
AREA	110	94.68	0.8607	24.01		-63.15	32.17	<0.0001
YEAR	106	112.89	1.0650	5.97		-72.26	13.96	0.0301
SEASON+								
AREA	108	85.02	0.7872	30.50	3.73	-58.32	6.21	0.0448
YEAR	104	85.82	0.8252	27.14		-58.72	5.41	0.4922
SEASON+AREA+								
YEAR	102	78.54	0.7701	32.01	1.51	-55.08	6.47	0.3722

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON	AREA	YEAR
SEASON+AREA+YEAR	250	252	248	0.0046	0.0204	0.2979

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

Table 4. Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the blacktip **shark** in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

SCDNR LL

Proportion positive

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	727	512.50	0.7050			-256.25		
YEAR	721	483.51	0.6706	4.88	4.88	-241.75	29.00	<0.0001
SEASON	725	495.17	0.6830	3.12		-247.58	17.33	0.0002
AREA	724	509.37	0.7036	0.20		-254.69	3.13	0.3717
YEAR+								
SEASON	719	471.84	0.6563	6.91	2.03	-235.92	11.66	0.0029
AREA	718	4787.11	0.6659	5.55		-239.06	5.39	0.1452
YEAR+SEASON+								
AREA	716	467.97	0.6536	7.29	0.38	-233.96	3.87	0.2754

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: YEAR	SEASON
YEAR+SEASON	3885	3890	3883	0.0013	0.0022

Positive catches

Factors	d.f.	Deviance	Deviance/df	% Reduction in deviance/df	% Difference	L	Chi Square	Pr>Chi Square
NULL	81	39.16	0.4834			-74.68		
YEAR	75	30.08	0.4011	17.03	17.03	-70.14	9.08	0.1692
SEASON	79	32.95	0.4170	13.74		-71.58	6.21	0.0448
AREA	79	38.66	0.4893	-1.22		-74.43	0.50	0.7779
YEAR+								
SEASON	73	26.18	0.3586	25.82	8.79	-68.19	3.90	0.1423
AREA	73	28.88	0.3956	18.16		-69.55	1.20	0.5492

FINAL MODEL RESULTS

Factors	Akaike's information criterion	Schwarz's Bayesian criterion	-2 Res L	Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: YEAR
YEAR	151	154	149	0.0037

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

Figure 7. Relative nominal and standardized catch rates of large coastal sharks, sandbar shark, and blacktip shark from SCDNR longline survey data. CPUE is the number of sharks caught per 120 hooks per 0.75 hours. The broken line denotes the nominal average CPUE and the solid line represents the standardized CPUE (with lower and upper 95% confidence limits).