Updated catch rates of sandbar sharks (*Carcharhinus plumbeus)* in the northwest Atlantic Ocean from the Shark Bottom Longline Observer Program, 1994-2015

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SEDAR54-WP-02

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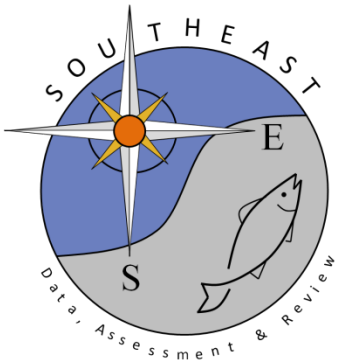

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Introduction

Observations by at-sea observers of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (e.g. Morgan et al. 2009, Enzenauer et al. 2015 and references therein). A previous stock assessment for sandbar shark shark utilized data from this fishery as an index of abundance and as an input to the stock assessment model (SEDAR21-DW-02). Herein, we update the abundance time series index.

Methods

Catch rate analysis

A combined data set was developed based on observer programs from Morgan et al. (2009) and Enzenauer et al. (2016). Historically, vessels in this fishery primarily targeted sandbar shark. With the introduction of the shark research fishery in 2008, vessels outside the research fishery were not permitted to target or land sandbar sharks. This change in management regulations likely influences the time series of abundance for sandbar shark such that vessels fishing in the research fishery should be modeled separately from those outside the research fishery. Therefore, two indices of abundance were created from this data series; 1994-2007 for all vessels and 2008-2015 for vessels in the research fishery. While observations of vessels outside the research fishery were made from 2008-2015, the low sample size in some years combined with the change in targeting practices precluded including those data.

For the purposes of analysis, several categorical variables were considered.

- "Year"
  - 1994-2007- Non-research fishery
  - 2008-2015- Research fishery only
- "Time of Day": the time of day the set started defined from the time the first hook was set in the water
  - Day = 0501-1800 hrs
  - Night = 1801-0500 hrs
- "Season"
  - Winter = January-March
  - Spring = April-June
  - Summer = July-September
  - Fall = October-December
- "Depth": defined as the mean depth when the first hook was set and the last hook was retrieved
  - 0-100 ft
  - 100-200 ft
  - 200-300 ft
  - >300 ft
- "Hook type": the hook that was used by the majority of the set
  - Large hook (> size 13 hook)
  - Medium hook (size 10-13 hook)
  - Small hook (< size 10 hook)
  - Hook size undefined
- "Bait type": the bait that was used by the majority of the set
  - Shark (Elasmobranchii)

Teleost
Other (undefined or multiple bait types)

Following previous methods in multiple SEDARs, the proportion of sets that caught sharks (when at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. Positive catches were modeled using a dependent variable of the natural logarithm of CPUE expressed as:

CPUE=log [(sharks kept+sharks released)/(number of hooks/10,000)]

Factors most likely to influence the probability of capturing a sandbar shark 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.

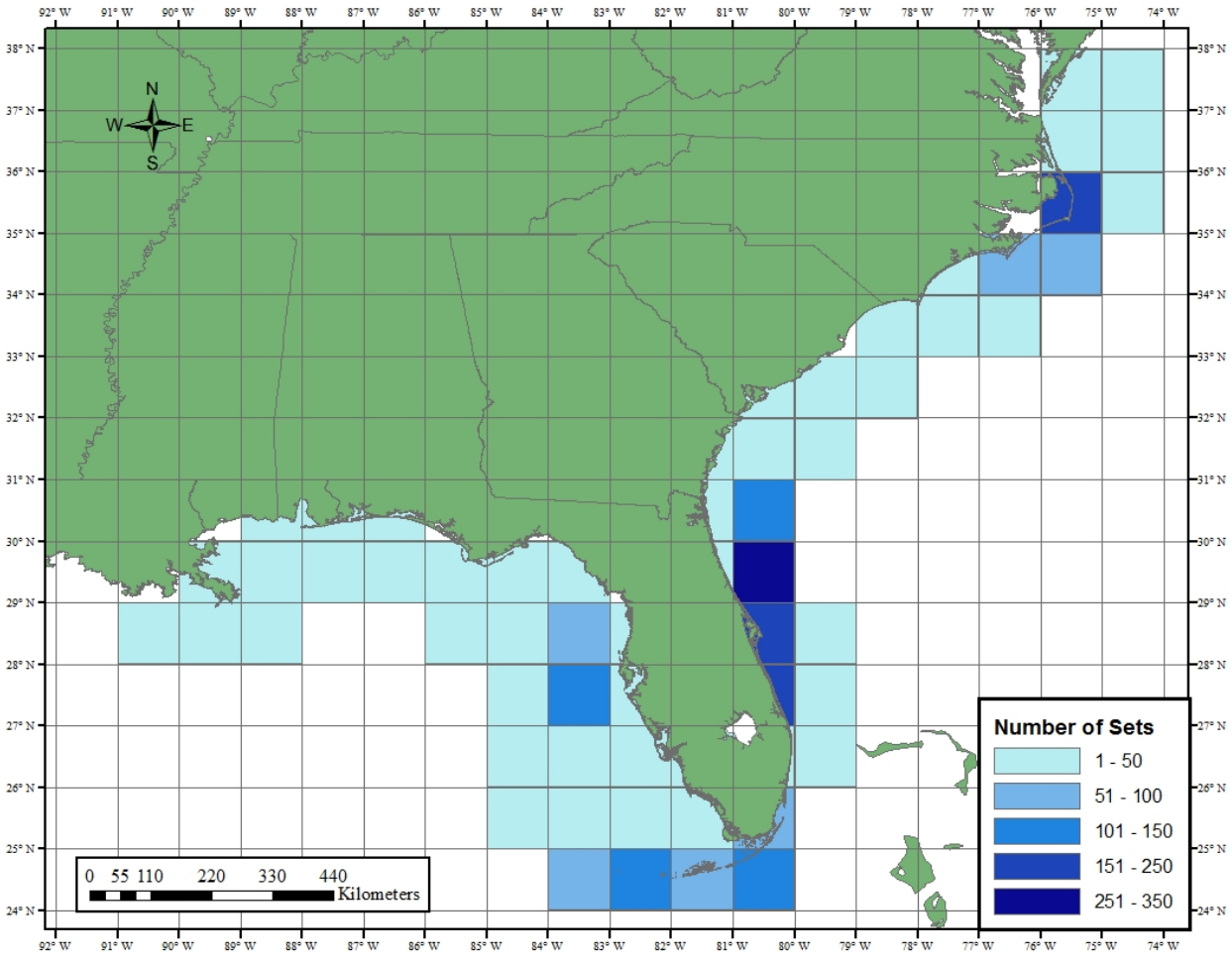
The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant ($p \leq 0.05$) based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. All analysis was conducted using the SAS statistical computer software (ver 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

A total of 1555 longline sets were made from 1994-2007 and 911 sets from 2008-2015 in the research fishery (Figure 1).

Figure 1. Distribution of fishing effort in the directed shark bottom longline fishery 1994-2007 and 2008-2015 for the research fishery. Individual plots by year and in some locations were not possible because of vessel confidentiality.



The proportion of positive sets (i.e. at least one sandbar shark was caught) was 71.2% from 1994-2007 and 84.7% from 2008-2015 for the research fishery. 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, the series were scaled to their respective average value.

Table 1. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear formulations of the proportion of positive and positive catches of sandbar shark from 1994-2007 and 2008-2015. Model is bold is the final selected model.

1994-2007

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.239				
YEAR	1.196	3.470	3.470	78.92	<.0001
YEAR+					
TIME	1.1218	9.481	6.011	109.81	<.0001
DEPTH	1.14	8.013		85.48	<.0001
BAIT	1.1624	6.205		51.76	<.0001
HOOKTYPE	1.1689	5.681		43.39	<.0001
AREA	1.1819	4.632		22.20	<.0001
SEASON	1.192	3.817		9.85	0.0199
YEAR+TIME+					
DEPTH	1.073	13.427	3.946	74.47	<.0001
AREA	1.091	12.007		46.70	<.0001
BAIT	1.100	11.256		34.22	<.0001
HOOKTYPE	1.110	10.417		20.26	<.0001
SEASON	1.111	10.369		19.32	0.0002
YEAR+TIME+DEPTH+					
AREA	1.033	16.646	3.220	59.05	<.0001
BAIT	1.0546	14.904		28.68	<.0001
HOOKTYPE	1.057	14.726		26.53	<.0001
SEASON	1.062	14.298		18.83	0.0003
YEAR+TIME+DEPTH+AREA+					
HOOKTYPE	1.010	18.502	1.856	36.56	<.0001
BAIT	1.025	17.324		14.29	0.0008
SEASON	1.026	17.211		13.23	0.0042
YEAR+TIME+DEPTH+AREA+HOOKTYPE+					
SEASON	1.004	18.995	0.492	11.82	0.0080
BAIT	1.005	18.898		9.07	0.0107
MIXED MODEL	**AIC**				
YEAR+TIME+DEPTH+AREA+HOOKTYPE YEAR*HOOK	**1033.2**				
YEAR+TIME+DEPTH+AREA+HOOKTYPE YEAR*AREA	1043.3				
YEAR+TIME+DEPTH+AREA+HOOKTYPE YEAR*TIME	1059.1				
YEAR+TIME+DEPTH+AREA+HOOKTYPE YEAR*DEPTH	1064.1				
YEAR+TIME+DEPTH+AREA+HOOKTYPE	1064.3				

Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**

NULL	1.7398				
YEAR	1.6856	3.115	3.115	47.85	<.0001
YEAR+					
AREA	1.6269	6.489	3.374	39.99	<.0001
DEPTH	1.6554	4.851		22.87	<.0001
BAIT	1.674	3.782		9.61	0.0082
HOOKTYPE	1.6769	3.615		8.69	0.0337
SEASON	1.6856	3.115		3.01	0.3904
TIME	1.6869	3.041		0.13	0.7233
YEAR+AREA+					
DEPTH	1.5864	8.817	2.328	30.71	<.0001
HOOKTYPE	1.6201	6.880		7.6	0.055
BAIT	1.6243	6.639		3.73	0.1545
MIXED MODEL	**AIC**				
YEAR+AREA+DEPTH YEAR*AREA	**3672.3**				
YEAR+AREA+DEPTH	3674.0				
YEAR+AREA+DEPTH YEAR*DEPTH	3674.0				

2008-2015: Shark Research Fishery

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.893				
YEAR	0.862	3.461	3.461	32.17	<.0001
YEAR+					
SEASON	0.8417	5.713	2.252	19.47	0.0002
BAIT	0.8576	3.932		5.27	0.0717
HOOKTYPE	0.8583	3.853		4.73	0.094
AREA	0.8585	3.831		3.64	0.0565
TIME	0.8627	3.361		0.11	0.7438
DEPTH	0.8629	3.338		0	0.9523
YEAR+SEASON+					
BAIT	0.835	6.475	0.762	7.32	0.0257
MIXED MODEL	**AIC**				
YEAR+SEASON	**55.0**				
YEAR+SEASON YEAR*SEASON	model would not converge				

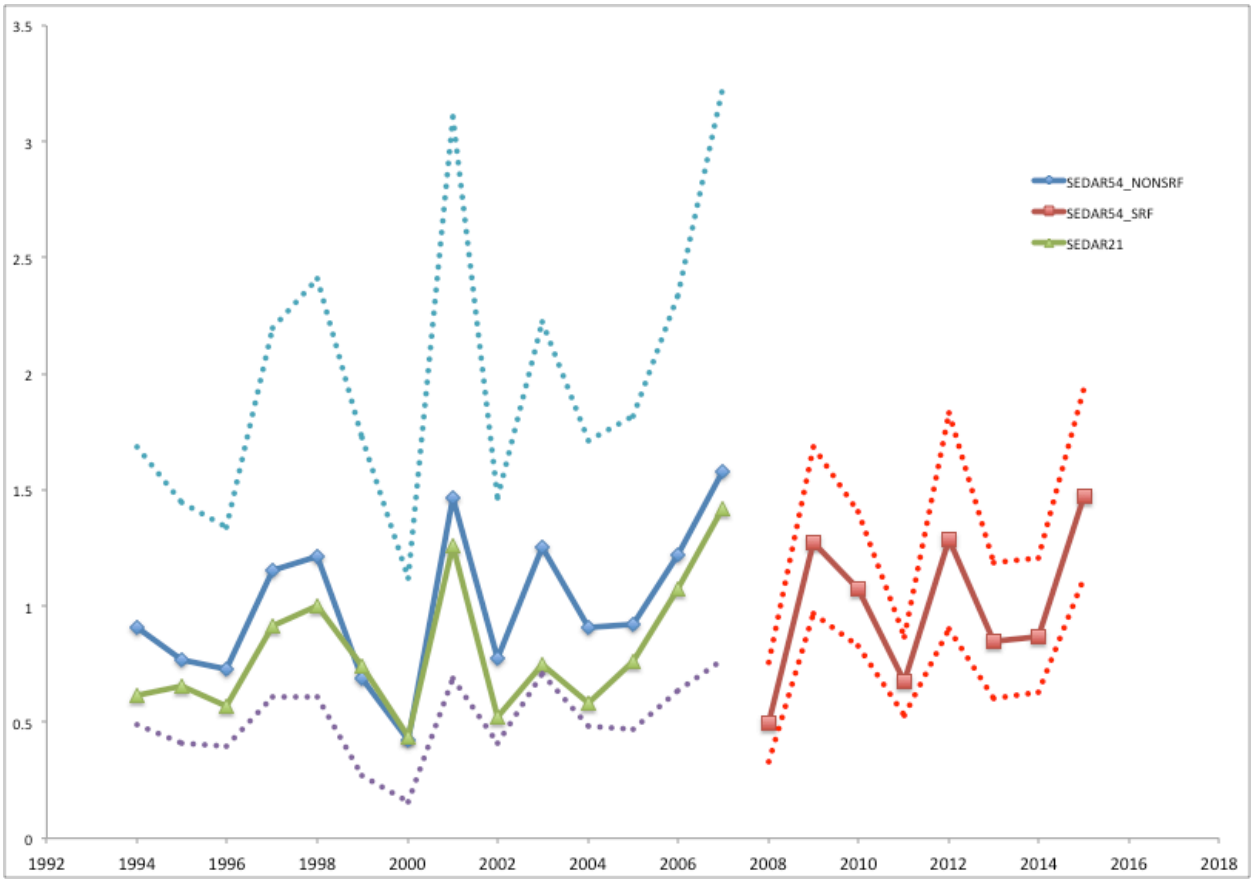
Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.5679				
YEAR	1.4426	7.992	7.992	71.22	<.0001
YEAR+					

SEASON	1.3627	13.088	5.096	46.91	<.0001
AREA	1.4119	9.950		17.57	<.0001
BAIT	1.4385	8.253		4.2	0.1222
DEPTH	1.4444	7.877		0.02	0.8744
TIME	1.4444	7.877		0	0.9645
HOOKTYPE	1.4463	7.756		0.03	0.9834
YEAR+SEASON+					
AREA	1.3143	16.175	3.087	28.81	<.0001
MIXED MODEL	**AIC**				
YEAR+SEASON+AREA	2415.4				
YEAR+SEASON+AREA YEAR*SEASON	model would not converge				
YEAR+SEASON+AREA YEAR*AREA	model would not converge				

Table 2. The standardized index (number of sharks per 10000 hook) of absolute abundance, the upper (UCL) and lower (UCL) 95% confidence limits and coefficients of variation (CV) for sandbar shark.

Year	Research Fishery	Number of sets	Standardized index	LCL	UCL	CV
1994	No	102	223.74	121.02	413.66	0.31
1995	No	162	188.64	99.93	356.13	0.33
1996	No	126	178.42	96.76	328.99	0.31
1997	No	80	284.33	149.61	540.37	0.33
1998	No	110	298.58	150.28	593.24	0.35
1999	No	99	168.69	67.05	424.40	0.49
2000	No	64	103.26	38.71	275.43	0.52
2001	No	77	360.60	170.01	764.88	0.39
2002	No	132	189.97	99.99	360.91	0.33
2003	No	174	308.88	174.36	547.16	0.29
2004	No	122	223.06	118.01	421.63	0.33
2005	No	127	226.42	114.78	446.65	0.35
2006	No	117	299.50	156.18	574.34	0.33
2007	No	63	388.02	189.67	793.78	0.37
2008	Yes	56	535.52	351.99	814.75	0.21
2009	Yes	106	1370.66	1037.52	1810.77	0.14
2010	Yes	148	1157.62	888.03	1509.06	0.13
2011	Yes	197	729.47	568.03	936.80	0.13
2012	Yes	83	1380.63	968.99	1967.14	0.18
2013	Yes	106	909.50	649.07	1274.41	0.17
2014	Yes	111	935.61	673.38	1299.97	0.17
2015	Yes	104	1584.08	1201.96	2087.67	0.14

Figure 2. The standardized relative abundance index (index/mean of the index) for sandbar shark. Dashed lines are upper and lower confidence limits. The index for sandbar shark from SEDAR 21 is provided as a comparison.



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