Catch rates of blacktip sharks (Carcharhinus limbatus) in US Atlantic Ocean from the Shark Bottom Longline Observer Program, 1994-2018

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SEDAR65-DW17

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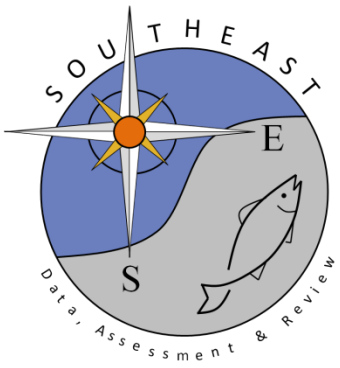

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Introduction

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, Mathers et al. 2018 and references therein). A previous stock assessment for Atlantic blacktip shark utilized data from this fishery as an index of abundance and as an input to the stock assessment model (SEDAR21). 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 Mathers et al. (2018). Following the definition of the South Atlantic from the Highly Migratory Species Office, data were excluded from the Gulf of Mexico. 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 sharks 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 2008-2018 for vessels in the research fishery. While observations of vessels outside the research fishery were made from 2008-2018, the low sample size in some years precluded including those data, as the model would have difficulty converging.

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

- "Year"
  1994-2007- Non-research fishery
  2008-2018- 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
  Circle hook
  J style hook
  Undefined

- "Bait type": the bait that was used by the majority of the set
  Shark (Elasmobranchii)
  Teleost
  Other (undefined or multiple bait types)

- "Soak": time from when the first hook was set until the first hook was removed during haulback

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:

$$\text{CPUE}=\log\left[(\text{sharks kept}+\text{sharks released})/(\text{number of hooks}/10{,}000)\right]$$

Factors most likely to influence the probability of capturing a blacktip 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 (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

A total of 907 longline sets were made from 1994-2007 and 767 sets from 2008-2018 in the research fishery (Figure 1). The proportion of positive sets (i.e. at least one blackip shark was caught) was 37% from 1994-2018 and 27% from 2008-2018 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.

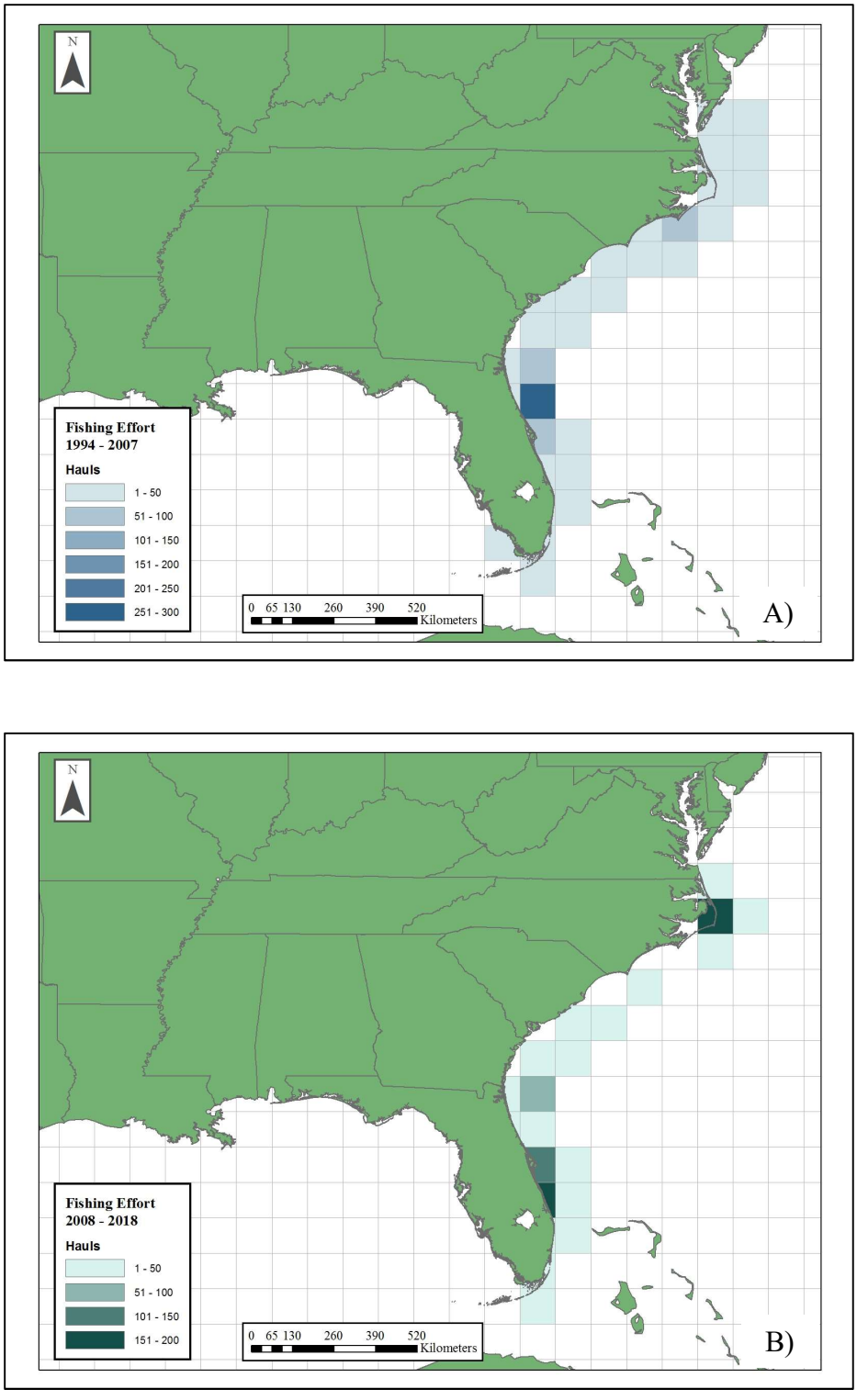

Figure 1. Distribution of fishing effort in the A) directed shark bottom longline fishery 1994-2007 and B) 2008-2018 for the research fishery. Individual plots by year and in some locations were not possible because of vessel confidentiality.

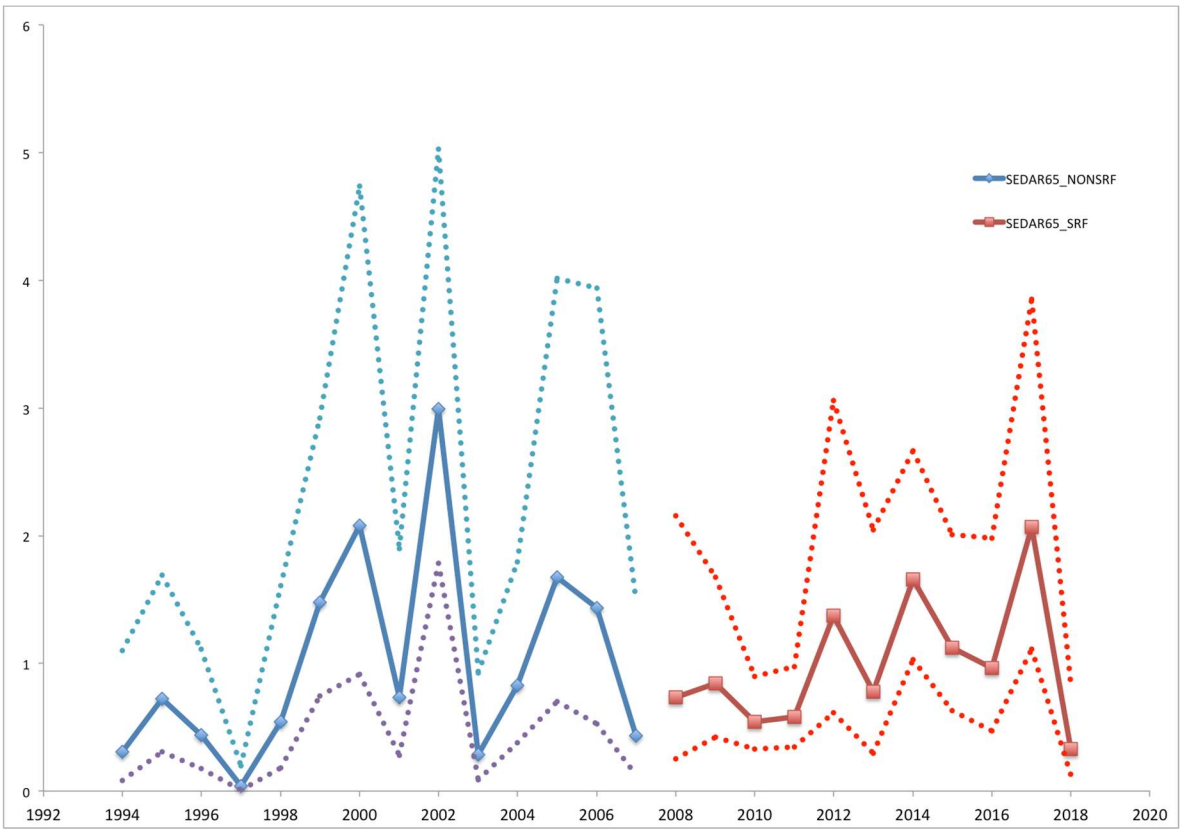

Figure 2. The standardized relative abundance index (index/mean of the index) for Atlantic blacktip shark. Dashed lines are upper and lower confidence limits.

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 Atlantic blacktip shark from 1994-2018 and 2008-2019. Model is bold is the final selected model.

1994-2007 Shark bottom longline fishery (non-research)

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.357				
YEAR	1.271	6.337	6.337	90.42	<.0001
YEAR+					
HOOKTYPE	1.2244	9.778	3.441	41.92	<.0001
DEPTH	1.2247	9.756		42.94	<.0001
TIME	1.2367	8.872		30.34	<.0001
SEASON	1.2379	8.783		31.83	<.0001
BAIT	1.2646	6.816		8.02	0.0182
SOAK	1.2726	6.227		0.02	0.8753
YEAR+HOOKTYPE+DEPTH					
TIME	1.1789	13.131	3.353	41.96	<.0001
SEASON	1.2002	11.561		24.03	<.0001
BAIT	1.2231	9.874		3.62	0.1636
YEAR+HOOKTYPE+DEPTH+TIME					
SEASON	1.113	17.987	4.856	19.02	0.0003
MIXED MODEL	**AIC**				
YEAR+HOOKTYPE+DEPTH+TIME+SEASON YEAR*HOOKTYPE	**854.9**				
YEAR+HOOKTYPE+DEPTH+TIME+SEASON YEAR*TIME	856.3				
YEAR+HOOKTYPE+DEPTH+TIME+SEASON YEAR*SEASON	856.8				
YEAR+HOOKTYPE+DEPTH+TIME+SEASON	857.9				
YEAR+HOOKTYPE+DEPTH+TIME+SEASON YEAR*DEPTH	859.5				

Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.5468				
YEAR	1.4269	7.751	7.751	40.25	0.0001
YEAR+					
DEPTH	1.3923	9.988	2.237	11.33	0.0101
SEASON	1.4146	8.547		6.04	0.1096
BAIT	1.4204	8.172		3.61	0.1645
TIME	1.4215	8.101		2.3	0.1291
HOOKTYPE	1.4273	7.726		2	0.3675
SOAK	1.4304	7.525		0.23	0.63
MIXED MODEL	**AIC**				
YEAR+DEPTH	**1055.0**				
YEAR+DEPTH YEAR*DEPTH	1055.1				

2008-2018: Shark Research Fishery

Proportion positive-Binomial error distribution						
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**	
NULL	1.2767					
YEAR	1.2594	1.355	1.355	24.13	0.0073	
YEAR+						
SOAK	1.2124	5.036	3.681	31.91	<.0001	
DEPTH	1.2353	3.243		Negative of Hessian not positive definite		
BAIT	1.2488	2.185		9.4	0.0091	
SEASON	1.2491	2.162		10.43	0.0152	
HOOKTYPE	1.2573	1.520		2.58	0.1083	
TIME	1.2601	1.300		0.79	0.3738	
YEAR+SOAK						
SEASON	1.1994	6.055	1.018	12.14	0.0069	
BAIT	1.2099	5.232		4.1	0.1288	
MIXED MODEL	**AIC**					
YEAR+SOAK+SEASON	**86.3**					
YEAR+SOAK+SEASON YEAR*SOAK	model unable to converge					
YEAR+SOAK+SEASON YEAR*SEASON	89.5					

Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.7168				
YEAR	1.5557	9.384	9.384	30.8	0.0006
YEAR+					
TIME	1.483	13.618	4.235	11.01	0.0009
HOOKTYPE	1.5071	12.215		7.66	0.0057
BAIT	1.5083	12.145		8.55	0.0139
SEASON	1.545	10.007		4.62	0.2016
DEPTH	1.5504	9.692		1.76	0.1848

SOAK	1.563	8.959		0.08	0.7779
YEAR+TIME+					
BAIT	1.4716	14.282	0.664	3.73	0.1551
HOOKTYPE	1.4774	13.945		1.84	0.1747
MIXED MODEL					
YEAR+TIME	**669.7**				
YEAR+TIME YEAR*TIME	671.5				

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

Year	Research Fishery	Number of sets	Standardized index	LCL	UCL	CV
1994	No	55	19.41	5.37	70.08	0.71
1995	No	109	46.05	19.69	107.69	0.44
1996	No	86	28.03	11.12	70.64	0.49
1997	No	54	2.58	0.53	12.59	0.93
1998	No	72	34.63	11.72	102.29	0.58
1999	No	68	93.87	47.46	185.69	0.35
2000	No	64	132.34	58.16	301.16	0.43
2001	No	54	46.57	17.95	120.85	0.51
2002	No	68	190.21	113.26	319.43	0.26
2003	No	93	18.29	5.67	58.97	0.64
2004	No	52	52.60	24.22	114.22	0.40
2005	No	48	106.58	44.50	255.26	0.46
2006	No	49	91.35	33.34	250.26	0.54
2007	No	35	27.48	7.95	94.99	0.68
2008	Yes	21	94.60	32.25	277.52	0.58
2009	Yes	40	108.41	54.45	215.87	0.35
2010	Yes	127	69.95	42.21	115.95	0.26
2011	Yes	144	74.77	44.60	125.36	0.26
2012	Yes	60	176.65	79.31	393.48	0.42
2013	Yes	51	100.09	38.04	263.38	0.51
2014	Yes	90	213.37	132.75	342.95	0.24
2015	Yes	61	144.80	81.23	258.12	0.30
2016	Yes	52	124.36	60.72	254.66	0.37
2017	Yes	62	266.44	143.22	495.67	0.32
2018	Yes	59	42.13	16.46	107.82	0.50

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