Standardized catch rates of blacktip sharks (*Carcharhinus limbatus*) collected during bottom longline surveys in Mississippi, Louisiana, and Alabama coastal waters from 2004 to 2010

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SEDAR29-WP-22

Date Submitted: 3 April 2012

SEDAR 29-WP-22

Please site this document as follows:
E. Hoffmayer, J. Hendon, M. Drymon, S. Powers, A. Pollack, and J. Carlson. 2012. Standardized catch rates of blacktip sharks (*Carcharhinus limbatus*) collected during bottom longline surveys in Mississippi, Louisiana, and Alabama coastal waters from 2004 to 2010. SEDAR29-WP-21. SEDAR, North Charleston, SC.

STANDARDIZED CATCH RATES OF BLACKTIP SHARKS (*CARCHARHINUS LIMBATUS*) COLLECTED DURING BOTTOM LONGLINE SURVEYS IN MISSISSIPPI, LOUISIANA, AND ALABAMA COASTAL WATERS FROM 2004 TO 2010.

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Originally three separate indices were created to detail bottom longline survey blacktip shark catches in the Alabama, Mississippi, and Louisiana coastal waters. Detailed information about the three surveys is found within the following documents: SEDAR29-WP-11 for the Alabama index, SEDAR29-WP14 for the inshore Mississippi index, and SEDAR29-WP-15 for the Louisiana/Mississippi index. The SEDAR 29 panel decided that this catch information would be most valuable if an index was created using the data from all three surveys combined. The combined index extended from 2004 to 2010, and resulted in 893 sets and 1,379 blacktip sharks. Standardized catch rates were estimated using a generalized linear mixed modeling approach assuming a delta-lognormal error distribution and negative binomial regression.

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INTRODUCTION

During the SEDAR 29 data workshop, the panel decided that it would be most appropriate to combine the indices from three regional bottom longline surveys in the north central Gulf of Mexico to develop a more temporally and spatially robust index. Details for the three surveys are found within the following documents: SEDAR29-WP-11 for the Alabama survey, SEDAR29-WP14 for the inshore Mississippi survey, and SEDAR29-WP-15 for the Louisiana/Mississippi survey. As a result, the following index was generated using all catch data for age 1+ blacktip sharks from the three indices.

METHODOLOGY

Alabama Survey

The sampling protocol and equipment follows the procedures established by the NOAA Fisheries Mississippi Laboratories bottom longline survey (Grace and Henwood 1997). The longline gear consisted of a 1.6 km (426 kg test) monofilament mainline and 100, 3.7 m gangions (332 kg test monofilament) outfitted with #15/0 circle hooks and baited with Atlantic mackerel (*Scomber scombrus*). The longline fished for one hour from the time of last high-flier deployment to the time of first high-flier retrieval. Bottom longline sampling for the Alabama nearshore survey began in May 2006 and employed a random stratified block design. Blocks were established both in the Mississippi Sound/Mobile Bay and waters south of Dauphin Island. Each month (January to December), stations were randomly selected within the blocks, and effort was allocated across three depth strata (0-5m, 5-10m, and 10-20m). For additional details see SEDAR29-WP-11.

Mississippi Inshore Survey

Sampling was conducted with a 152.4 m bottom longline that consisted of 50 hooks (#12/0 circle), 1.0 m gangions (2.0 mm monofilament), with menhaden (*Brevoortia patronus*) as bait. The longline was typically fished between the hours of 0800 and 2000, and was allowed to soak for one hour prior to retrieval. The bottom longline sampling employed a random stratified block design, with twelve 10.6 km^2 blocks select throughout the Mississippi Sound region. Each month from March to October, stations were randomly selected within each block. For additional details see SEDAR29-WP-14.

Mississippi/Louisiana Survey

The sampling protocol and equipment follows the procedures established by the NOAA Fisheries Mississippi Laboratories bottom longline survey (Grace and Henwood 1997). The longline gear consisted of a 1.6 km (426 kg test) monofilament mainline and 100, 3.7 m gangions (332 kg test monofilament) outfitted with #15/0 circle hooks and baited with Atlantic mackerel, (*Scomber scombrus*). The longline fished for one hour from the time of last high-flier deployment to the time of first high-flier retrieval. The bottom longline sampling employed a random stratified block design with effort within each block allocated across three depth strata (0-5m, 5-10m, and 10-20m). The study area was broken into three regions: Mississippi Sound, South of barrier islands, and Chandeleur Sound. Each month from March to October, three stations were sampled from each region. For additional details see SEDAR29-WP-15.

Combined Survey Modifications
The study area for the Alabama, Mississippi inshore, and Mississippi/Louisiana surveys was approximately 1,450, 190, and 1,050 km^2, respectively. Due to the spatial overlap in the three surveys, the entire study area was divided into eleven 26 x 6 km blocks (blocks 1-6, 8-12), and one 17 x 18 km block (Chandeleur Sound; block 7) (Figure 1). Each station sampled by the individual surveys was defined as being within one of these 12 blocks. Soak time was calculated differently between the three surveys. However, as all three surveys allowed the gear to fish for one hour prior to retrieval, one hour was chosen to use as the soak time in the combined index.

The three surveys also utilized different model input factors. To aggregate all three surveys for analysis, the Mississippi inshore and Mississippi/Louisiana datasets removed the 2011 catch data, as well as the monthly rainfall, previous month rainfall, temperature, salinity, and dissolved oxygen factors. The factors that remained in the combined dataset included survey, year, month, area, depth, set time, soak time, and hook size**.** Finally, because there was variability in the sample size among the surveys, the three indices were weighted by the spatial area covered by the survey.

Index Construction
Delta-lognormal modeling methods were used to estimate relative abundance indices for blacktip sharks (Lo *et al*. 1992). The main advantage of using this method is the allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes the proportion of positive abundance values (i.e. presence/absence), and a lognormal model which describes variability in only the non-zero abundance data (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(1) $I_y = c_y p_y$,

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $\ln(c) = X\beta + \varepsilon$

and

(3) $$p = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated as:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\mathrm{Cov}(c, p) \approx \rho_{c,p}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denotes correlation of c and p among years.

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.10$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Due to differences in area surveyed among the data sets, the time series was weighed by sample size or area surveyed.

RESULTS

From 2004 to 2010, 893 sites were sampled resulting in the catch of 1,379 blacktip sharks. The number of sites sampled varied across surveys with Alabama (406) having the highest, followed by Mississippi inshore (276) and Mississippi/Louisiana (211). The total number of blacktip sharks captured each year ranged from 61 to 340 sharks. Approximately 37% of the stations sampled contained positive catches of blacktip sharks, with Mississippi/Louisiana (46.4%) having the highest, followed by Alabama (38.4%), and Mississippi inshore (28.0%).

The model outputs for the series are in Table 1. Table 2 contains the standardized abundance series for both weighing schemes and Figure 2 illustrates the time series.

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Table 1. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear and mixed model formulations of the proportion of positive and positive catches for blacktip sharks.

Proportion positive-Binomial error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1.7452				
YEAR	1.7251	1.152	1.15	17.28	0.0083
YEAR+					
AREA	1.5656	10.291	9.14	72.71	<.0001
SEASON	1.6107	7.707		43.49	<.0001
SURVEY	1.6494	5.489		28.87	<.0001
DEPTH	1.6579	5.002		26.04	<.0001
HOOK	1.6701	4.303		20.26	<.0001
YEAR+AREA+					
SEASON	1.4188	18.703	8.41	52.11	<.0001
DEPTH	1.5331	12.153		13.66	0.0011
HOOK	1.555	10.898		5.01	0.0253
SURVEY	1.5585	10.698		5.42	0.0664
YEAR+AREA+SEASON					
DEPTH	1.3871	20.519	1.82	13	0.0015
HOOK	1.4018	19.677		6.87	0.0088
SURVEY	1.406	19.436		6.92	0.032

Proportion positive-Lognormal error distribution					
FACTOR	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	0.7458				
YEAR	0.7359	1.327	1.327	10.43	0.1077
YEAR+					
SEASON	0.7296	2.172	0.845	4.86	0.0879
DEPTH	0.7311	1.971		4.21	0.122
AREA	0.7312	1.958		13.56	0.2586
SURVEY	0.7318	1.877		3.9	0.1421
HOOK	0.732	1.850		2.77	0.0962

Table 2. The standardized index (number of sharks per set) of absolute abundance and coefficients of variation (CV) for all blacktip sharks. Indices are provided for the time series weighed by sample size or area.

Year	**Sets**	**Sample size index**	**CV**		**Area index**	**CV**
2004	44	2.23	0.26		2.49	0.27
2005	29	2.46	0.19		2.59	0.20
2006	127	2.11	0.11		2.18	0.12
2007	176	1.35	0.10		1.39	0.11
2008	210	1.34	0.09		1.30	0.10
2009	131	1.28	0.14		1.21	0.16
2010	176	1.89	0.10		1.86	0.10

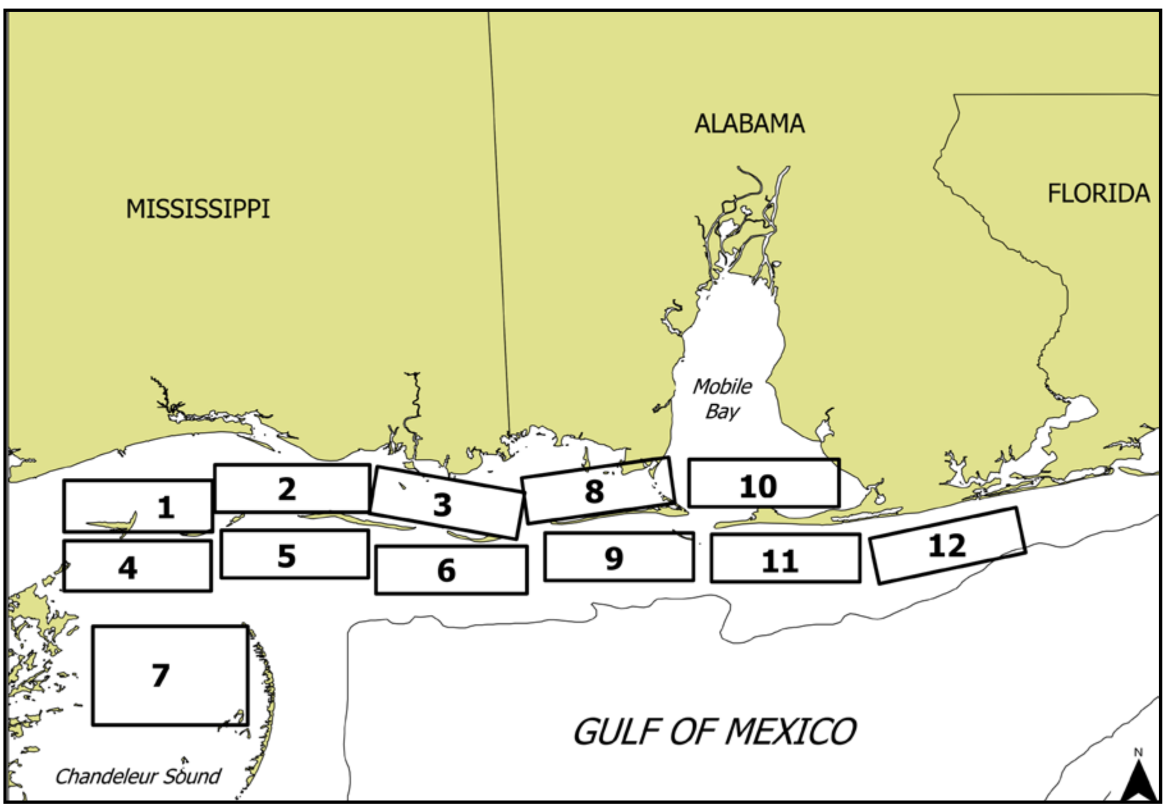

Figure 1. Sampling universe for the combined Louisiana/Mississippi/Alabama bottom longline index. The study area was divided into 12 blocks: 11 blocks were the same size (156 km^2), and one block (7) was larger (306 km^2). Monthly sampling sites were randomly selected within each of the blocks.

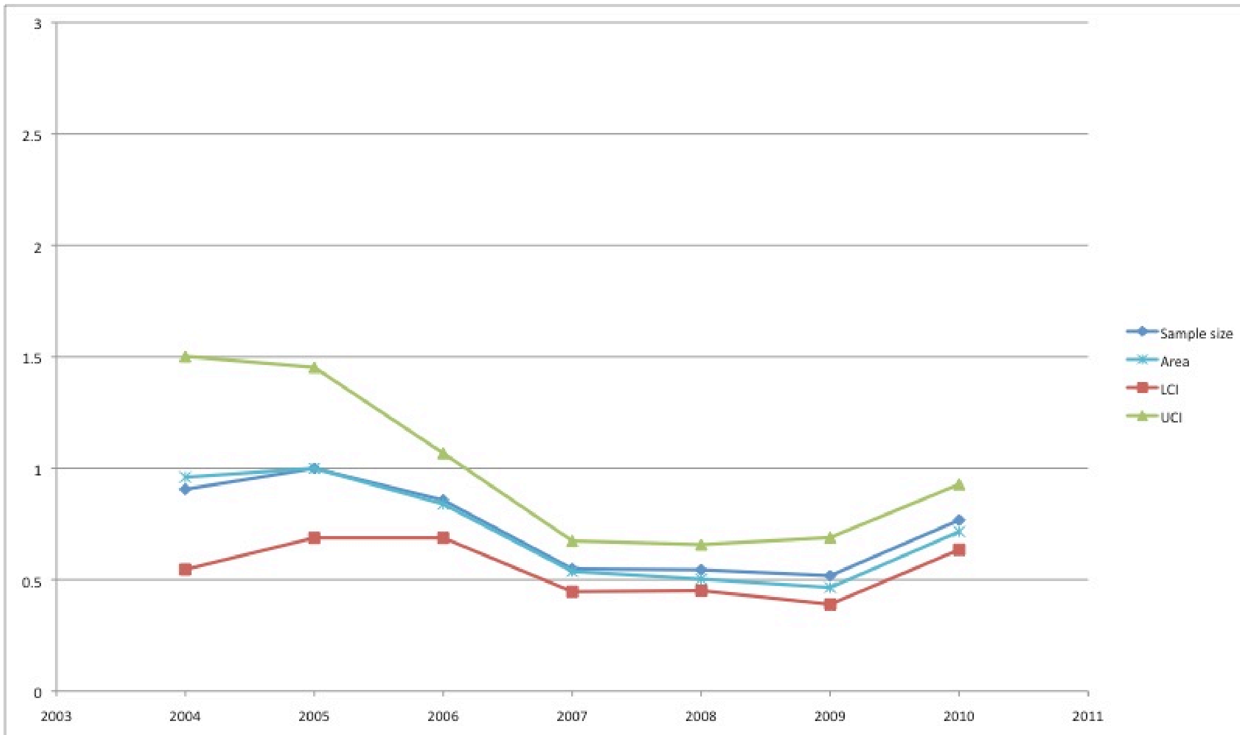

Figure 2. Standardized indices of abundance for all blacktip sharks. Time series are provided for indices weighed by sample size or area sampled. Each index has been divided by the maximum of the index