Catch rates and size distribution of blacktip shark *Carcharhinus limbatus* in the northern Gulf of Mexico, 2006-2010

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Abstract

Blacktip sharks *Carcharhinus limbatus* are one of the most frequently caught sharks on a monthly longline survey initiated off the coast of Alabama in 2006. Between May 2006 and December 2010, 539 blacktip sharks were captured during 410 bottom longline sets. Nominal and modeled catch per unit effort (CPUE, sharks/100 hooks/hour) and length frequency distributions by sex are presented. Length frequency histograms indicate that the majority of male blacktip sharks sampled span the size at which 50% of the population is mature. Nominal CPUE was highest in 2006 and has varied annually thereafter. The yearly pattern of relative abundance was similar between nominal and standardized indices. Monthly analysis of nominal mean CPUE showed peak occurrence of blacktip sharks during June, in line with previous studies suggesting blacktip sharks may use coastal waters in the northern Gulf of Mexico for parturition of their young.

Introduction

In May 2006, the Dauphin Island Sea Lab (DISL), in conjunction with the National Marine Fisheries Service Mississippi Labs (NMFS MS Labs), initiated a monthly nearshore longline survey in Alabama coastal waters. This survey was initially designed as to complement the annual NMFS bottom longline survey (SEFSC BLL), while sampling throughout the year and in waters inaccessible to large NMFS vessels. Since its inception, several survey design changes have taken place, and ancillary surveys have been initiated to sample adjacent areas. Across all surveys, blacktip sharks *Carcharhinus limbatus* are one of the most common components. Between May 2006 and December 2010, 539 blacktip sharks were captured during 410 bottom longline sets. Nominal and standardized catch per unit effort (CPUE, sharks/100 hooks/hour) and length frequency distributions by sex are presented below.

Materials and Methods

DISL/NMFS cooperative survey

Nearshore bottom longline sampling for the DISL/NMFS cooperative survey began in May 2006 and employed a random stratified block design. Four blocks were established along the Mississippi/Alabama coast. Blocks 1 and 2 were located west of Mobile Bay (western blocks), and blocks 3 and 4 were located east of Mobile Bay (eastern blocks) (Figure 1A). Each block was 37 kilometers east to west and extended from the shoreline to approximately the 20 m isobath. Each month from May 2006 – February 2007, twelve stations were randomly chosen within a single block and evenly allocated across three depth strata (0-5 m, 5-10 m and 10-20 m). The survey design was modified from March 2007 through November 2008. During this period, six stations were selected at random each month within an eastern block, and six stations were selected at random within a western block. This survey modification ensured equal station dispersion within the block (two stations across each depth stratum), while always sampling one eastern and one western block each month.

DISL transect

In March 2007 a monthly transect survey was initiated (Figure 1B) in addition to the DISL/NMFS cooperative survey. This survey design extended sampling effort into Mobile Bay, while establishing a north to south time series to compliment the previously described east to west survey design. Each month, 12 stations were randomly selected, three in each of the four blocks.

DISL shark survey

Beginning in 2009, four new blocks were established. These blocks encompassed the entire area of the previous two surveys, while extending coverage into Mississippi Sound (Figure 1C). Each month, three stations were randomly selected in each of the four blocks. To incorporate an offshore component, four times per year a line of longitude off the Alabama coastline was randomly selected, and six equidistant stations were sampled between 20 and 200 meters. The offshore component of this survey is ongoing.

Alabama SEAMAP survey

Beginning in 2010, four new blocks were established. Two of these blocks were set north of the barrier islands, and two south out to 20 m (Figure 1D). This design was intended to sample all of Alabama's coastal waters, exclusive of Mobile Bay. Each month, one station was randomly selected in each of the four blocks. This survey is ongoing.

Sampling gear

While survey design changed throughout the history of this project, bait and gear have remained consistent throughout. At each station, a single bottom-longline was set and soaked for one hour. The main line consisted of 1.85 km (1 nm) of 4 mm monofilament (545 kg test) sampled with 100 gangions. Each gangion was made of 3.66 m of 3 mm (320 kg test) monofilament. Gangions consisted of a longline snap and a 15/0 circle hook, baited with Atlantic mackerel (*Scomber scombrus*). The longline was anchored to the bottom with weights at the start, middle and end of the mainline, and identified with buoys at each end. All sharks that could be safely boated were removed from the mainline, unhooked and identified to species. Biotic variables collected included sex, length (precaudal, fork, natural and stretch total), weight and maturity (when possible). Maturity in males was assessed following Clark and Von Schmidt (1965). Sharks were tagged in the primary dorsal fin with a plastic rototag. Abiotic variables collected included depth as well as surface and bottom values for temperature, salinity and dissolved oxygen using a Seabird SBE911 plus, or an SBE 25 CTD (2006-2009), and recently with a Hydrolab MS5 multiprobe.

Data Reduction and Analysis

All catch data from May 2006 through December 2010 were converted to CPUE, expressed as sharks/100 hooks/hour. Based on the consensus from SEADR 21 for blacknose sharks, catch and effort data from inside Mobile Bay and in waters greater than 20m deep were excluded from the current index due to the short nature of the time series. Total survey effort for each year and the combined (reduced) effort is shown in

Figure 2. Length frequency histograms, boxplots and scatterplots for blacktip sharks by sex are shown in Figure 3. To determine size at which 50% of the population of males was mature, a logistic model [$Y=1/(1+e^{-(a+bx)}$] was fitted to binomial maturity data using least squares nonlinear regression, where 0 = immature and 1 = mature. Median size at maturity was determined as –a/b (Mollet et al 2000), where a = y-intercept and b = slope (Figure 4).

Nominal and standardized catch per unit effort were calculated for blacktip sharks captured between May 2006 and December 2010. Nominal mean monthly and yearly CPUE are shown in Figures 5 and 6, respectively. A delta-lognormal approach (Lo et al. 1992) was used to develop a standardized index of abundance. In general, this approach models separately the proportion of positive sets (PPS, sets that captured blacktip sharks/total sets made) and the catch rates on positive sets and combines these indices to construct a single standardized CPUE index (Cass-Calay and Schmidt 2009). Specifically,

(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) $\ln(\mathbf{c}) = \mathbf{X\beta} + \boldsymbol{\varepsilon}$

and

(3) $\mathbf{p} = \dfrac{e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}{1+e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}$, 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 (Ingram et al 2010). Coefficients of variation for the index were estimated using a jackknife routine. To stabilize the routine, data were filtered prior to analysis. For factor levels with less than 2 positive observations, all records within that factor were deleted prior to index construction. Only year and month were considered as factors in the analysis; therefore, no stepwise selection routine was used. Calculations were performed in R using code provided by EJ Dick, NMFS Santa Cruz. Table 1 provides the summary statistics for the standardized index, and Figure 7 shows both the nominal and standardized indices as a function of year.

Results and Discussion

Despite changes in survey design between 2006 and 2010, the standardized methods employed allowed us to analyze a subset of combined data from a region that has been continuously sampled off the coast of Alabama since 2006, with no sampling artifacts. Standardized CPUE ranged from a high of 1.5 sharks/100 hooks/hour in 2006 to a low of 0.5 sharks/100 hooks/hour in 2009. The low CPUE in 2009 may be explained in part by a reduction in sampling effort in the nearshore waters that year, when more effort was diverted to offshore sampling. The trend in nominal CPUE closely matches the trend in standardized CPUE, suggesting that the bottom longline survey in this region is sufficiently capturing population level trends in relative abundance.

In addition to annual trends in relative abundance, our survey design allowed us to examine monthly (i.e. seasonal) variation in mean nominal CPUE. Blacktip sharks were sampled during all months except November, January and February. Peak abundance for blacktip sharks was seen in June. This trend is most likely a function of water temperature, where blacktip sharks move into deeper water during winter months. Offshore winter transect cruises from 2009 through current (most recently, February 21-22, 2012) have confirmed the occurrence of blacktip sharks at depths rangig from 50-100 meters, where water temperature is ~18-20°C.

Analysis of maturity data highlighted trends for both males and females. The size at which fifty percent of the male blacktip sharks in our study are mature is 101.7 cm fork length. Examining length frequency histograms shows that our longline survey catches male blacktip sharks spanning the size at 50% maturity. While maturity was not directly measured for female blacktip sharks, females outnumbered males 1.7:1 (Chi-sq test with Yates correction, P<0.0.01), in line with previous work suggesting that female blacktip sharks may be using coastal waters off Alabama for parturition of their young (Drymon et al 2010).

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Table 1: Abundance index statistics for blacktip shark sampled during the Dauphin Island Sea Lab (DISL) bottom longline survey, 2006-2010. Shown are nominal CPUE (catch/100 hooks/hour), total sets conducted, proportion positive sets (PPS), standardized CPUE, upper and lower confidence intervals (UCI and LCI, respectively) and coefficients of variation (CV).

Year	Nominal CPUE	Sets	PPS	Standardized CPUE	UCI	LCI	CV
2006	1.777	94	0.457	1.493	2.219	0.766	0.248
2007	1.008	132	0.356	0.746	1.059	0.434	0.214
2008	1.339	109	0.376	1.119	1.531	0.706	0.188
2009	0.893	28	0.250	0.523	1.212	-0.167	0.673
2010	1.447	47	0.383	1.103	1.825	0.382	0.334

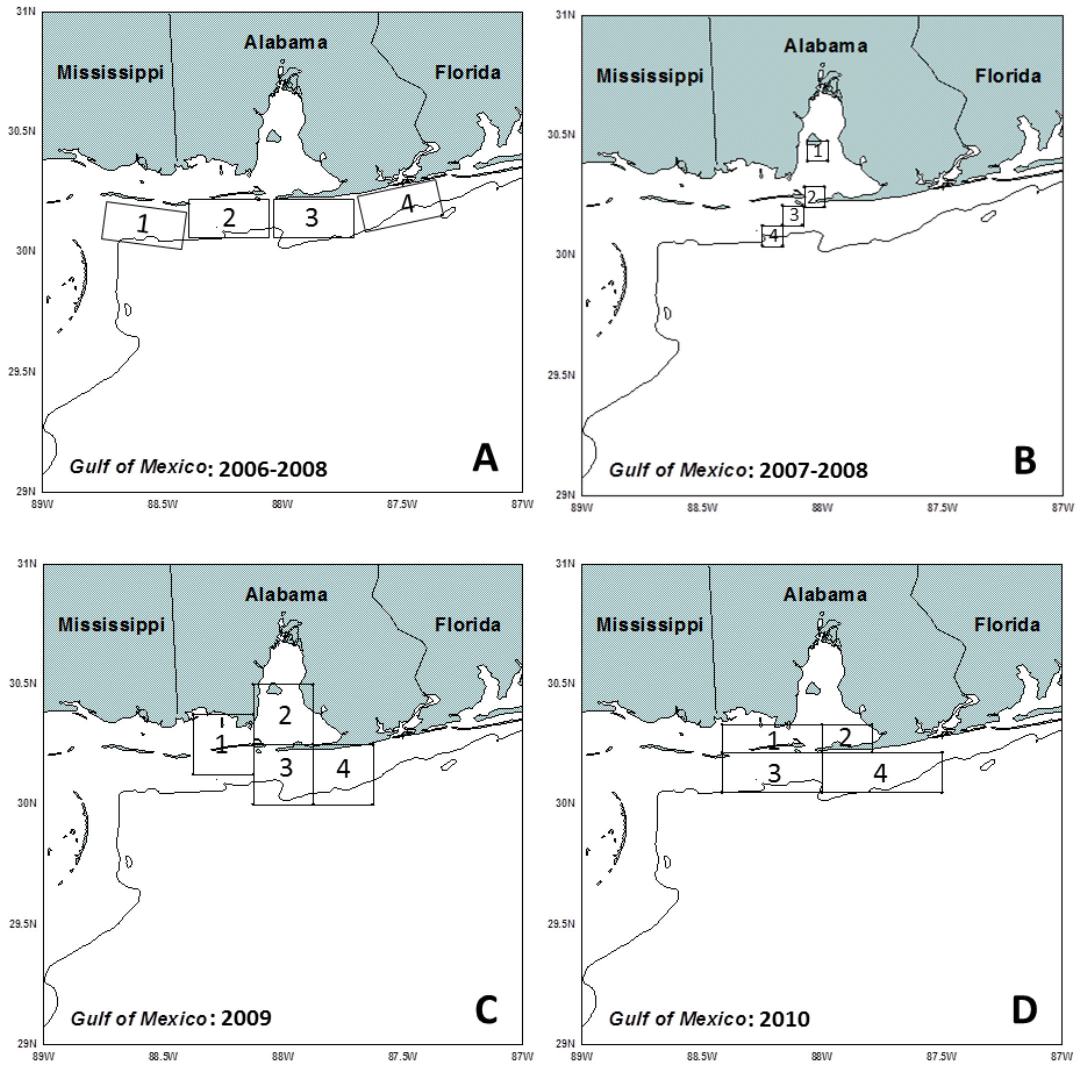

Figure 1: Description of the survey design for the A) DISL/NMFS cooperative longline survey, B) DISL transect survey and C) DISL shark survey and D) Alabama SEAMAP survey. For survey designs C and D, randomized block sampling was supplemented with transect sampling along a randomly selected line of longitude.

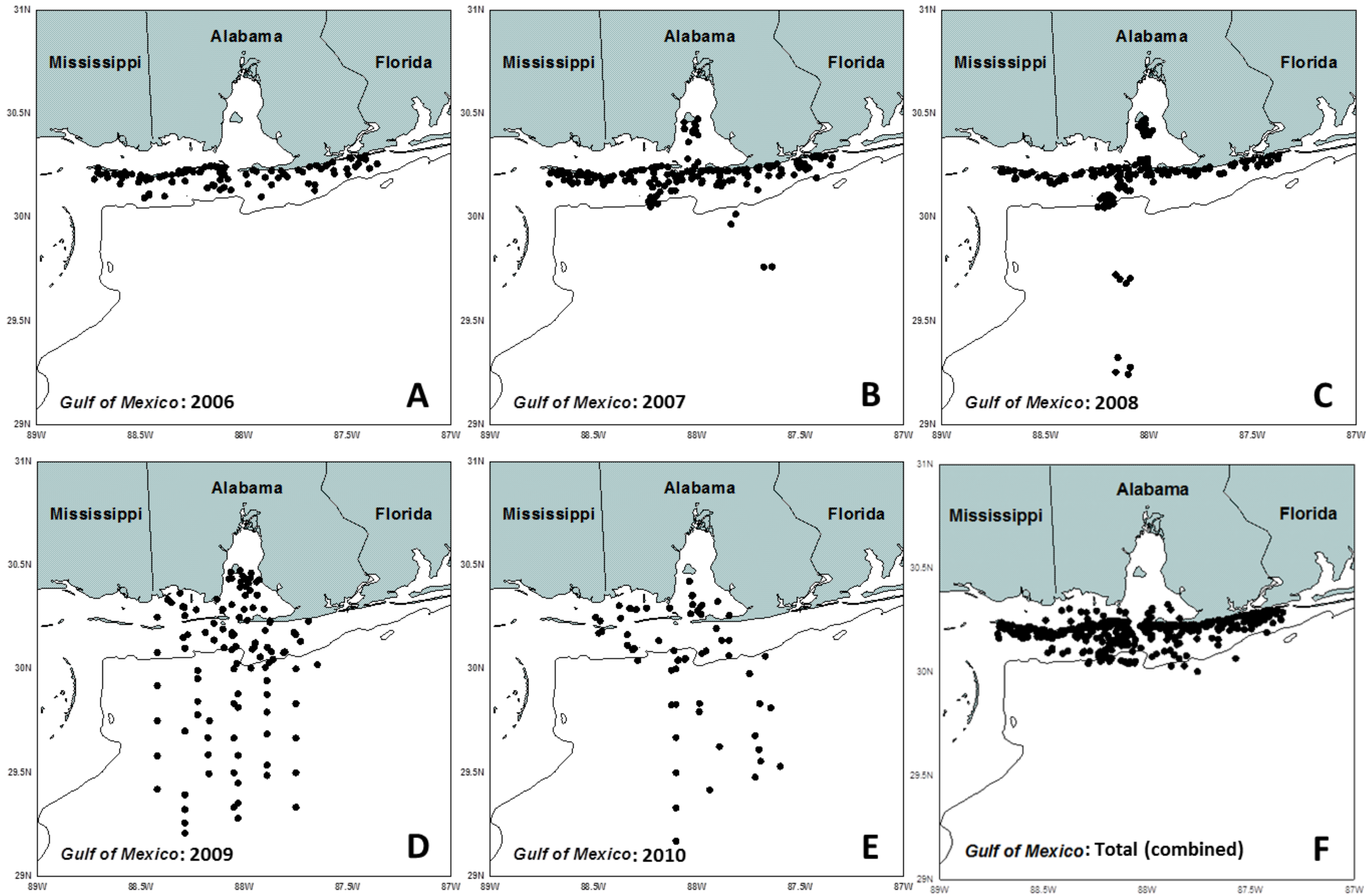

Figure 2: Effort for the years A) 2006, B) 2007, C) 2008, D) 2009 and E) 2010. Total effort used for index calculation is shown in panel F.

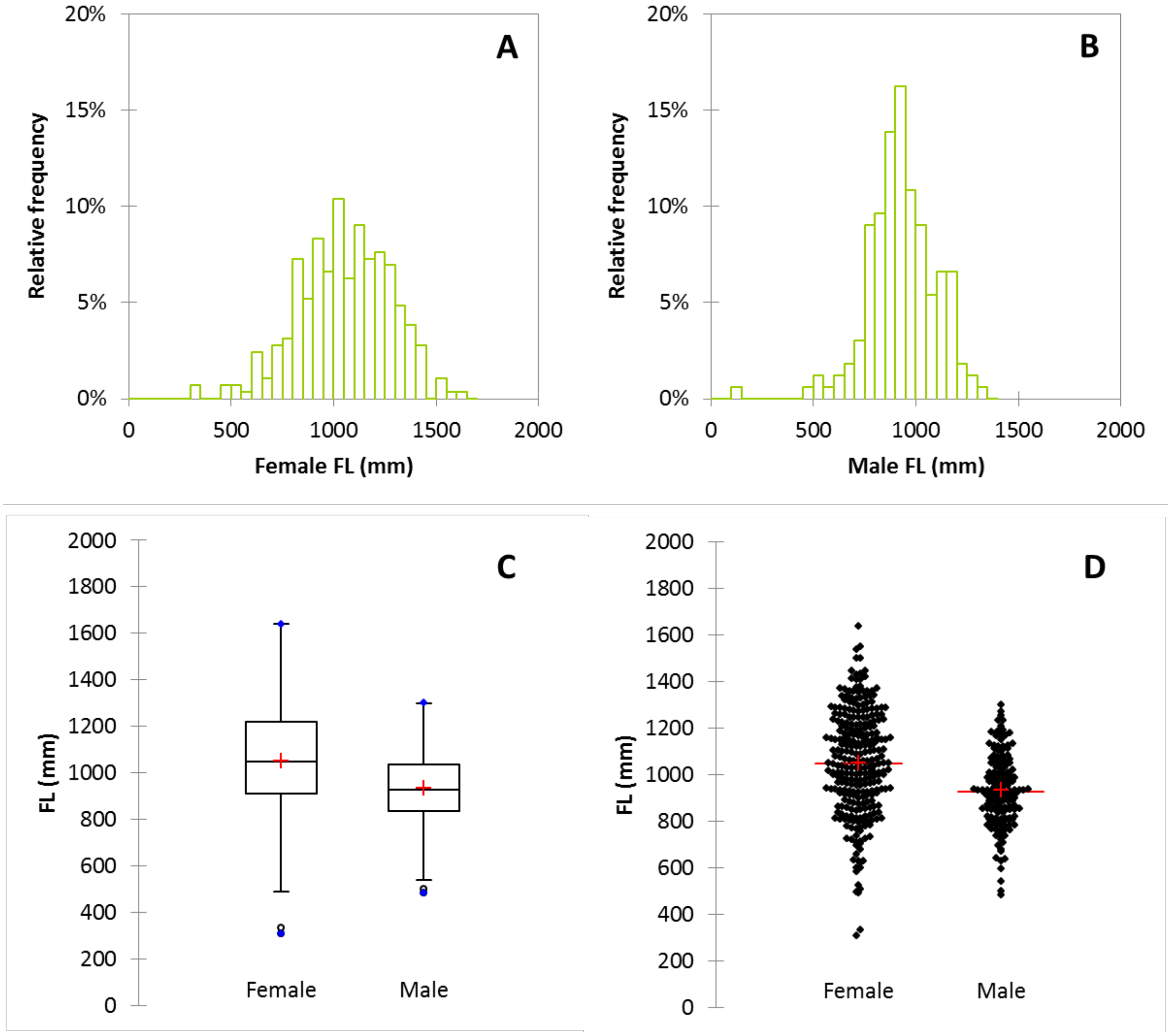

Figure 3: Size frequency histograms for A) female (n=288) and B) male (n=166) blacktip sharks, 2006-2010. Also shown are C) boxplots and D) scattergrams of fork length (mm) by sex.

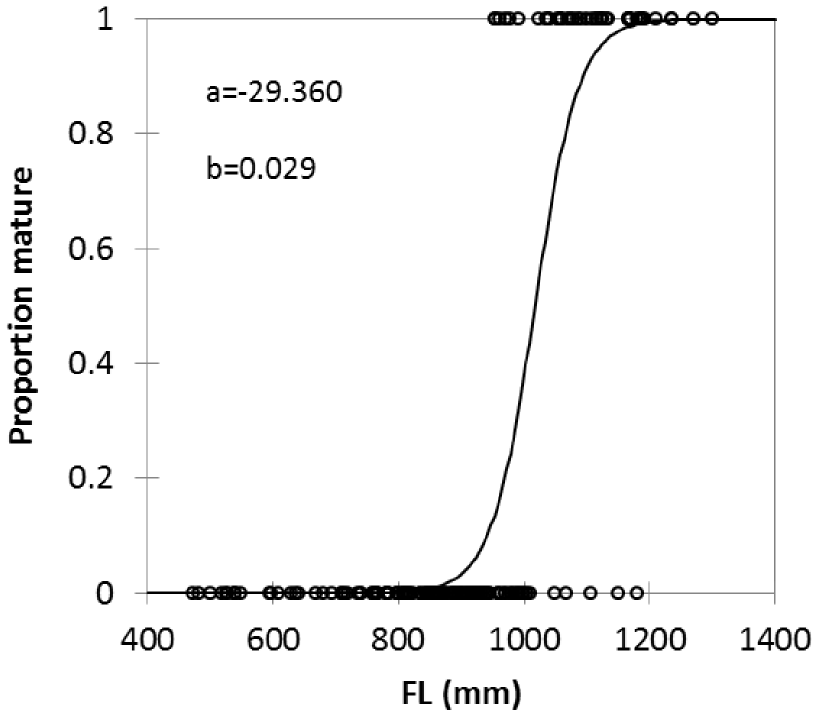

Figure 4: Binomial maturity data fitted using least squares non-linear regression. Median size at maturity was determined as –a/b, where a is the y-intercept and b is the slope (Mollet et al 2000).

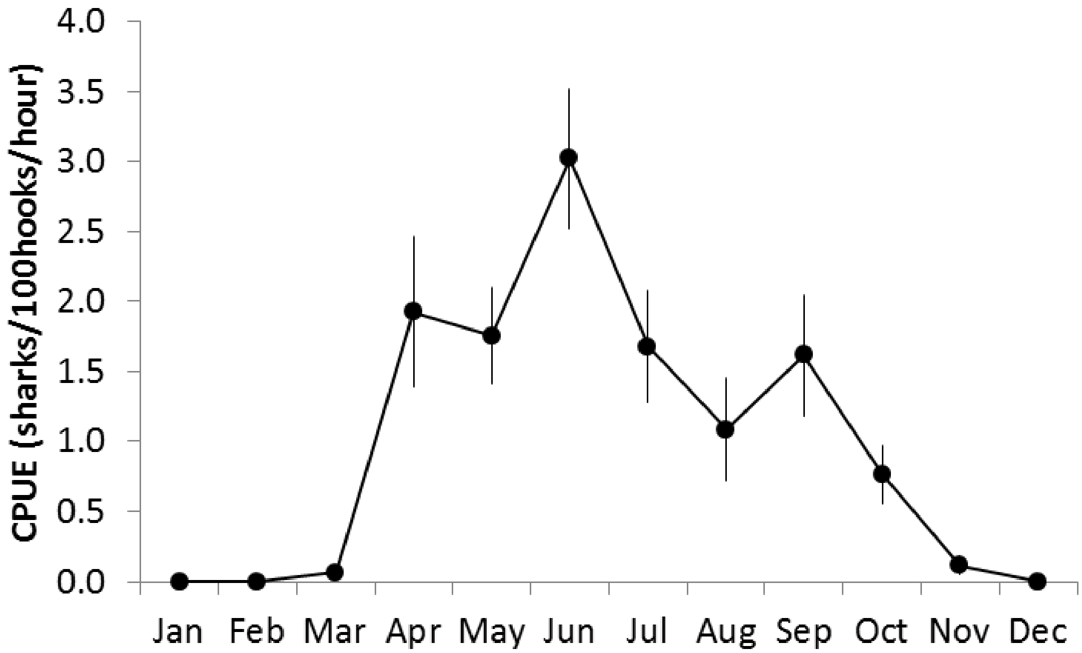

Figure 5: Nominal monthly CPUE (sharks/100 hooks/hour) for blacktip sharks, 2006-2010. Error bars are ± SE. No blacktip sharks were encountered December – February.

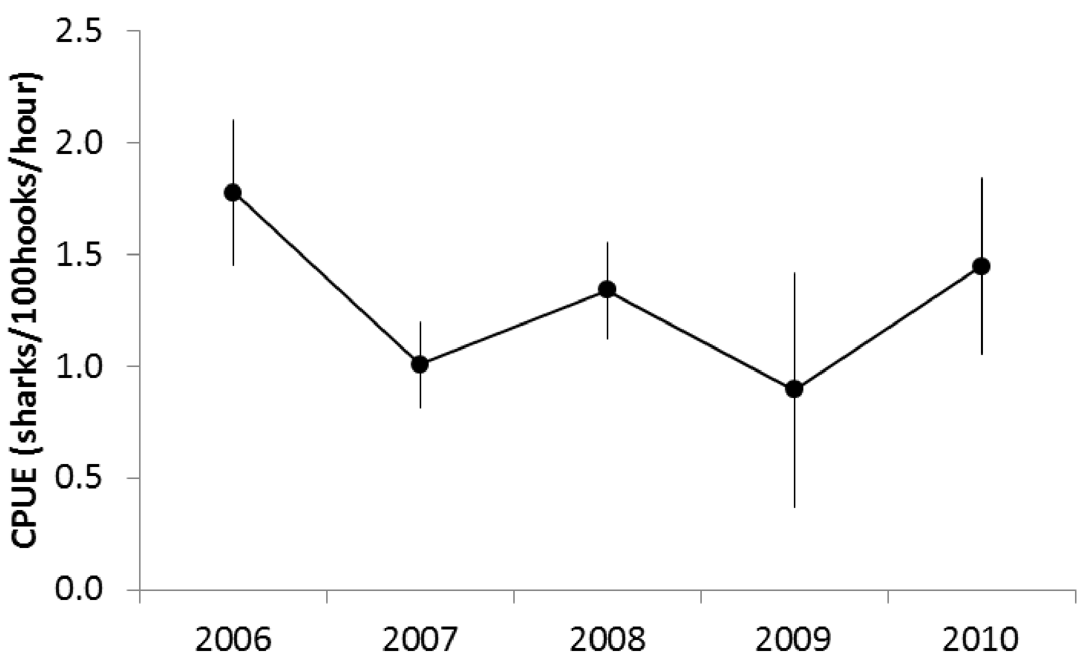

Figure 6: Nominal yearly CPUE (sharks/100 hooks/hour) for blacktip sharks, 2006-2010. Error bars are ± SE.

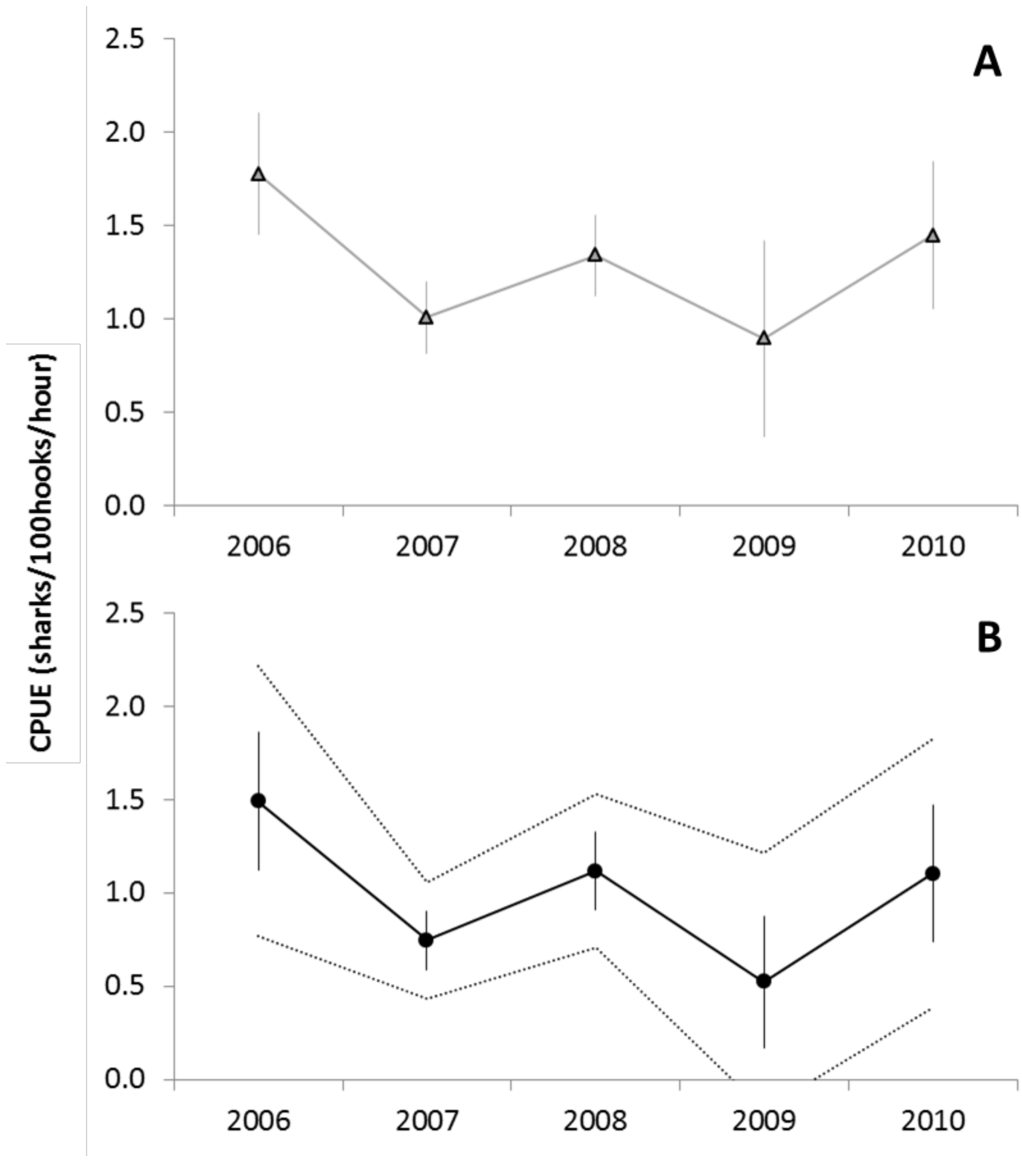

Figure 7: A) Nominal and B) standardized yearly abundance indices for blacktip shark in the DISL bottom longline, 2006-2010. Error bars are ± SE. Dashed lines are upper and lower confidence intervals (panel B).