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CATCH RATES AND SIZE COMPOSITION OF SMALL COASTAL SHARKS COLLECTED DURING A GILLNET SURVEY OF MISSISSIPPI COASTAL WATERS, 2001–2006

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SUMMARY

This document examines a catch rate series for the small coastal shark (SCS) complex (four species), Atlantic sharpnose, finetooth, and bonnethead sharks, calculated from a gillnet survey which was conducted in Mississippi coastal waters from 2001 to 2006. During 53 sampling events, 240 net sets and 210 hours of effort, 509 Atlantic sharpnose, 184 finetooth, and 27 bonnethead sharks were collected. Because the work was conducted in a known nursery area, shark catch was further divided into young-of-the-young (YOY, age-0), juvenile, and adult catch. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution and negative binomial regression. Atlantic sharpnose shark exhibited a positive trend, finetooth sharks and the SCS complex exhibited a slightly negative trend in relative standardized catch rates from 2001 to 2006.

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1. INTRODUCTION

Historically, sharks have received little attention in the northcentral Gulf of Mexico (GOM), compared to the rest of the GOM, Atlantic or Pacific Oceans. The Gulf Coast Research Laboratory (GCRL) has been conducting a fisheries independent shark gillnet survey since 2001. The sampling effort during the first three years of the survey was minimal due to limited amount of funds dedicated to the project. From 2004 to present, the project received additional funding and consistent monthly sampling was performed. This five year fisheries independent shark gillnet dataset was analyzed in this document.

2. MATERIALS AND METHODS

Sampling Locations

From March 2001 to October 2006 sharks were collected at sites along the Mississippi coast extending from Petit Bois Island to St. Louis Bay. In general, collections were made from March to October with at least two locations sampled each month. Sampling was typically confined to the Mississippi Sound although some sampling was conducted south of the barrier islands. Sampling locations were selected such that a large geographical area and a range of environmental conditions could be covered. However, unless collecting was limited by conditions such as weather, sea state, and shrimp boat activity, we typically selected locations in close proximity to the barrier islands.

Despite no funding being available during 2001, the Horn Island location was sampled monthly, along with a few other locations when available. With limited funding in 2003, only a few locations were sampled, primarily locations where previous sampling was conducted. From 2004 to 2006, two to three locations were sampled monthly, two of which were long-term sampling locations (Horn and Cat Islands).

Sampling Protocol

Sampling was conducted with a 152.4 meter gill net consisting of five 30.5 meter panels of 4.5, 5.1, 5.7, 6.4, and 7.0 cm (1.75, 2.0, 2.25, 2.5, and 2.75 in) square mesh. The net was usually deployed from 1500 until 2000 hours each day. Following Parsons and Hoffmayer (2007), depending upon the rate of capture and the environmental conditions prevalent, the net was checked every 0.25 to 1.0 hour. Each time the net was checked, the time of day over which the sharks were captured was recorded. As expeditiously as possible, each shark captured was identified and measured (total length, TL) and its sex and, when possible, state of maturity recorded. Water temperature, salinity, and dissolved oxygen were measured at the water's surface and near the bottom at each site. Water depth, visibility (secchi depth), G.P.S. location, weather conditions, and sea state were also recorded.

Analysis

Data were divided into four categories; Atlantic sharpnose, *Rhizoprionodon terraenovae*, finetooth, *Carcharhinus isodon*, bonnethead, *Sphyrna tiburo*, and small coastal species (SCS) complex, which includes Atlantic sharpnose, finetooth, bonnethead, and blacknose, *Carcharhinus acronotus*, sharks.

For the purpose of analysis, sharks were divided into size classes based on estimates of their growth rates and size at maturity. Atlantic sharpnose sharks were designated young-of-year (YOY) when between 33 and 59 cm total length (TL), juvenile when between 60 and 80 cm TL (male) and between 60 and 85 cm TL (female), and adult when >81 cm TL (male) and >85 cm TL (female)(Parsons, 1983). Finetooth sharks were designated YOY when between 45 and 75 cm TL, juvenile when between 76 and 119 cm TL (male) and between 76 and 139 cm TL (female), and adult when >119 cm TL (male) and >139 cm TL (female)(Castro, 1993). Bonnetheads were designated YOY when between 33 and 59 cm TL, juvenile when between 60 and 80 cm TL (male) and between 60 and 85 cm TL (female), and adult when >81 cm TL (male) and >85 cm TL (female)(Parsons, 1993). Catch rates were standardized as catch per unit effort (CPUE) in sharks 100 m net $^{-1}$ hour $^{-1}$ for each size class of sharks, each species as a whole, and for the SCS complex as a whole. Because of the small numbers of adult finetooth, blacknose, and bonnethead sharks encountered, no additional analyses were performed with these data.

The delta lognormal model approach (Lo et al. 1992) was attempted for all data sets (e.g. all sharpnose, all finetooth, SCS complex, etc.), however the models would not converge. After further examination of the distribution of the data, the loglinear negative binomial regression model was used to develop standardized indices of abundance for Atlantic sharpnose, finetooth, and the SCS complex. The loglinear negative binomial regression model closely resembles that of the Poisson regression model except for the dispersion parameter located in the systematic component of the model. The parameters of the log negative binomial are interpreted exactly like those of a Poisson or lognormal regression model (i.e. by taking the inverse natural log of both sides of the regression model and describing the multiplicative effect of each parameter on μ (McCullagh and Nelder, 1989; Agresti, 1996). There are three primary statistics used in evaluating parameter significance, lack-of-fit, and the significance of each step in the model building process of the aforementioned models: Pearson's chi-square statistics (from type 3 analyses), the deviance (likelihood-ratio statistic), and the Akaike's Information Criterion (AIC) statistic, respectively.

For all indices developed, the factors **YEAR, MONTH, AREA, DEPTH, MONTHLY RAINFALL (RAINFALL), SURFACE (SUR) AND BOTTOM (BOT) TEMPERATURE (TEMP), SALINITY (SAL), and DISSOLVED OXYGEN (DO)** were examined for inclusion in the catch rate models. The factor **YEAR** included each year in the time series, the factor **MONTH** included the months that sampling was conducted from March to October. The Mississippi Sound was divided into four zones from east to west (1 to 4) which is represented by factor **AREA**. The factor **MONTHLY RAINFALL** included the mean monthly rainfall along the Mississippi coast. The factors **DEPTH**, **TEMP, SAL**, and **DO** included values present in the data set. The factor **YEAR** was included in the model whether it explained the data or not, so that an annual catch rate series was produced. Some factors were left in certain models that only marginally explained the catch rates because it provided the best model fit statistics (e.g. lowest AIC).

Length frequency distributions were constructed for Atlantic sharpnose, finetooth, and bonnethead sharks using 10 cm size classes. Annual length frequency distributions were also constructed for Atlantic sharpnose and finetooth sharks. An annual length frequency distribution was not constructed for bonnetheads, due to their low abundance in Mississippi waters (n = 27).

3. RESULTS AND DISCUSSION

From 2001 to 2006, 53 locations within Mississippi coastal waters were sampled resulting in 240 net sets and 210 hours of effort. During this time, 509 Atlantic sharpnose, 184 finetooth, and 27 bonnethead sharks were collected. Atlantic sharpnose shark catch consisted primarily of juveniles (n = 189) and adults (n = 290), with relatively few YOY (n = 30). Finetooth shark catch consisted primarily of YOY (n = 76) and juveniles (n = 93), with relatively few adults (n = 15), and bonnethead catch consisted primarily of juveniles (n = 11) and adults (n = 16), with no YOY being captured.

Atlantic sharpnose sharks – Due to the limited number of YOY sharks in the dataset, YOY and juvenile sharks were combined and designated as immature, whereas the adults were designated as mature. Approximately 72 % of the data sets analyzed contained Atlantic sharpnose sharks, with immature and mature sharks occurring in 55 and 58 % of the data sets, respectively. Mean catch rates for all sharks were explained by **YEAR, AREA,** and **MONTH** (Table 1). Mean catch rates for immature and mature sharks were explained by **YEAR** and **MONTH** (Table 3), and **YEAR**, **MONTH**, and **SAL BOT** (Table 5), respectively. The relative standardized catch rate series for all and immature sharks exhibited similar patterns to the nominal catch rate series, with a positive trend observed from 2003 to 2006 (Figures 1 & 2, Tables 2 & 4). The nominal catch rate series for mature sharks also exhibited a positive trend, whereas the relative standardized catch rate series exhibited a slightly negative trend from 2003 to 2006 (Figure 3, Table 6). All catch rates were relatively high in 2001, which may have been the result of a small sample size (n = 5) and limited effort (n = 20 hrs).

Finetooth sharks - Approximately 53 % of the data sets analyzed contained finetooth sharks, with YOY and juvenile sharks occurring in 21 and 34 % of the data sets, respectively. Mean catch rates for all sharks were explained by **RAINFALL, DO SUR** and marginally by **AREA** (Table 7). Mean catch rates for YOY sharks were explained by **DO SUR** and marginally by **DEPTH** (Table 9). Mean catch rates for juvenile sharks were explained by **RAINFALL** and marginally by **SAL BOT** (Table 11). The nominal catch rate series for all, YOY and juvenile sharks exhibited little to no change from 2001 to 2006, whereas the relative standardized catch rate series exhibited a slightly negative trend from 2001 to 2006 (Figures 4,5,6; Tables 8,10,12).

Bonnethead – About 23 % of the data sets contained bonnetheads. Nominal catch rates for all bonnetheads ranged from 0.00 to 0.15 sharks 100 m net^{-1} h^{-1} with a mean CPUE of 0.09 ± 0.03 sharks 100 m net^{-1} h^{-1}. When broken down to size group, nominal catch rates ranged from 0.00 to 0.08 sharks 100 m net^{-1} h^{-1} with a mean CPUE of 0.04 ± 0.02 sharks 100 m net^{-1} h^{-1} for juveniles, and from 0.00 to 0.11 sharks 100 m net^{-1} h^{-1} with a mean CPUE of 0.05 ± 0.02 sharks 100 m net^{-1} h^{-1} for adult sharks. Young-of-the-year bonnetheads were not encountered during this time series. The nominal catch rate series exhibited on overall positive trend from 2001 to 2006 (Figure 7); however, due to the small sample size (n = 27), no additional analyses were performed.

SCS complex - Approximately 83 % of the data sets analyzed contained small coastal shark species. Mean catch rates were explained by **MONTH**, **RAINFALL**, **SAL BOT**, **TEMP SUR**, **DEPTH**, and **SAL SUR** and marginally by **YEAR** (Table 13). The nominal catch rate series exhibited a positive trend from 2003 to 2006, whereas the relative standardized catch rate series exhibited a slightly negative trend from 2003 to 2006 (Figures 8, Tables 14). Catch rates were relatively high in 2001, which may have resulted from a small sample size (n = 5) and limited effort (n = 20 hrs).

Length frequency distributions - Atlantic sharpnose sharks ranged in size from 37.0 to 106.8 cm TL, with a mean TL of 80.7 ± 0.7 cm. The majority of Atlantic sharpnose sharks collected (85 %) were between 60 and 100 cm TL (Figure 9). Finetooth sharks ranged in size from 50.6 to 149.0 cm TL, with a mean TL of 81.6 ± 1.6 cm. The majority of finetooth sharks collected (89 %) were between 50 and 100 cm TL (Figure 9). Bonnetheads ranged in size from 46.8 to 110.5 cm TL, with a mean TL of 86.3 ± 1.8 cm. The majority of bonnetheads collected (87 %) were between 70 and 100 cm TL (Figure 9).

Annual length frequency distribution of the Atlantic sharpnose shark revealed a bimodal distribution with consistent peaks around 60-70 cm TL (juvenile) and 90-100 cm TL (adult) within each year sampled (Figure 10). Finetooth shark annual length frequency distribution revealed that small finetooth sharks (< 100 cm, TL) were collected during each year of the survey (Figure 11).

4. ACKNOWLEDGMENT

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Table 1. Negative binomial regression fit statistics and type III test of the fixed effects for all Atlantic sharpnose sharks.

Fit Statistics	
-2 Log Likelihood	126.17
AIC (smaller is better)	158.17
AICC (smaller is better)	173.28
BIC (smaller is better)	189.69
CAIC (smaller is better)	205.69
HQIC (smaller is better)	170.29
Pearson Chi-Square	38.28
Pearson Chi-Square / DF	1.01

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	38	3.73	0.0117
Area	3	38	4.34	0.0100
Month	7	38	7.84	<.0001

Figure 1. Relative indices of abundance for all Atlantic sharpnose sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

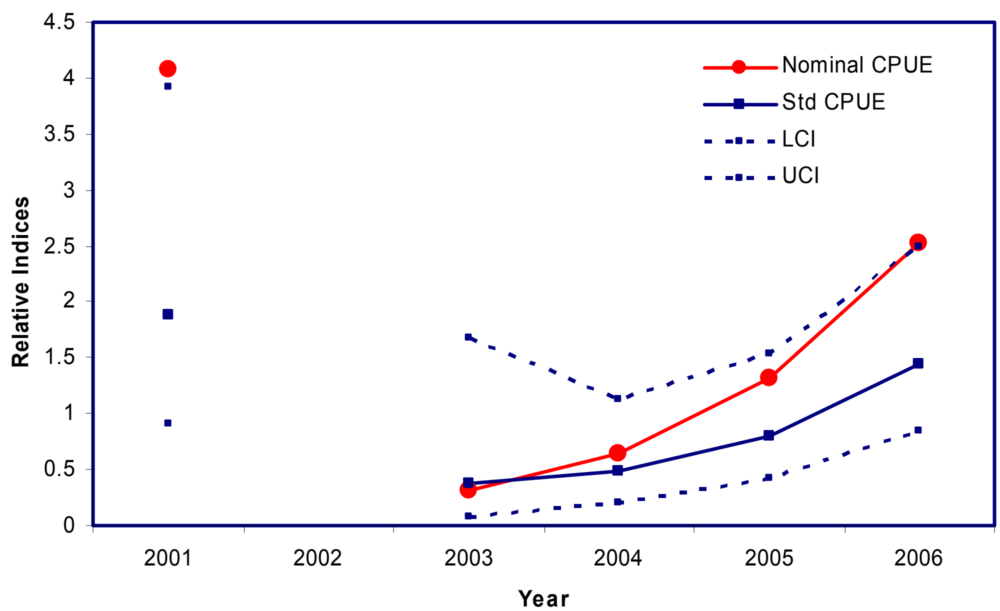


Table 2. Negative binomial regression indices for all Atlantic sharpnose sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	4.08	1.549	1.883	0.380
2002	0	-	-	-	-
2003	21	0.32	0.311	0.378	0.859
2004	45	0.65	0.397	0.483	0.443
2005	54	1.31	0.663	0.806	0.331
2006	60	2.53	1.192	1.449	0.278

Table 3. Negative binomial regression fit statistics and type III test of the fixed effects for immature Atlantic sharpnose sharks.

Fit Statistics	
-2 Log Likelihood	89.09
AIC (smaller is better)	115.09
AICC (smaller is better)	124.42
BIC (smaller is better)	140.70
CAIC (smaller is better)	153.70
HQIC (smaller is better)	124.94
Pearson Chi-Square	26.09
Pearson Chi-Square / DF	0.64

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	41	3.40	0.0171
Month	7	41	3.91	0.0024

Figure 2. Relative indices of abundance for immature Atlantic sharpnose sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

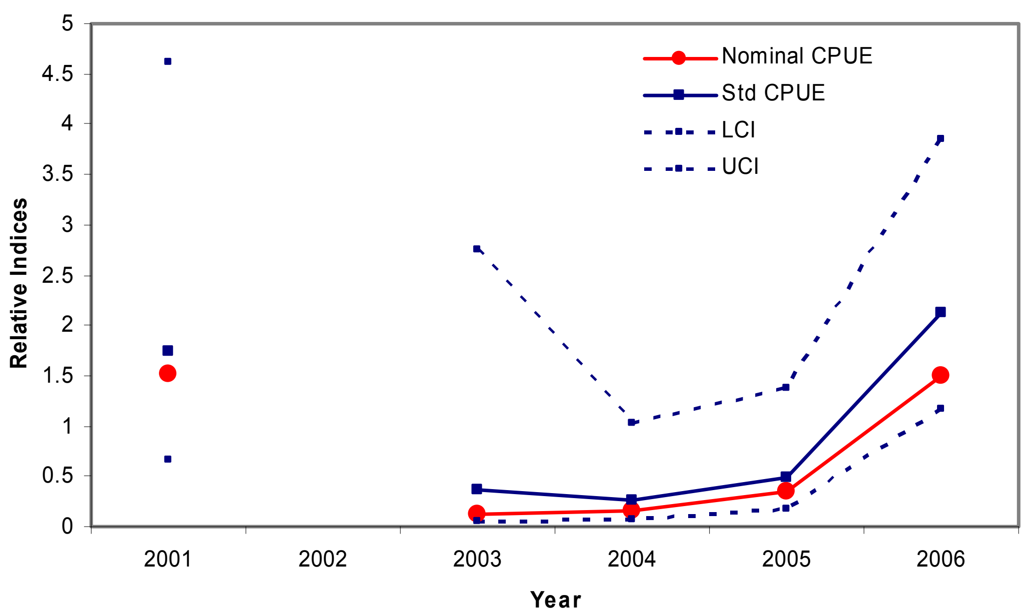


Table 4. Negative binomial regression indices for immature Atlantic sharpnose sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	1.51	0.717	1.749	0.515
2002	0	-	-	-	-
2003	21	0.13	0.153	0.374	1.307
2004	45	0.16	0.109	0.266	0.763
2005	54	0.34	0.199	0.485	0.556
2006	60	1.49	0.872	2.127	0.303

Table 5. Negative binomial regression fit statistics and type III test of the fixed effects for mature Atlantic sharpnose sharks.

Fit Statistics	
-2 Log Likelihood	95.04
AIC (smaller is better)	123.04
AICC (smaller is better)	134.09
BIC (smaller is better)	150.62
CAIC (smaller is better)	164.62
HQIC (smaller is better)	133.65
Pearson Chi-Square	33.11
Pearson Chi-Square / DF	0.83

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	40	2.99	0.0300
Month	7	40	4.29	0.0013
Sal bot	1	40	6.26	0.0166

Figure 3. Relative indices of abundance for mature Atlantic sharpnose sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

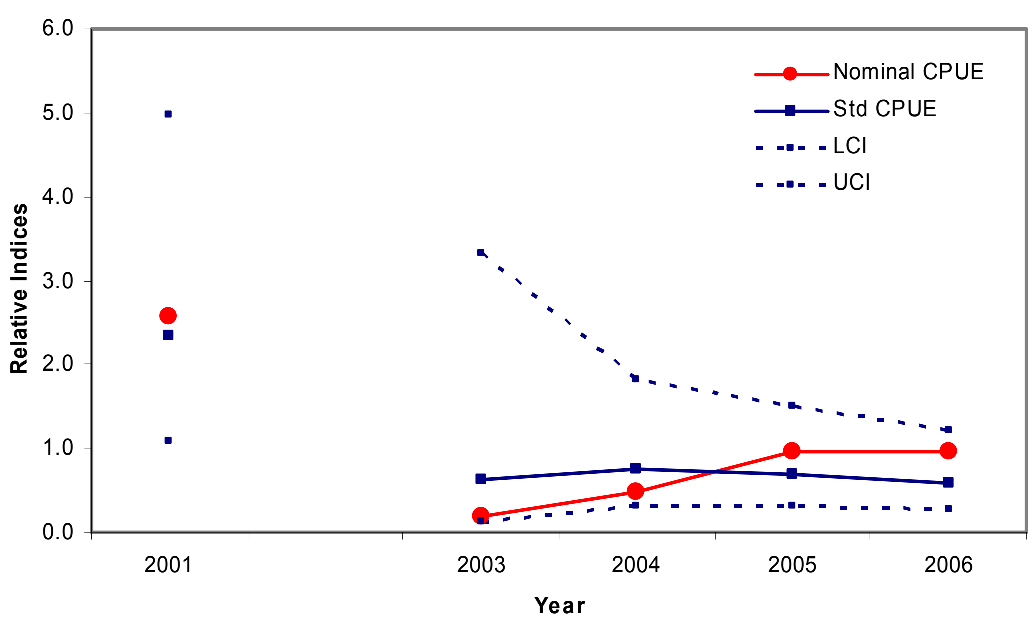


Table 6. Negative binomial regression indices for mature Altantic sharpnose sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	2.57	1.412	2.335	0.392
2002	0	-	-	-	-
2003	21	0.18	0.385	0.637	0.989
2004	45	0.49	0.46	0.761	0.46
2005	54	0.97	0.414	0.685	0.407
2006	60	0.96	0.352	0.582	0.38

Table 7. Negative binomial regression fit statistics and type III test of the fixed effects for all finetooth sharks.

Fit Statistics	
-2 Log Likelihood	84.42
AIC (smaller is better)	106.42
AICC (smaller is better)	112.85
BIC (smaller is better)	128.09
CAIC (smaller is better)	139.09
HQIC (smaller is better)	114.75
Pearson Chi-Square	33.54
Pearson Chi-Square / DF	0.78

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	43	0.41	0.7990
Area	3	43	2.52	0.0704
Rainfall	1	43	14.27	0.0005
DO sur	1	43	4.26	0.0451

Figure 4. Relative indices of abundance for all finetooth sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

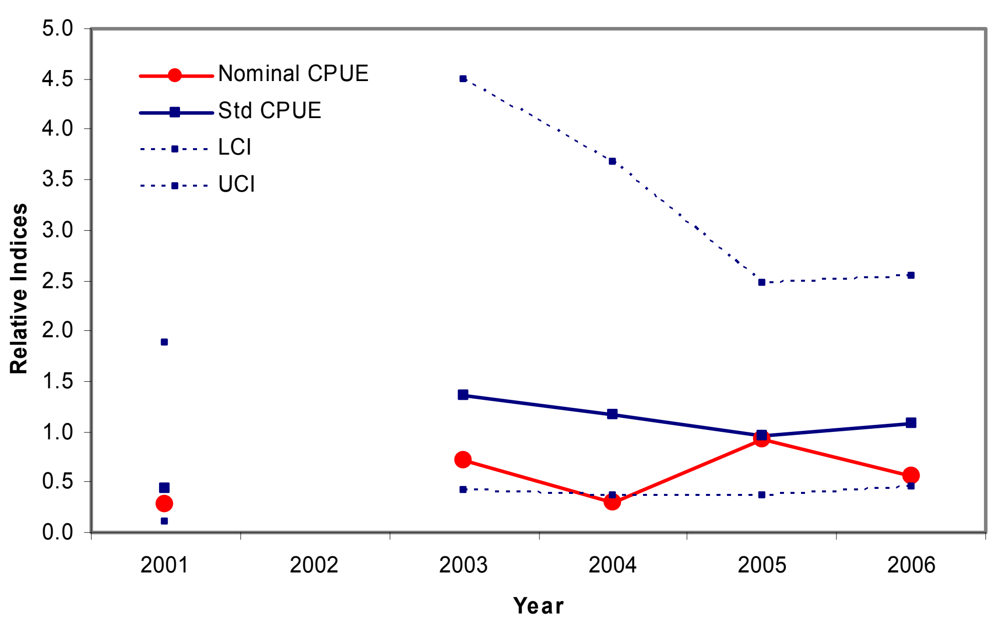


Table 8. Negative binomial regression indices for all finetooth sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	0.28	0.18	0.435	0.842
2002	0	-	-	-	-
2003	21	0.71	0.562	1.36	0.656
2004	45	0.3	0.481	1.162	0.626
2005	54	93	0.398	0.962	0.502
2006	60	0.56	0.447	1.08	0.447

Table 9. Negative binomial regression fit statistics and type III test of the fixed effects for young-of-the-year finetooth sharks.

Fit Statistics	
-2 Log Likelihood	46.91
AIC (smaller is better)	60.91
AICC (smaller is better)	64.30
BIC (smaller is better)	72.91
CAIC (smaller is better)	79.91
HQIC (smaller is better)	65.28
Pearson Chi-Square	42.43
Pearson Chi-Square / DF	1.21

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	3	35	0.67	0.5780
DO sur	1	35	5.85	0.0209
Depth	1	35	3.08	0.0880

Figure 5. Relative indices of abundance for young-of-the-year finetooth sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

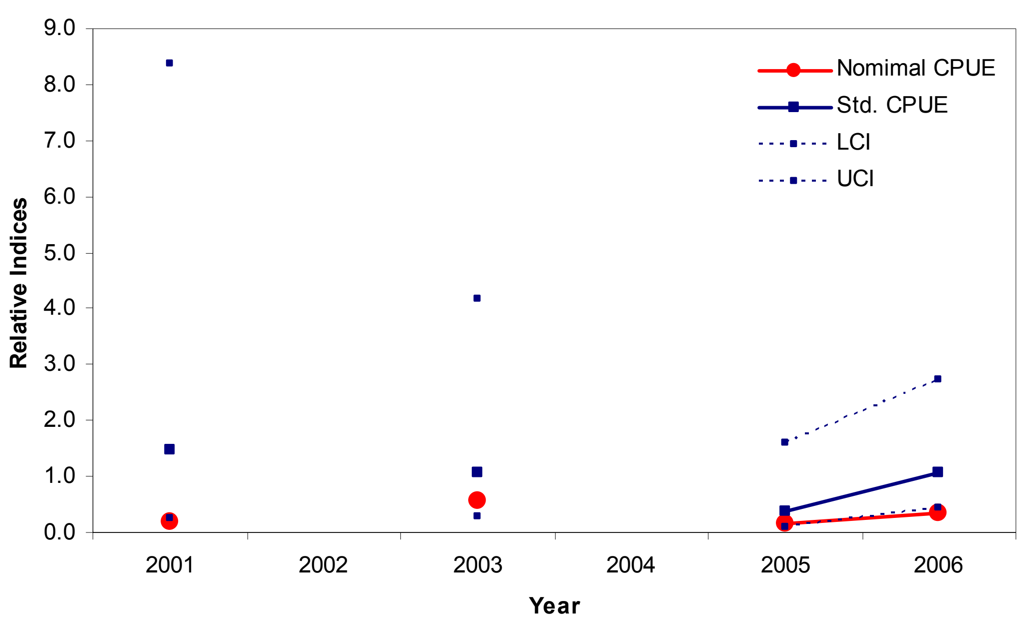


Table 10. Negative binomial regression indices for young-of-the-year finetooth sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	0.18	0.311	1.47	1.062
2002	0	-	-	-	-
2003	21	0.56	0.228	1.081	0.76
2004	45	-	-	-	-
2005	54	0.17	0.089	0.371	0.84
2006	60	0.36	0.228	1.078	0.489

Table 11. Negative binomial regression fit statistics and type III test of the fixed effects for juvenile finetooth sharks.

Fit Statistics	
-2 Log Likelihood	51.29
AIC (smaller is better)	65.29
AICC (smaller is better)	68.09
BIC (smaller is better)	78.39
CAIC (smaller is better)	85.39
HQIC (smaller is better)	70.24
Pearson Chi-Square	37.64
Pearson Chi-Square / DF	0.90

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	3	42	0.65	0.5860
Rainfall	1	42	13.86	0.0006
Sal bot	1	42	3.22	0.0799

Figure 6. Relative indices of abundance for juvenile finetooth sharks from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

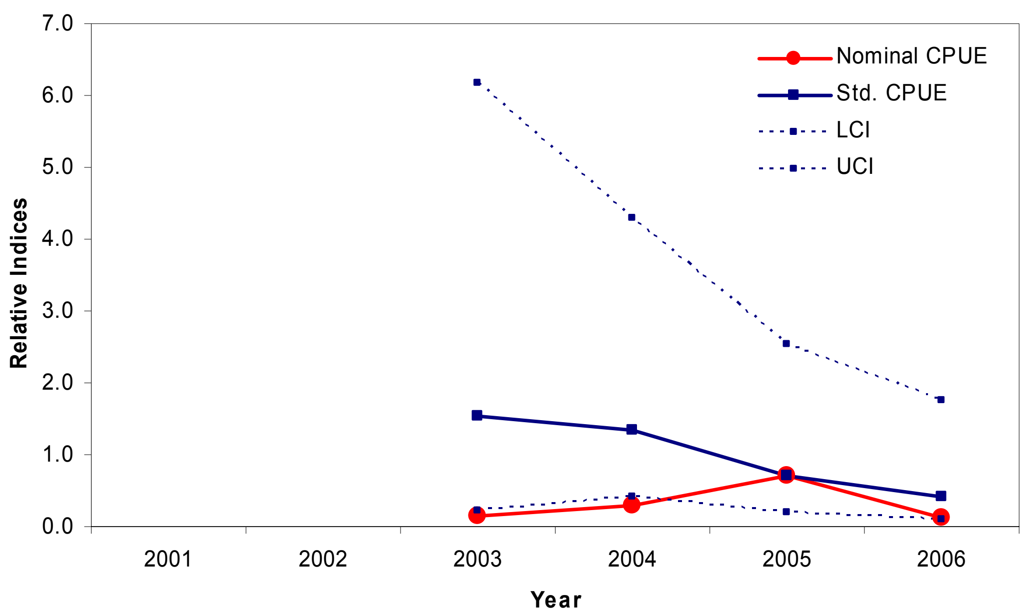


Table 12. Negative binomial regression indices for juvenile finetooth sharks.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	-	-	-	-
2002	0	-	-	-	-
2003	21	0.15	0.293	1.53	1.206
2004	45	0.3	0.56	1.338	0.636
2005	54	0.71	0.136	0.712	0.705
2006	60	0.12	0.081	0.421	0.817

Figure 7. Nominal catch rate series for all bonnethead sharks from Mississippi coastal waters, 2001-2006.

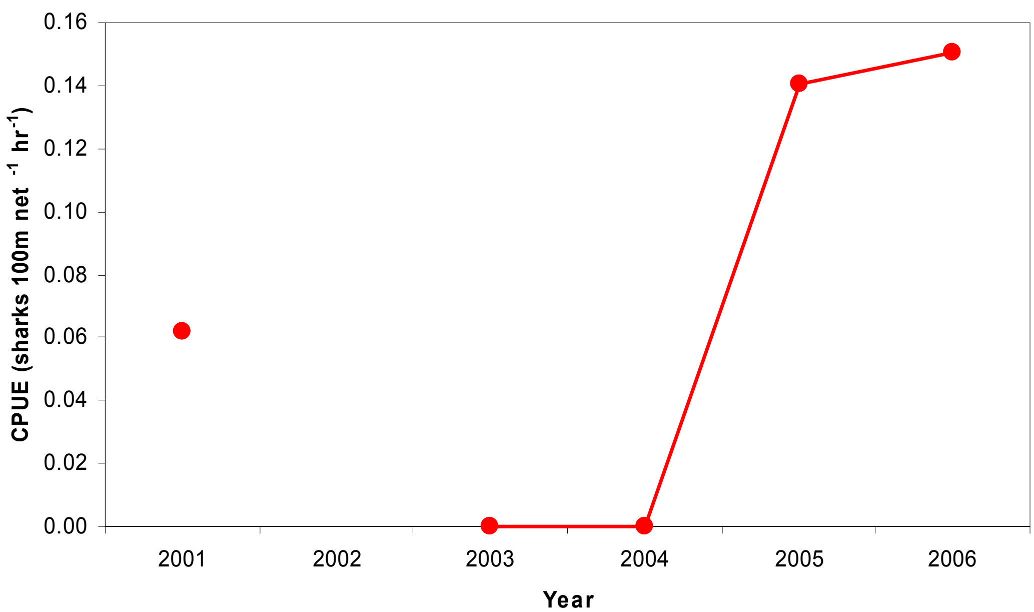


Table 13. Negative binomial regression fit statistics and type III test of the fixed effects for the SCS complex.

Fit Statistics	
-2 Log Likelihood	165.94
AIC (smaller is better)	201.94
AICC (smaller is better)	222.06
BIC (smaller is better)	237.41
CAIC (smaller is better)	255.41
HQIC (smaller is better)	215.58
Pearson Chi-Square	52.72
Pearson Chi-Square / DF	1.46

Type III Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	36	2.40	0.0680
Month	7	36	9.75	<.0001
Rainfall	1	36	8.52	0.0060
Salbot	1	36	5.47	0.0250
Tempsur	1	36	7.40	0.0100
Depth	1	36	4.86	0.0339
Salsur	1	36	7.18	0.0110

Figure 8. Relative indices of abundance for the SCS complex from Mississippi coastal waters, 2001-2006. Both nominal and standardize (Std) catch per unit effort (CPUE) are plotted along with both upper (UCI) and lower (LCI) confidence intervals.

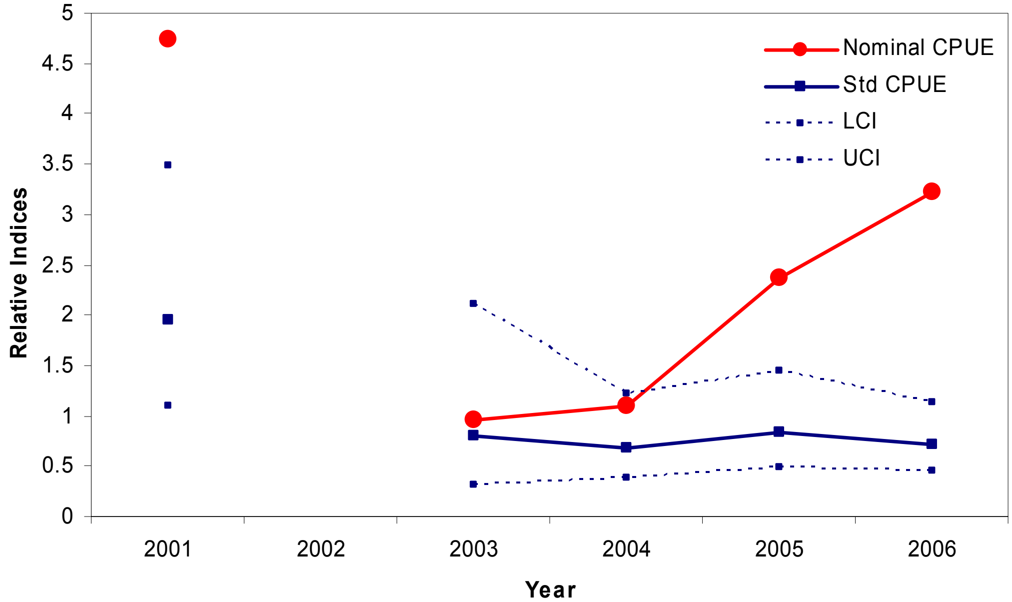


Table 14. Negative binomial regression indices for the SCS complex.

Year	Effort (h)	Nominal CPUE	Mu	Std. Index	CV
2001	20	4.74	3.399	1.959	0.294
2002	0	-	-	-	-
2003	21	0.96	1.401	0.807	0.509
2004	45	1.09	1.176	0.678	0.298
2005	54	2.37	1.465	0.844	0.277
2006	60	3.23	1.235	0.712	0.232

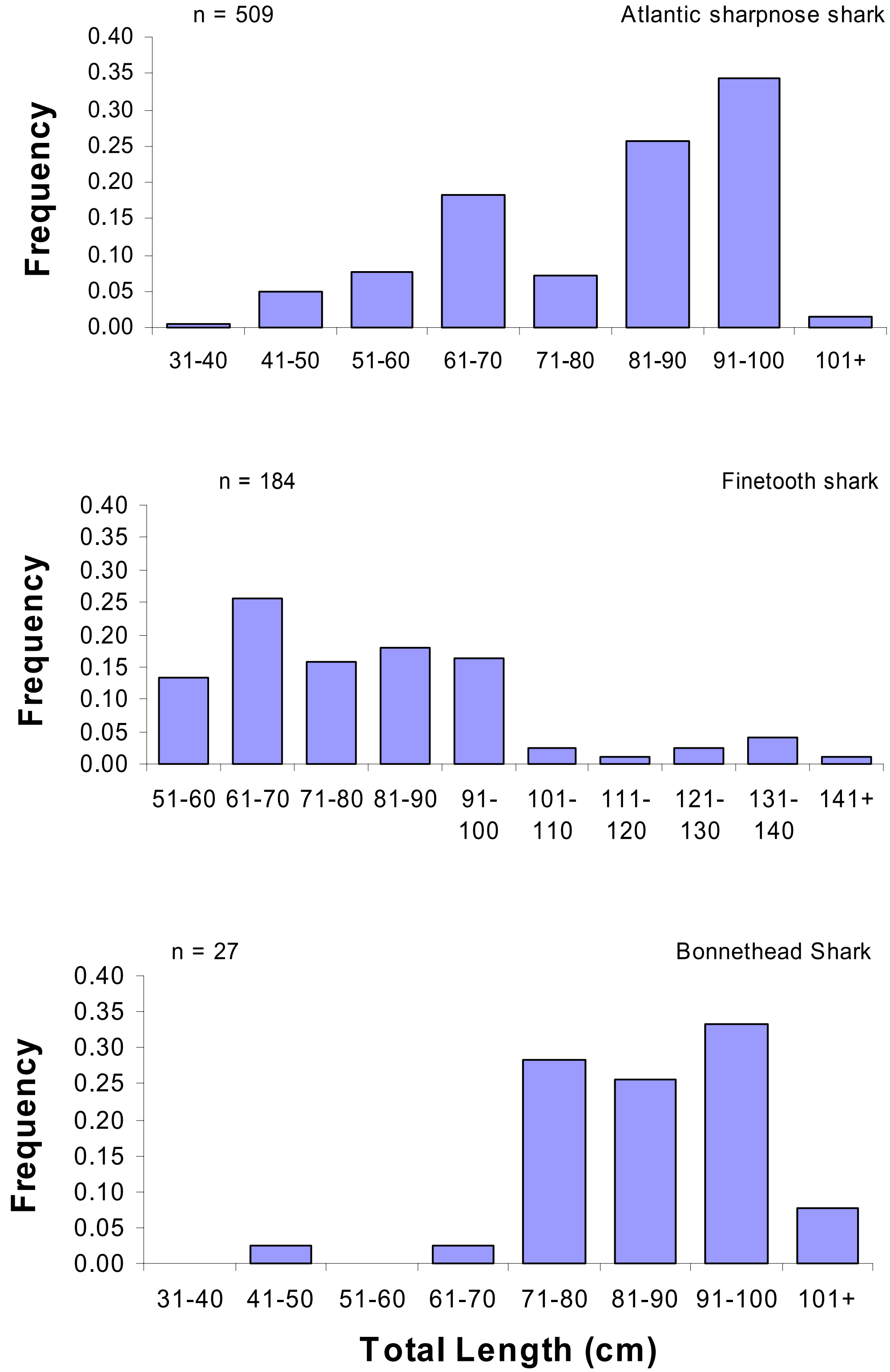


Figure 9. Length frequency distribution of Alantic sharpnose, finetooth, and bonnethead sharks collected from Mississippi coastal waters from 2001-2006. Sample size (n) is indicated.

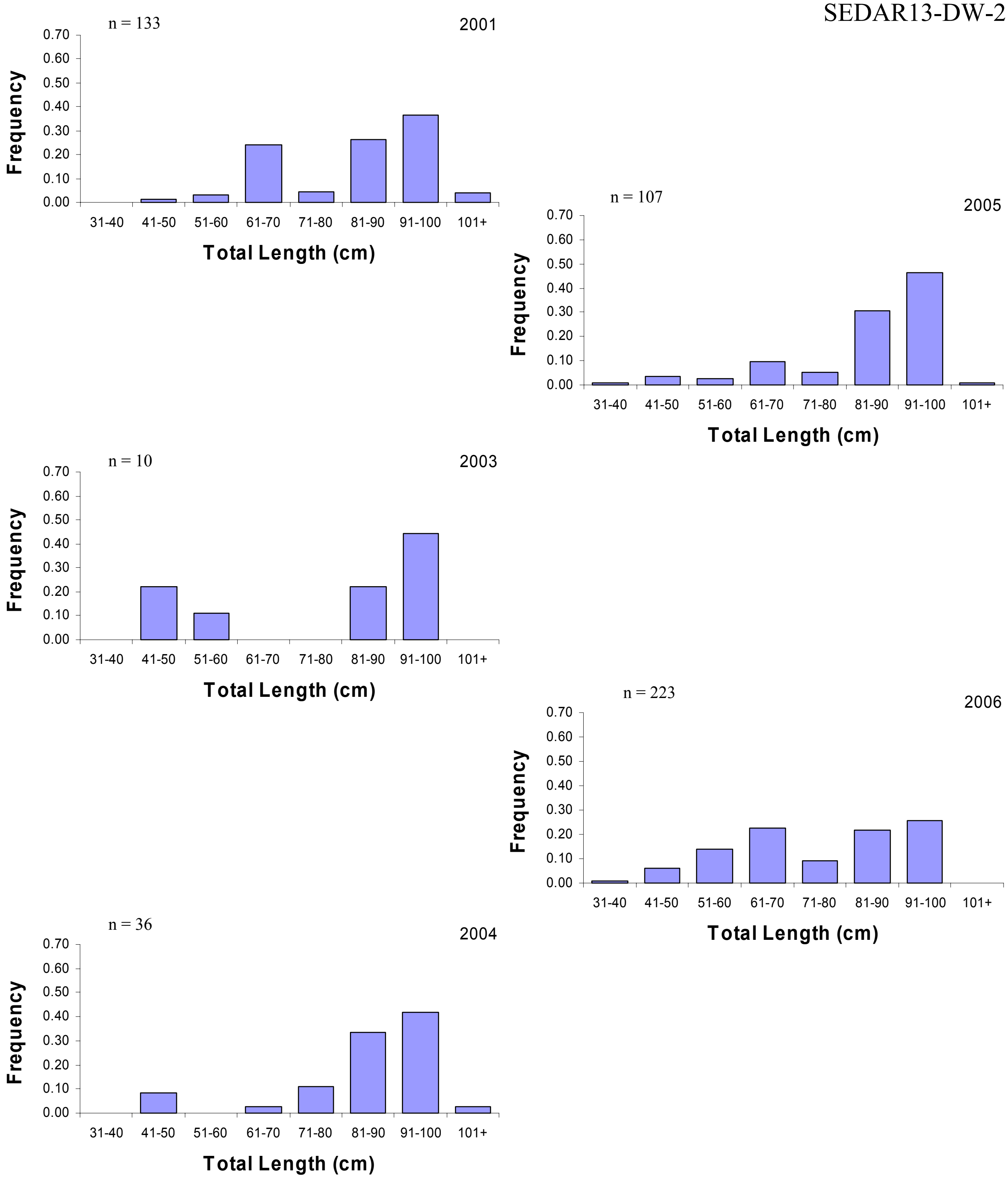
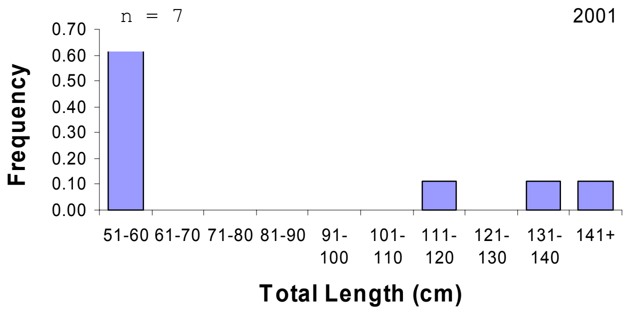
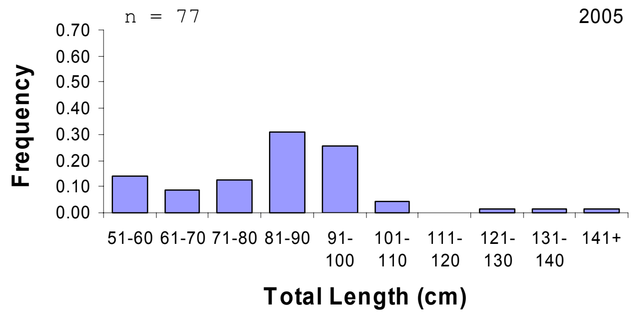
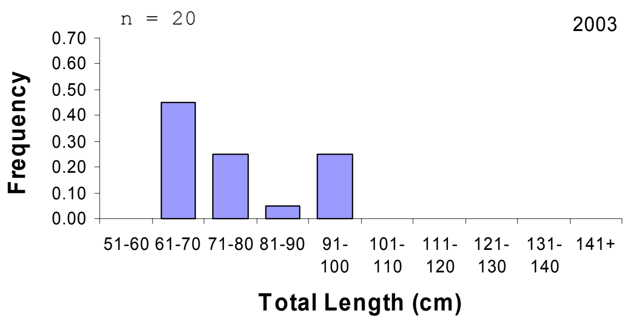
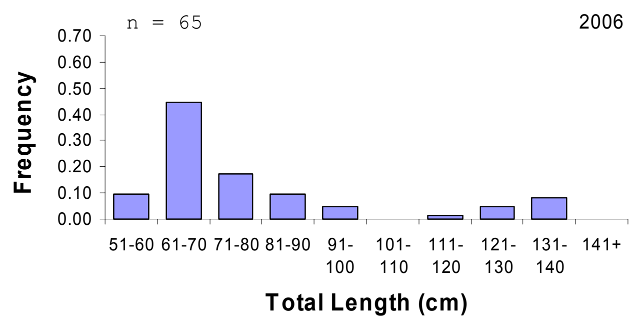


Figure 10. Length frequency distributions of Atlantic sharpnose sharks collected in Mississippi coastal waters from 2001 – 2006. Sample size (n) is indicated for each year.









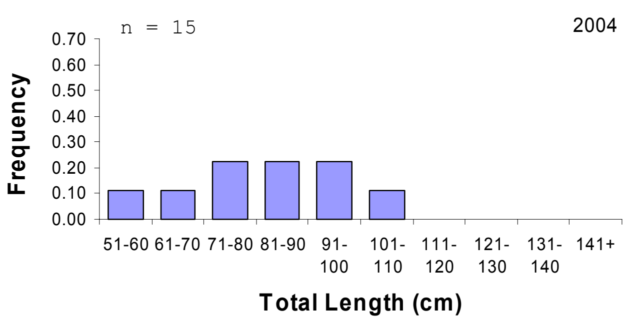


Figure 11. Length frequency distributions of finetooth sharks collected in Mississippi coastal waters from 2001 – 2006. Sample size (n) is indicated for each year.