Standardized catch rates of Small Coastal Sharks from the SEAMAP-South Atlantic Shallow Water Trawl Survey

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Summary

This document presents an updated analysis of the relative abundance of small coastal sharks, Atlantic sharpnose shark, and bonnethead from the SEAMAP-SA Shallow Water Trawl Survey for 1989-2006. Time series data from this survey were standardized with Generalized Linear Model (GLM) procedures. All series showed increasing trends. Examination of lengths of Atlantic sharpnose shark and bonnethead over the time period considered revealed no trend. Length-frequency information revealed that mostly immature individuals of these species area caught, but adults are also present.

1. Background

Time series from the SEAMAP (Southeast Area Monitoring and Assessment Program) survey were first examined for the 2002 stock assessment of small coastal sharks (Cortés 2002) for the period 1989-2001. The SEAMAP-South Atlantic Shallow Water Trawl Survey samples nearshore areas where commercial shrimping occurs along the southeastern coast of the U.S. between Cape Hatteras, North Carolina and Cape Canaveral, Florida (ASMFC 2000). In this document, we derived updated indices of relative abundance of small coastal sharks for the period 1989-2005.

2. Materials and Methods

Data

Methodological details of the SEAMAP survey can be found in various documents that have been made available for this SEDAR Data Workshop (SEAMAP 200 and 2005 reports, SEAMAP methods). Briefly, cruises are conducted in spring (early April-mid-May), summer (mid-July-early August), and fall (October-mid-November) in coastal waters between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. Paired trawl nets are towed for 20 minutes during daylight hours only, thus catch rates are expressed on a tow basis. The survey uses a stratified random sampling design, where the strata correspond to different latitudinal areas and depth zones. We used the following variables for this analysis: season (consisting of spring, summer, and fall), region (Florida, Georgia, South Carolina, and North Carolina), and year, as well as interactions between each pair of these factors. The four species of small coastal sharks (Atlantic sharpnose, bonnethead, blacknose, and finetooth) are caught in this survey, but blacknose (n=188) and finetooth (n=9) sharks did not occur in sufficient numbers to conduct a standardized CPUE analysis. We thus conducted analyses for the small coastal shark complex (the sum of the four species) and for Atlantic sharpnose shark and bonnethead separately. Data were available for the period 1989-2006.

Statistical analysis

Relative abundance indices were estimated using a Generalized Linear Modeling (GLM) approach assuming a delta lognormal model distribution. A binomial error distribution was used for modeling the proportion of positive sets with a logit function as link between the linear factor component and the binomial error. A lognormal error distribution was used for modeling the catch rates of successful sets, wherein estimated CPUE rates assume a lognormal distribution (lnCPUE) of a linear function of fixed factors. The models were fitted with the SAS GENMOD procedure (SAS Institute Inc. 1999) using a forward stepwise approach in which each potential factor was tested one at a time. Initially, a null model was run with no explanatory variables (factors). Factors were then entered one at a time and the results ranked from smallest to greatest reduction in deviance per degree of freedom when compared to the null model. The factor which resulted in the greatest reduction in deviance per degree of freedom was then incorporated into the model if two conditions were met: 1) the effect of the factor was significant at least at the 5% level based on the results of a Chi-Square statistic of a Type III likelihood ratio test, and 2) the deviance per degree of freedom was reduced by at least 1% with respect to the less complex model. Single factors were incorporated first, followed by fixed first-level interactions. The year factor was always included because it is required for developing a time series. Results were summarized in the form of deviance analysis tables including the deviance for proportion of positive observations and the deviance for the positive catch rates.

Once the final model was selected, it was run using the SAS GLIMMIX macro (which itself uses iteratively re-weighted likelihoods to fit generalized linear mixed models with the

SAS MIXED procedure; Wolfinger and O'Connell 1993, Littell et al. 1996). In this model, any interactions that included the year factor were treated as a random effect. Goodness-of-fit criteria for the final model included Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion, and –2* the residual log likelihood (-2Res L). The significance of each individual factor was tested with a Type III test of fixed effects, which examines the significance of an effect with all the other effects in the model (SAS Institute Inc. 1999). The final mixed model calculated relative indices as the product of the year effect least squares means (LSMeans) from the binomial and lognormal components. LSMeans estimates were weighted proportionally to observed margins in the input data, and for the lognormal estimates, a back-transformed log bias correction was applied (Lo et al. 1992).

The relative abundance indices obtained were compared to those from the 2002 SCS stock assessment (Cortés 2002), which examined the period 1989-2001. Additionally, we examined length-frequency distributions for Atlantic sharpnose shark and bonnethead and trends in length for individuals of these two species that were measured.

3. Results

Catch rates

Small coastal shark (SCS) complex. The vast majority of small coastal sharks represented in this survey are Atlantic sharpnose sharks (n=15,661 for the entire period examined), followed by bonnetheads (n=6,187), whereas blacknose sharks (n=188) and finetooth sharks (n=9) were very rare (**Figure 1a**). Factors retained for the SCS proportion of positive tows were season, year, region, and the region*season, year*season, and year*region interactions; and for the positive catches, the factors season, year, region, and year*season, year*region, and region*season were retained in that order (**Table 1**). The index shows good agreement with that developed previously (Cortés 2002), and shows a 2.5-fold, increase from beginning to end of the time series (**Figure 2**). However, total effort increased from 234 tows during 1992-2000 to 306 tows in 2001-2006 (**Figure 1b**), which coincides with an increase in CPUE and the proportion of positive tows in 2001-2006 (**Figure 2**). If we consider the period spanning 1989-2000 only, the time series only increases by 10% from beginning to end. Diagnostic plots showed good agreement with model assumptions and there were no systematic patterns in the residuals (**Figure 3**). The annual index values with CVs are listed in **Table 2**.

Atlantic sharpnose shark. Factors retained for the SCS proportion of positive tows were season, year, region*season, year*season, and year*region; and for the positive catches, the factors season, year, year*region, and year*season were retained in that order (**Table 3**). The index also shows good agreement with that developed previously (Cortés 2002), and shows a 2-fold, increase from beginning to end of the time series (**Figure 4**). As with SCS above, the increased effort in 2001-2006 vs. 1992-2000 coincides with an increase in CPUE and the proportion of positive tows in 2001-2006 (**Figure 4**). Considering the period 1989-2000 only, the time series only increases by 14% from beginning to end. Diagnostic plots showed good agreement with model assumptions and there were no systematic patterns in the residuals (**Figure 5**). The annual index values with CVs are listed in **Table 4**.

Bonnethead shark. Factors retained for the SCS proportion of positive tows were region, season, year, year*season, and region*season; and for the positive catches, the factors region, year, season, year*region, and year*season were retained in that order (**Table 5**). The index also shows good agreement with that developed previously (Cortés 2002), and a 5-fold, increase from beginning to end of the time series (**Figure 6**). As above, the increased effort in 2001-2006 vs. 1992-2000 coincides with an increase in CPUE and the proportion of positive tows in 2001-2006 (**Figure 6**). Considering the period 1989-2000 only, the time series only increases 2.1-fold from beginning to end. Diagnostic plots showed good agreement with model assumptions and there were no systematic patterns in the residuals (**Figure 7**). The annual index values with CVs are listed in **Table 6**.

Trends in size

Examination of length-frequency distributions for Atlantic sharpnose shark revealed that most animals were immature—with two size classes clearly dominating—, although mature animals were also caught (**Figure 8**). A similar pattern was observed for bonnethead, albeit there were proportionally more mature animals (**Figure 9**). There was no clear trend in length over the time period considered for any of the two species examined (**Figure 10**).

4. Discussion

The three indices of relative abundance examined (SCS, Atlantic sharpnose shark, and bonnethead) showed markedly increasing trends. It must be noted that sharks became a priority species for SEAMAP-SA in 2001, but that should not have affected catch rates as these species were unofficially sampled in the exact same way since about 1994. The increase in the total number of tows per year starting in 2001 may explain, at least in part, the sharp increases in the time series from 2001 to 2006, although the indices also fluctuated during that period. However, in addition to the increase in the number of stations sampled, the station allocation scheme also changed in 2001 from a fixed number of stations per stratum to an optimal allocation scheme whereby strata with higher variability were allocated more stations, and vice versa. This was an attempt to lower overall variability and it is possible that areas of high variability tend to have higher shark density, although there is no evidence to support this. If we truncate the time series in 2000, the total increases become much more attenuated. In all, the three series examined still showed increasing tendencies from 1989 to 2000. The lack of trend observed in scatter plots of lengths of SCS and Atlantic sharpnose shark also suggests that the stocks of these two species have remained stable over the time period analyzed.

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Table 1. Factors retained in the model of proportion of positive sets and positive catch of **small coastal sharks** for SEAMAP-SA trawl data.

Proportion positive	Degrees of freedom	Deviance	Log-likelihood
Null model	4564	6180	-3090
Final model SEASON YEAR REGION REGION*SEASON YEAR*SEASON YEAR*REGION	4451	4533	-2266

Positive catches	Degrees of freedom	Deviance	Log-likelihood
Null model	2692	3394	-4133
Final model SEASON YEAR REGION YEAR*SEASON YEAR*REGION REGION*SEASON	2579	2345	-3635

Table 2. Estimates of mean annual CPUE (numbers of sharks per 20-minute tow) and coefficients of variation (CV) for **small coastal sharks** for SEAMAP-SA trawl data.

Year	Mean CPUE	CV
1989	4.138	0.283
1990	3.543	0.285
1991	4.059	0.269
1992	3.530	0.254
1993	2.569	0.293
1994	2.747	0.301
1995	4.433	0.221
1996	2.169	0.306
1997	4.790	0.237
1998	3.817	0.243
1999	3.664	0.252
2000	4.532	0.243
2001	4.998	0.193
2002	7.635	0.165
2003	7.170	0.191
2004	4.576	0.216
2005	6.195	0.218
2006	10.279	0.174

Table 3. Factors retained in the model of proportion of positive sets and positive catch of **Atlantic sharpnose sharks** for SEAMAP-SA trawl data.

Proportion positive	Degrees of freedom	Deviance	Log-likelihood
Null model	4564	6324	-3162
Final model SEASON YEAR REGION*SEASON YEAR*SEASON YEAR*REGION	4451	4642	-2321

Positive catches	Degrees of freedom	Deviance	Log-likelihood
Null model	2212	2634	-3333
Final model SEASON YEAR YEAR*REGION YEAR*SEASON	2105	1869	-2953

Table 4. Estimates of mean annual CPUE (numbers of sharks per 20-minute tow) and coefficients of variation (CV) for **Atlantic sharpnose shark** for SEAMAP-SA trawl data.

Year	Mean CPUE	CV
1989	3.377	0.310
1990	2.983	0.305
1991	3.163	0.284
1992	2.908	0.296
1993	2.240	0.325
1994	1.623	0.361
1995	3.052	0.255
1996	1.860	0.347
1997	3.855	0.264
1998	2.679	0.293
1999	2.734	0.29
2000	3.835	0.271
2001	3.385	0.228
2002	5.306	0.207
2003	5.686	0.233
2004	3.851	0.239
2005	4.969	0.269
2006	6.730	0.221

Table 5. Factors retained in the model of proportion of positive sets and positive catch of **bonnethead sharks** for SEAMAP-SA trawl data.

Proportion positive	Degrees of freedom	Deviance	Log-likelihood
Null model	4564	5234	-2617
Final model REGION SEASON YEAR YEAR*SEASON REGION*SEASON	4502	3928	-1964

Positive catches	Degrees of freedom	Deviance	Log-likelihood
Null model	1187	1201	-1692
Final model REGION YEAR SEASON YEAR*REGION YEAR*SEASON	1085	802	-1452

Table 6. Estimates of mean annual CPUE (numbers of sharks per 20-minute tow) and coefficients of variation (CV) for **bonnethead shark** for SEAMAP-SA trawl data.

Year	Mean CPUE	CV
1989	0.777	0.543
1990	1.37	0.359
1991	2.1	0.343
1992	1.448	0.323
1993	1.031	0.407
1994	1.563	0.347
1995	1.749	0.324
1996	0.711	0.439
1997	1.578	0.331
1998	1.248	0.356
1999	1.122	0.382
2000	1.644	0.34
2001	2.237	0.277
2002	3.415	0.243
2003	2.936	0.26
2004	1.264	0.343
2005	2.731	0.269
2006	3.901	0.251

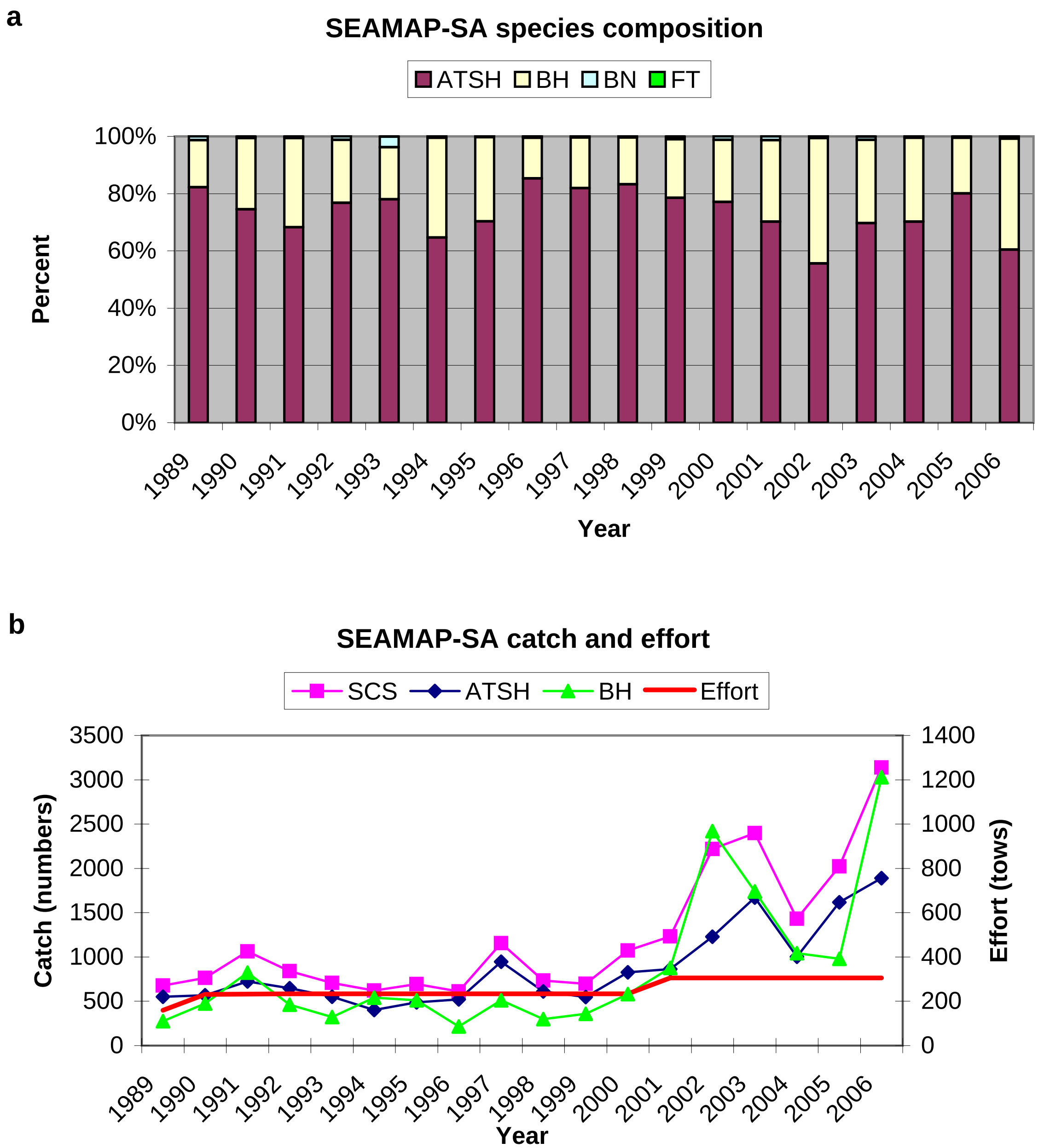
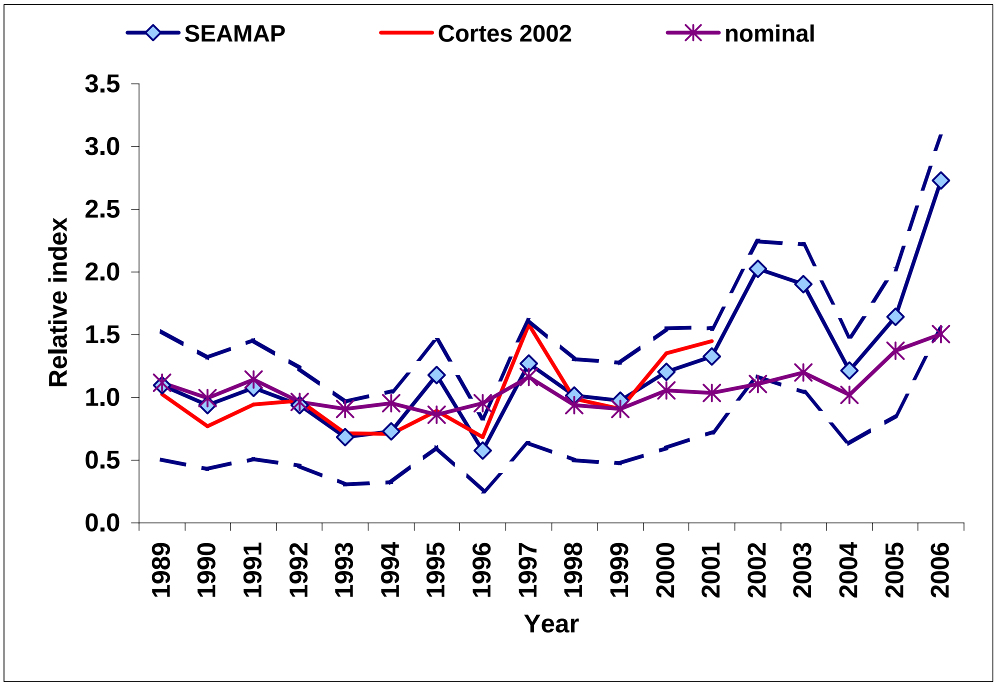


Figure 1. (a) Species composition of small coastal sharks from the SEAMAP-SA trawl survey; (b) catch and effort (number of tows) per year.



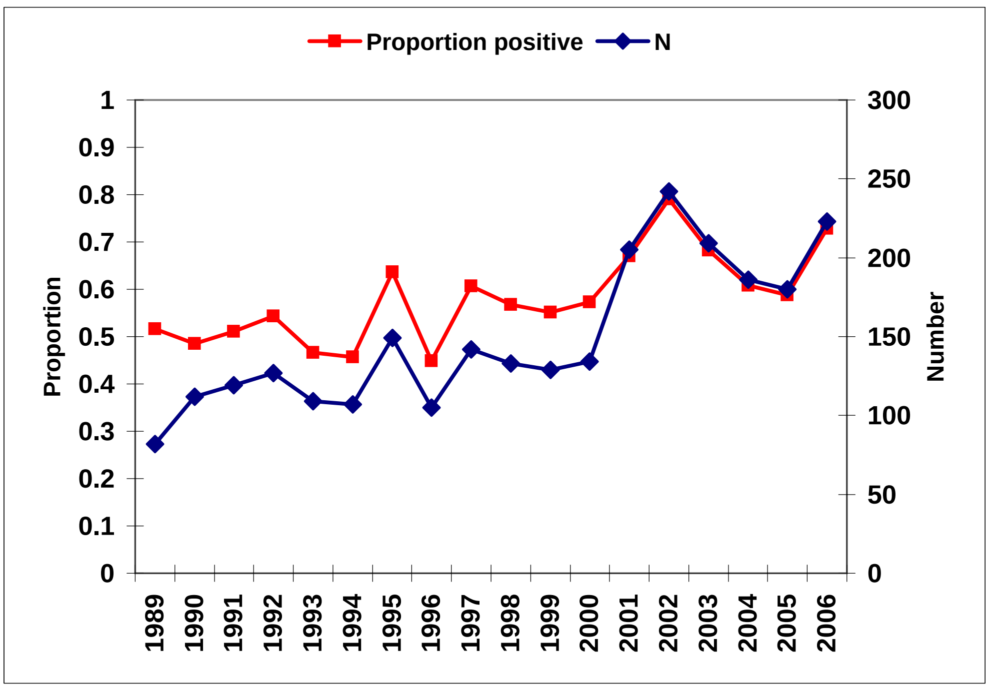


Figure 2. Standardized CPUE (in number) and 95% confidence intervals for **small coastal sharks** from the SEAMAP trawl survey compared to a previous study. All indices are standardized to the mean of the overlapping years. The lower panel shows the proportion of positive sets and sample size by year.

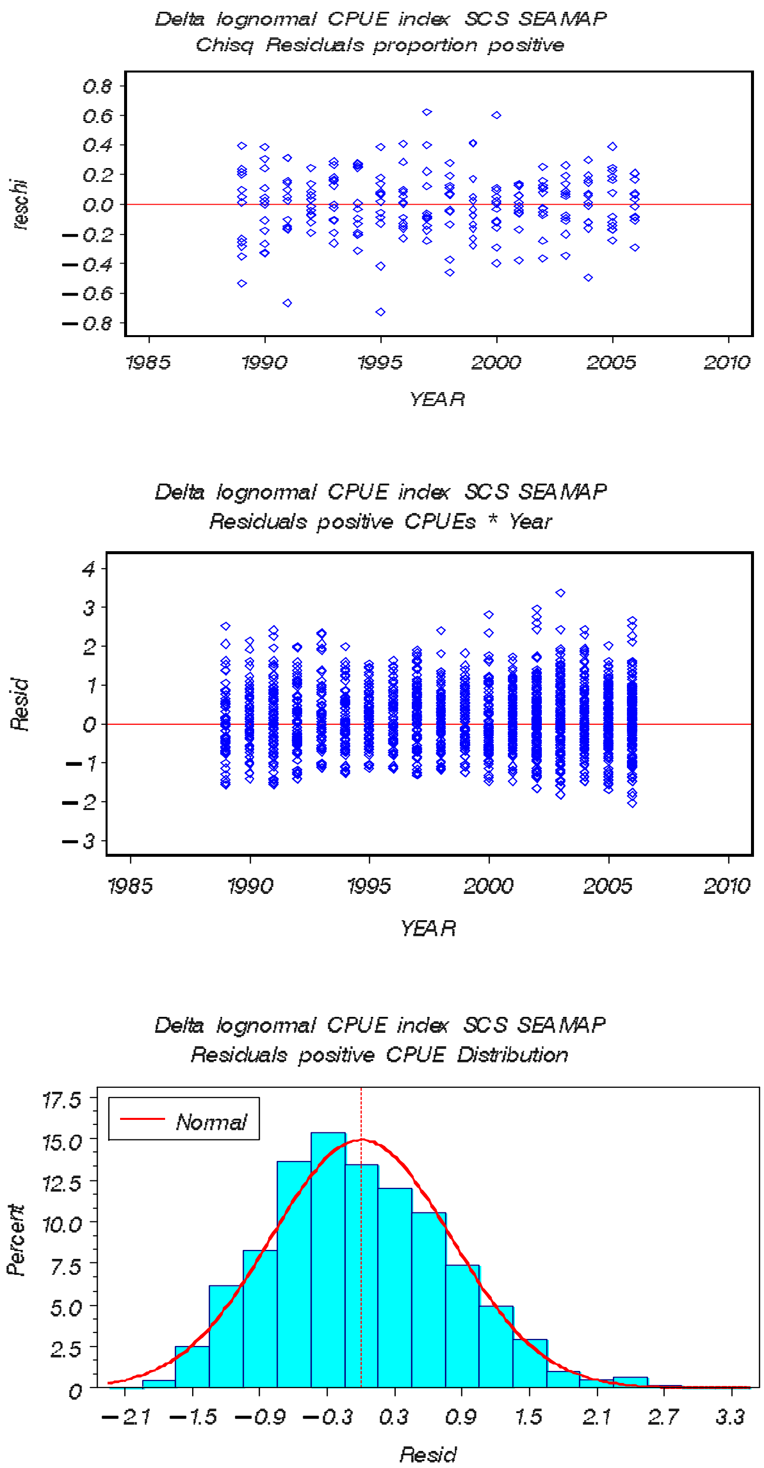


Figure 3. Diagnostic plots of CPUE model from SEAMAP trawl data for**small coastal sharks**.
Top: residuals of proportion positive sets; middle: residuals of positive catch;
bottom: residual positive catch distribution.

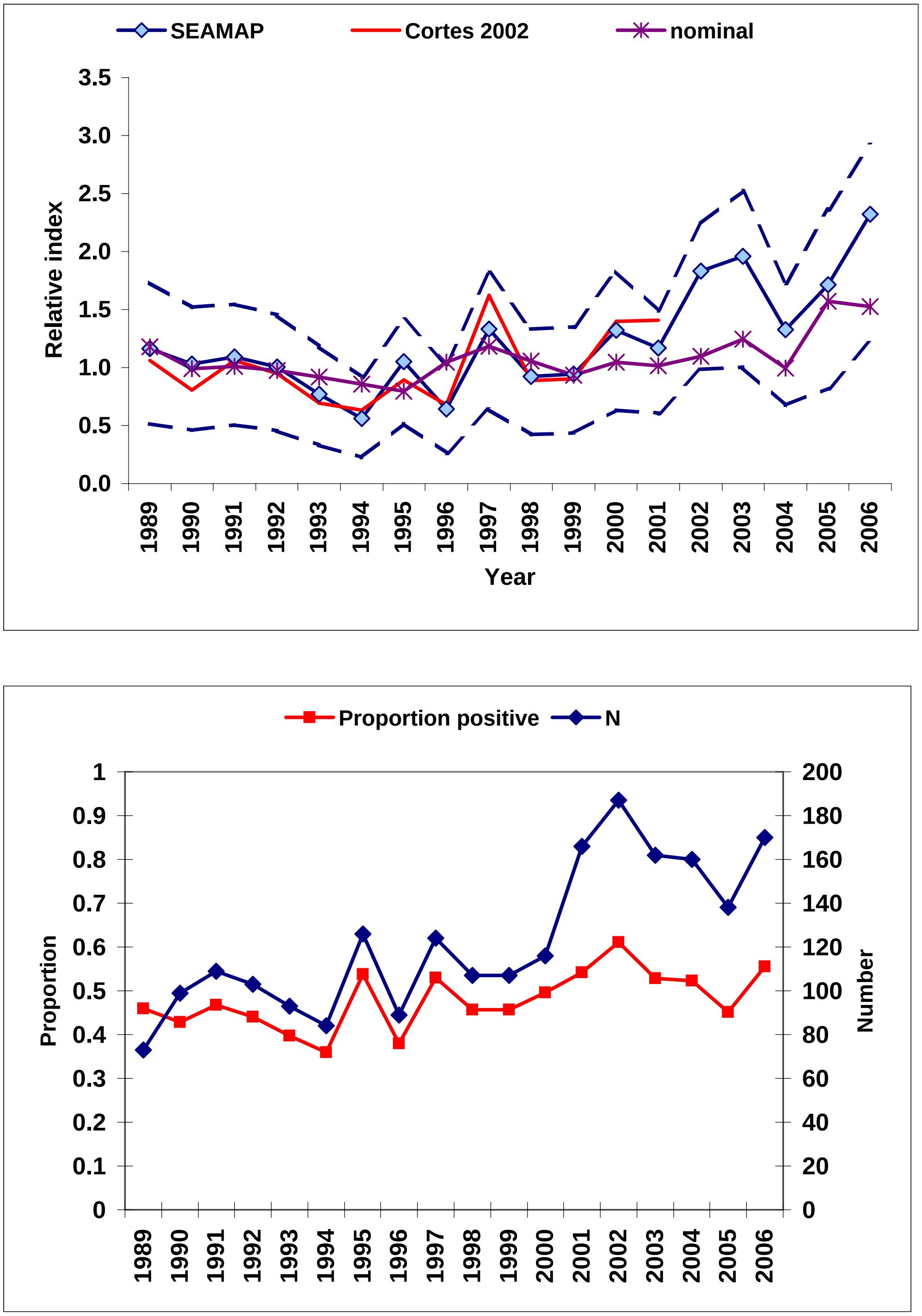


Figure 4. Standardized CPUE (in number) and 95% confidence intervals fo**Atlantic sharpnose sharks** from the SEAMAP trawl survey compared to a previous study. All indices are standardiz to the mean of the overlapping years. The lower panel shows the proportion of positive sets and sample size by year.

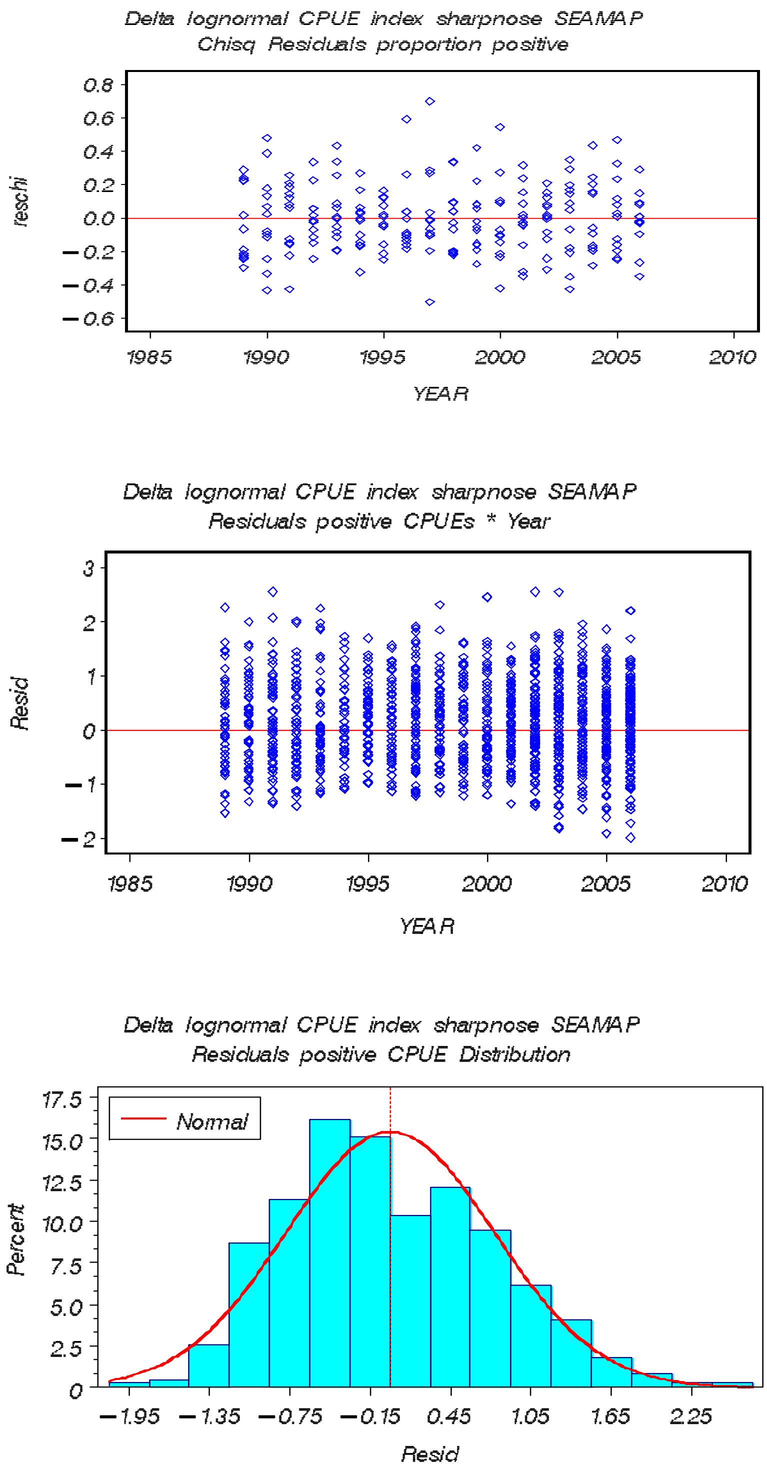
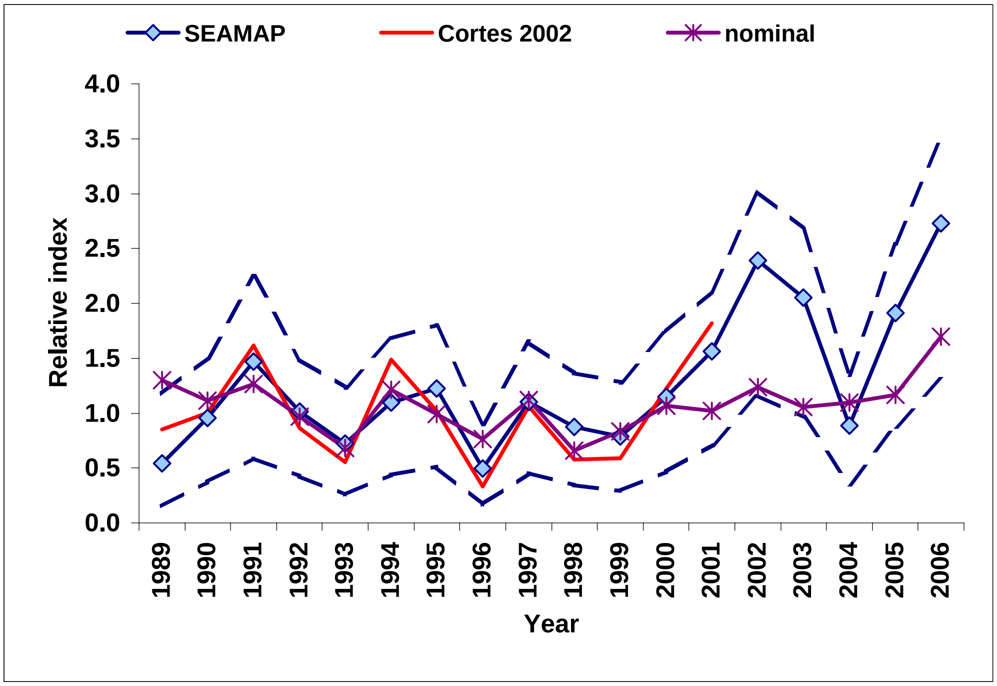


Figure 5. Diagnostic plots of CPUE model from SEAMAP trawl data for**Atlantic sharpnose sharks**. Top: residuals of proportion positive sets; middle: residuals of positive catcl bottom: residual positive catch distribution.



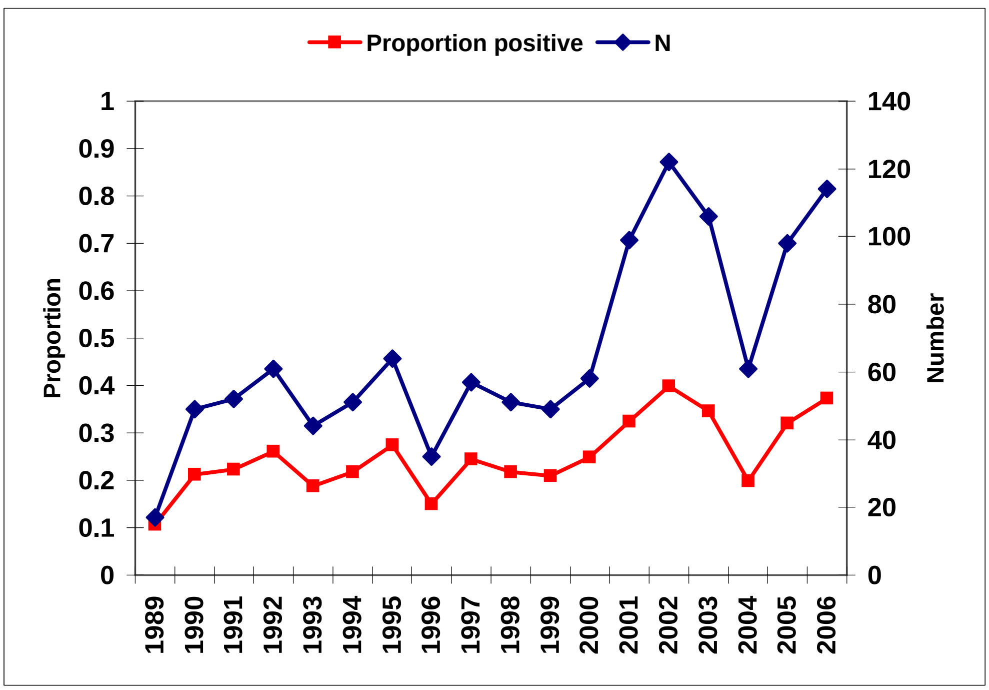


Figure 6. Standardized CPUE (in number) and 95% confidence intervals for **bonnetheads** from the SEAMAP trawl survey compared to a previous study. All indices are standardized to the mean of the overlapping years. The lower panel shows the proportion of positive sets and sample size by year.

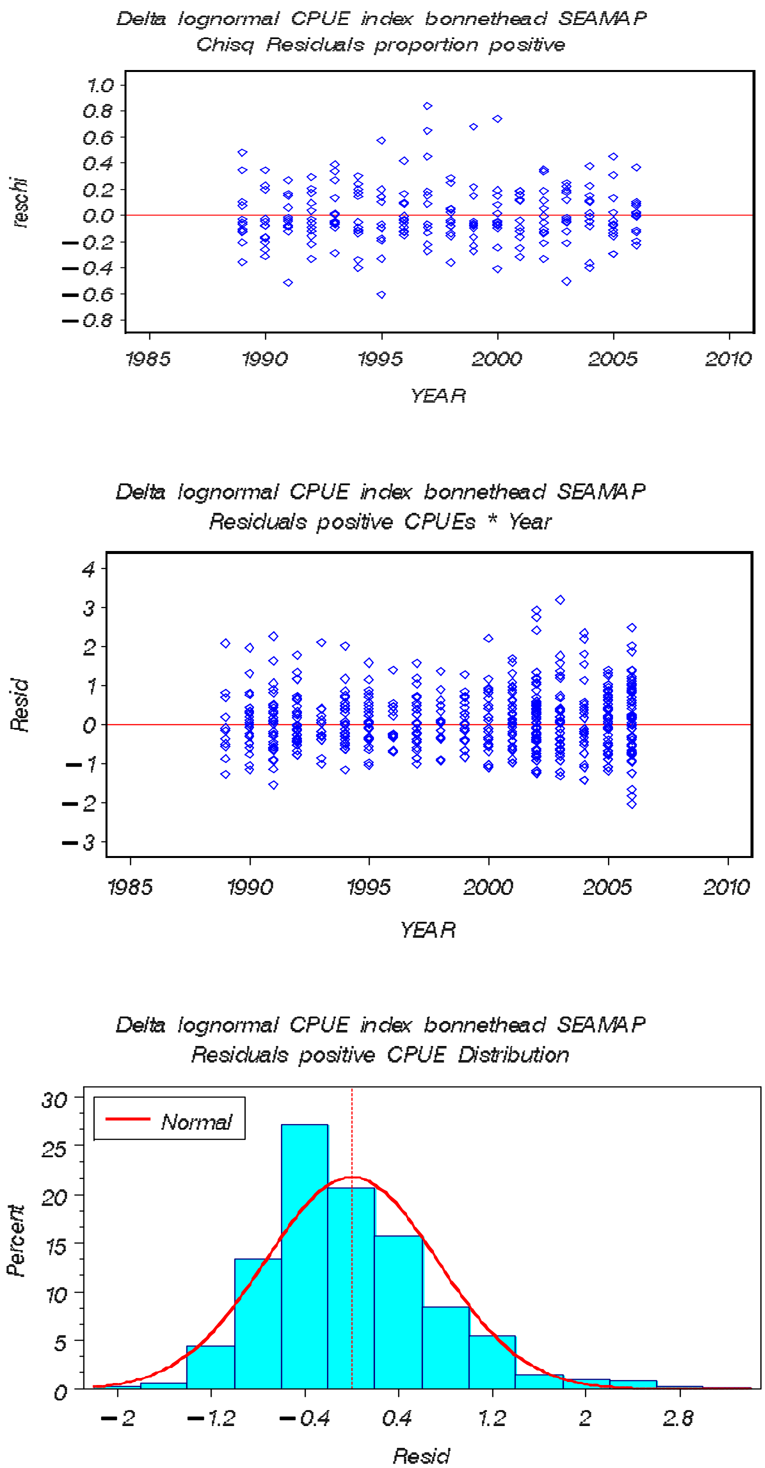


Figure 7. Diagnostic plots of CPUE model from SEAMAP trawl data for **bonnetheads**.
Top: residuals of proportion positive sets; middle: residuals of positive catch;
bottom: residual positive catch distribution.

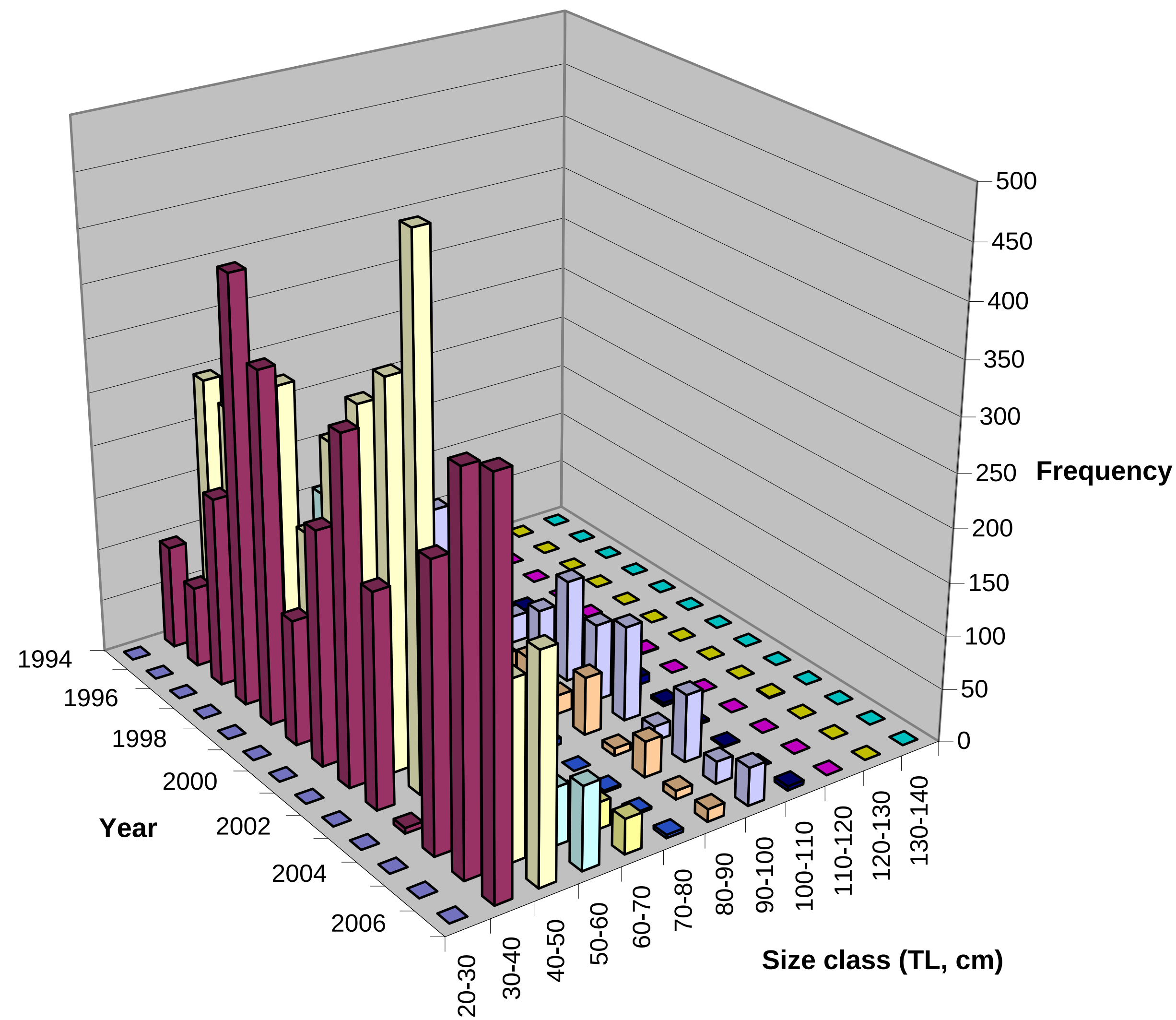


Figure 8. Length frequencies of **Atlantic sharpnose sharks** observed in the SEAMAP-SA trawl survey (1994 - 2006).

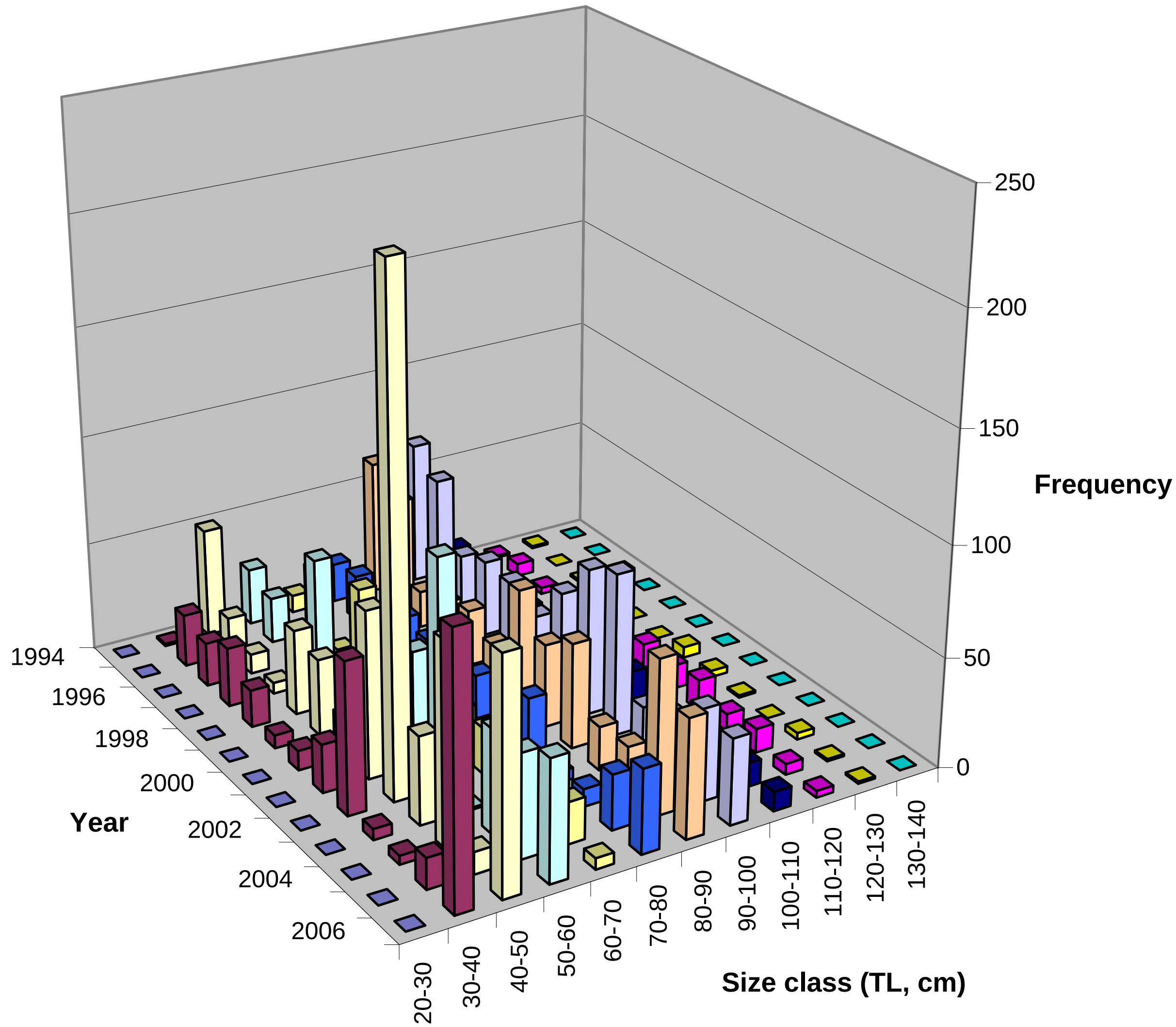
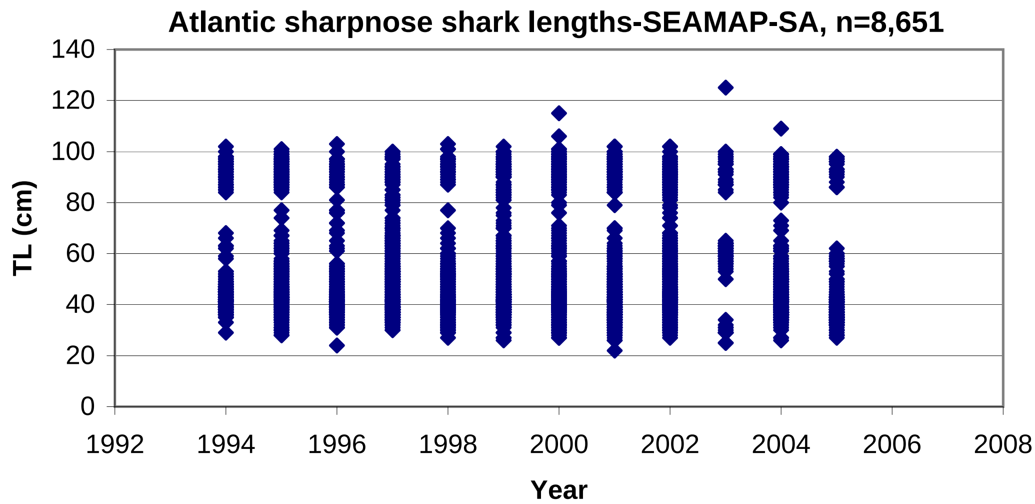


Figure 9. Length frequencies of **bonnetheads** observed in the SEAMAP-SA trawl survey (1994 - 2006).



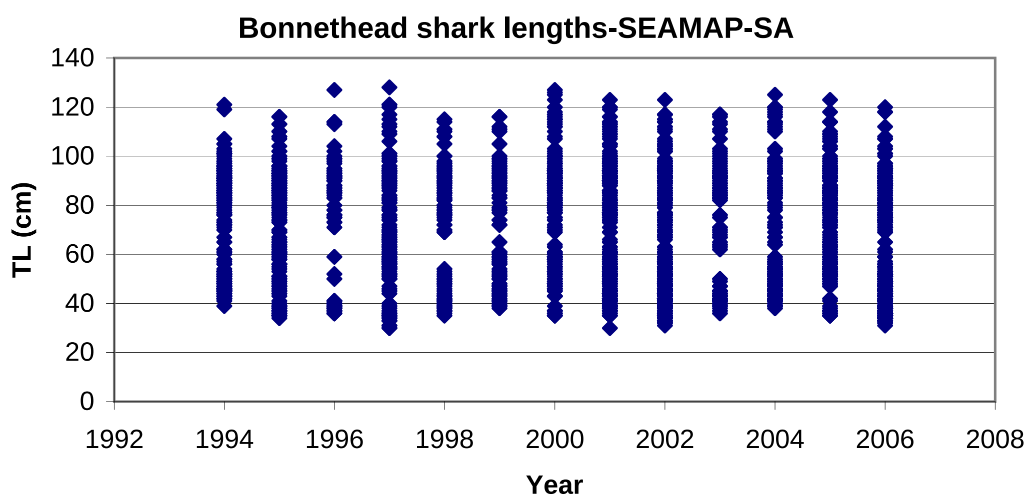


Figure 10. Scatter plot of observed lengths of **Atlantic sharpnose shark** and **bonnethead** from the SEAMAP-SA trawl survey.