LARGE COASTAL SHARK 05/06 DATA WORKSHOP DOCUMENT

Relative abundance trends for juvenile sandbar sharks in Delaware Bay from 2001 to 2005

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Summary

Delaware Bay is one of the principal pupping and nursery grounds for sandbar sharks, *Carcharhinus plumbeus*, in the East Coast waters of the United States (Merson and Pratt 2001). To provide information for effective management of this essential sandbar shark habitat, we need to understand and monitor its use by this species. Researchers from the National Marine Fisheries Service (NMFS) and the University of Rhode Island have been conducting gillnet and/or longline surveys for juvenile sandbar sharks in Delaware Bay since 1995. In 2001, a random stratified sampling plan based on depth and geographic location was initiated to assess and monitor the juvenile sandbar shark population. The geographic regions and depth strata ranges were chosen based on differences seen during sampling for juvenile sandbar sharks in Delaware Bay by the National Marine Fisheries Service from 1995 to 2000. Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of juvenile sandbar sharks in Delaware Bay between the summer nursery seasons from 2001 to 2005. The CPUE was standardized using an offset of the natural logarithm of the CPUE in a generalized linear model which took into account the effects of year, month, region, and depth strata. This study also attempts to standardize the CPUE using a modified two-step approach originally proposed by Lo et al (1992). This approach is based on a delta-lognormal model and is a two-step approach that models the zero catch separately from the positive catch. Results from both standardization methods and the nominal CPUE values indicated that the relative abundance of juvenile age 1+ and young of the year sandbar sharks during the summer nursery season in Delaware Bay from 2001 to 2005 has remained fairly constant with only a significant drop in juvenile age 1+ abundance in 2002, which may be attributed to a large storm that passed through the Bay that year.

Methods

Sampling Gear and Data Collection

A 50-hook bottom longline was used at random stratified sampling stations during the summer months from 2001 to 2005. The mainline consisted of 305 m (1000 ft) of

0.64 cm (1/4 in) braided nylon mainline, and 50 gangions comprised of 12/0 Mustad circle hooks with barbs depressed, 50 cm of 1/16 stainless cable, and 100 cm (39 in) of 0.64 cm (1/4 inch) braided nylon line with 4/0 longline snaps. Hooks were baited with uniform strips of thawed Atlantic mackerel, *Scomber scombrus*. The 50 gangions were placed along the mainline in 6 m (20 ft) intervals. The gear was set with weights to maintain position and enough line to account for the depth at the sampling location for attachment to a fluorescent ball buoy and a staff buoy with a fluorescent flag to mark each end of the gear. Longline soak time was approximately 30 minutes.

Station location, water and air temperatures, depth, salinity, and time of day were recorded for each set. When possible, bottom type was determined by observing bottom sediment on the anchor. The sex, weight, fork length, total length, and umbilical scar condition of all sandbar sharks were recorded. Umbilical scar condition was recorded in six categories: "umbilical remains," "fresh open," "partially healed," "mostly healed," "well healed," and none. Sandbar sharks were then tagged with a NMFS blue rototag in the first dorsal fin and released.

Sampling Design

A random stratified sampling plan based on depth and geographic location was initiated in July 2001 to assess and monitor the juvenile sandbar shark population in Delaware Bay. The Bay was split into nine different geographic regions, three across the northern section of the Bay (NW, NC, NE), three across the middle section of the Bay (CW, CC, CE) and three across the southern section of the Bay (SW, SC, SE) (Figure 1). Within each of these regions, different sampling areas were determined based on the mean low water depth strata (0-2 m, 2-5 m, 5-10 m, and 10+ m) located within that region (Figure 1). The geographic regions and depth strata ranges were chosen based on differences seen during sampling for juvenile sandbar sharks in Delaware Bay by the National Marine Fisheries Service from 1995 to 2000. In some locations throughout the Bay where small areas of one depth stratum occur within another, and there is no significant difference between catch rates during historical sampling in these areas, the two areas are combined into one sample area under the larger of the two depth strata. When a depth stratum from one geographic region crosses into another geographic region, but only a very small portion, then that small portion will remain attached to the larger portion in the original geographic region.

Depth data used in this study were derived from a bathymetric digital elevation model (30 m resolution) based on 17 surveys containing 321,774 soundings in Delaware Bay conducted by the National Ocean Service (NOS). The surveys dated from 1945 to 1993. This data was verified and corrected using field observations and a geographically referenced, digital version of the 2000 NOS nautical chart of Delaware Bay (# 12304).

Stations in each depth stratum within the nine geographic regions of the Bay were chosen randomly from a list of every point (latitude, longitude) within that depth stratum in decimal degrees out to four decimal places. A macro was created in Excel that randomly chose a station from these lists of possible station locations for each month sampled. Sampling occurred during a one-week time frame in mid July and early August from 2001 to 2005.

Data Analysis

Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of juvenile sandbar sharks in Delaware Bay between the summer nursery seasons from 2001 to 2005. The CPUE was standardized using the natural logarithm of the CPUE +1 in a generalized linear model (GLM) which took into account the effects of year, month, region, and depth strata. This analysis was done for three dependent variables: total juvenile sandbar shark CPUE, young of the year (YOY) sandbar shark CPUE, and juvenile (age 1+) sandbar shark CPUE. GLM statistical procedures were performed in Statgraphics Plus 3.3 (Statistical Graphics Corporation). Statistically significant differences were determined using an $\alpha = 0.05$. The standardized indices of abundance were based on the year effect least square means determined from the GLM.

Log-normal error models, as used in the GLM statistical procedures above, have been used to standardize fishery-independent catch rates from shark surveys (Carlson 2001, Simpfendorfer et al. 2002). Currently, there is another approach to modeling catch data that takes into account highly skewed data with many zeros which is commonly seen in marine data (Pennington 1983, 1996). This approach is based on a delta-lognormal model and is a two-step approach that models the zero catch separately from the positive catch, which was originally proposed by Lo et al. (1992) for use in analyzing fish spotter data for northern anchovy, *Engraulis mordax*, from the southern California purse-seine fishery. Carlson (2002) also used this method to conduct a fishery independent assessment of shark stock abundance for large coastal species in the northeast Gulf of Mexico. The Lo et al. method for standardizing data can correct the bias that may be introduced into log-normal error models when a significant number of zero catches in the data may cause zero catches with low effort to appear higher. The data used in this study to develop a relative index of abundance for juvenile sandbar sharks is skewed with many zeros. Even though the effort in this study is evenly distributed over the sets and throughout the years it was decided that incorporating this type of model into the data analyses for this study may be beneficial.

This study attempted to standardize the CPUE using this two-step approach to compare to the nominal CPUE and the results from the GLM model described earlier for each of the three dependent variables (total juvenile sandbar shark CPUE, young of the year (YOY) sandbar shark CPUE, and juvenile (age 1+) sandbar shark CPUE). Based on the results of the GLM, factors considered as potential influences on the CPUE for these analyses were: year, month, region and depth strata. The proportion of sets with positive CPUE values was modeled assuming a binomial distribution with a logit link function and the positive CPUE sets were modeled assuming a Poisson distribution with a log link function. Models were fit in a stepwise forward manner adding one potential factor at a time after initially running a null model with no factors included (Gonzáles-Ania et al. 2001, Carlson 2002). Each potential factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor resulting in the greatest reduction in deviance was then incorporated into the model providing the effect was significant at $\alpha = 0.05$ based on a Chi-Square test, and the deviance per degree freedom was reduced by at least 1% from the less complex model. This process was continued until no additional factors met the criteria for incorporation into the final model. All models in the stepwise approach were fitted using the SAS GENMOD procedure (SAS Institute, Inc.). The final models were run through the SAS GLIMMIX macro to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Institute, Inc). The factor "year" was kept in all final models, regardless of its significance, to allow for calculation of indices. The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and Poisson components.

Results

A total of 681 juvenile sandbar sharks (282 YOY and 399 juveniles age 1+) were caught during 280 50-hook longline sets during the peak months of the summer nursery season (July and August) in Delaware Bay from 2001-2005. These sharks ranged in size from 43 to 128 cm fork length. Juvenile sandbar sharks were caught in surface water temperatures ranging from 16.5 to 31.0 ^{o}C, bottom water temperatures from 17.6 to 29.5 ^{o}C, surface water dissolved oxygen from 2.8 to 13.6 mg/l, bottom water dissolved oxygen from 1.7 to 9.3 mg/l, surface water salinity from 11.0 to 32.0 ppt, and bottom water salinity from 11.1 to 31.6 ppt. The nominal relative indices of abundance for total juvenile, YOY and juvenile age 1+ CPUE are reported in Table 1 and illustrated in Figures 2, 3, and 4.

GLM

The GLM for all three dependent variables (total juvenile CPUE, YOY CPUE, and juveniles age 1+ CPUE) was significant ($p<.001$, $p<.001$, $p<.001$, respectively) when modeled including the effects of year, month, region, and depth strata. The resulting relative indices of abundance based on the standardized year effects obtained from the GLM analyses for total juvenile, YOY, and juveniles age 1+ CPUE are reported in Table 2 and illustrated in Figures 2, 3 and 4.

For total juvenile CPUE, all four independent variables were significant at the α = 0.05 level (Table 3). Post hoc multiple comparisons using Fisher's least significant difference (LSD) procedure indicated that there were significant differences between years 2001 to 2002 and 2002 to 2003 for total juvenile CPUE at the α = 0.05 level. No significant differences were found between the remaining years for total juvenile CPUE. There was a significant difference in total juvenile CPUE between July and August during 2001 to 2005 sampling ($p=.003$, Table 3)). Fisher's LSD procedure indicated that there were significant differences in total juvenile CPUE between many of the geographic regions in Delaware Bay (Table 4, Figure 1). There were also significant differences found in total juvenile CPUE between the deepest depth range (10+ m) and all other depth ranges (0-2, 2-5 and 5-10 m) at the α = 0.05 level using Fisher's LSD procedure.

For YOY, only region and depth zone had significant effects on CPUE at the α = 0.05 level (Table 3). There were no significant differences in YOY CPUE from 2001 to 2005 or between the months of July and August during the same years. Fisher's LSD procedure indicated that there were significant differences in YOY CPUE between many of the geographic regions in Delaware Bay (Table 5, Figure 1). There were also significant differences found in total juvenile CPUE between the shallower depth ranges (0-2 and 2-5 m) and the deeper depth ranges (5-10 and 10+ m) at the α = 0.05 level using Fisher's LSD procedure.

For juvenile age 1+ CPUE, all independent variables except depth zone were significant at the $\alpha = 0.05$ level (Table 3). As seen with the total juveniles, post hoc multiple comparisons using Fisher's LSD procedure indicated that there were significant differences in CPUE between years 2001 to 2002 and 2002 to 2003 for juveniles age 1+ at the $\alpha = 0.05$ level. There was a significant difference in juvenile age 1+ CPUE between July and August during 2001 to 2005 sampling (p=.002, Table 2)). Fisher's LSD procedure indicated that there were significant differences in juvenile age 1+ CPUE between many of the geographic regions in Delaware Bay (Table 6, Figure 1).

Two-step approach based on Lo et al. method

The percentage of sets with zero catches was 44.3% for total juvenile sandbar sharks. The stepwise construction of the binomial model of the probability of a positive juvenile sandbar CPUE for a set and the Poisson model of positive juvenile sandbar CPUE sets is in Table 7. The final binomial model was *Proportion positive total juvenile CPUE sets = Region + Year + Month + Depth*. The final Poisson model was *Positive total juvenile CPUE sets = Region + Month + Year*.

The percentage of sets with zero catches was 71.4% for YOY sandbar sharks. The stepwise construction of the binomial model of the probability of a positive YOY sandbar CPUE for a set and the Poisson model of positive YOY sandbar CPUE sets is in Table 8. The final binomial model was *Proportion positive YOY CPUE sets = Region + Depth + Year*. Year was not a significant factor in the final model for the proportion positive YOY CPUE sets but was kept in the model to allow for calculation of the indices. The final Poisson model was *Positive YOY CPUE sets = Month + Year*.

The percentage of sets with zero catches was 50.4% for juvenile age 1+ sandbar sharks. The stepwise construction of the binomial model of the probability of a positive juvenile age 1+ sandbar CPUE for a set and the Poisson model of positive juvenile age 1+ sandbar CPUE sets is in Table 9. The final binomial model was *Proportion positive juvenile (age 1+) CPUE sets = Region + Year + Month*. The final Poisson model was *Positive juvenile (age 1+) CPUE sets = Region + Month + Year*.

The resulting relative indices of abundance based on the standardized year effects obtained from the Lo et al. method for total juvenile, YOY, and juveniles age 1+ CPUE are reported in Table 10 and illustrated in Figures 2, 3 and 4.

Discussion

The significant decrease in relative abundance found for total juveniles and juveniles age 1+ in 2002 using both nominal and standardized methods (Tables 1, 2 and 10) and illustrated in Figures 2 and 4 is thought to be caused by a large storm that passed through Delaware Bay in August due to a hurricane offshore. A large reduction in catch was noted after the storm, especially in juvenile age 1+ catch. It is likely that the storm caused the juveniles age 1+ to migrate out of the Bay early that year and our tag recapture data from that year supports these findings. The significant difference in CPUE between July and August for total juveniles and juveniles age 1+ (Table 3, 7, and 9) was likely also influenced by the effects of the storm in August of 2002. There was not a significant decrease in YOY catch in 2002 (Tables 1, 2 and 7). This is most likely because they were not fully prepared to migrate due to the short amount of time spent in the bay up to that point. The YOY may have simply refuged in the deeper waters of the Bay until the storm passed. Besides the drop in CPUE during 2002 the relative juvenile sandbar shark abundance in Delaware Bay has remained steady from 2001 to 2005.

The significantly lower catch rates found in the different regions (Tables 4, 5 and 6) and depth strata of the bay appear to occur in the shallow less productive waters of the northeast regions of the Bay (NC and NE) and the deeper less protected regions of the Bay where the tidal current is strongest (CC, SC and SE). The YOY sandbar sharks are more abundant in the shallower regions of the Bay where small prey items are abundant and extensive shoals may help provide protection from large predators. Juvenile age 1+ CPUE was not significantly affected by depth strata (Tables 3 and 9), likely because juveniles are more adept at capturing prey and, with increased size, need less protection, which would allow them to have a wider distribution throughout the Bay.

The different regions and depth strata chosen for this study's sampling plan in Delaware Bay were chosen based on differences seen in juvenile sandbar shark catch rates between these regions and depth strata during longline and gillnet surveys conducted from 1995 to 2000. By standardizing the catch rates to include the effects of these variables a more accurate picture of the trends in relative abundance for juvenile sandbar sharks can be developed. The addition of year and month effects can also reduce the temporal variability due to a combination of environmental variables during those times. Even though the factors of region, year, month and depth were significant in the GLM (Table 3) and the majority of the Lo et al method models (Tables 7, 8 and 9), results from this study indicate that any bias associated with these factors did not significantly change the trends between the nominal and standardized data (Figures 2, 3 and 4). Individual environmental parameters were not considered in this study because of the well mixed nature of the bay. Furthermore, previous studies conducted during the summer nursery season in Delaware Bay have reported no significant relationships between sandbar shark catch and salinity, temperature and tidal cycle (Merson and Pratt 2001).

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Table 1. Nominal relative (CPUE/mean) abundance indices for juvenile sandbar sharks in Delaware Bay from 2001-2005. N = the number of sets observed.

Total juvenile sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	0.918	0.654	1.182	1.099	56
2002	0.488	0.242	0.735	1.929	56
2003	1.317	0.735	1.899	1.687	56
2004	1.088	0.633	1.543	1.597	56
2005	1.189	0.703	1.675	1.560	56

YOY sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	0.664	0.319	1.009	1.984	56
2002	0.592	0.201	0.983	2.523	56
2003	1.633	0.493	2.772	2.665	56
2004	0.895	0.392	1.398	2.146	56
2005	1.216	0.579	1.854	2.002	56

Juvenile age 1+ sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	1.098	2.176	4.038	1.144	56
2002	0.417	0.599	1.758	1.878	56
2003	1.086	2.721	3.422	0.435	56
2004	1.239	3.081	3.928	0.461	56
2005	1.160	2.886	3.678	0.461	56

Table 2. GLM relative (index/mean) standardized abundance indices for juvenile sandbar sharks in Delaware Bay from 2001-2005. CV = coefficient of variation, N = the number of sets observed.

Total juvenile sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	1.141	0.055	1.404	0.878	56
2002	0.550	0.287	0.813	1.819	56
2003	1.198	0.934	1.461	0.836	56
2004	1.030	0.767	1.294	0.972	56
2005	1.080	0.816	1.343	0.927	56

YOY sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	0.895	0.375	1.414	2.208	56
2002	0.640	0.120	1.159	3.087	56
2003	1.287	0.767	1.806	1.535	56
2004	0.950	0.430	1.469	2.079	56
2005	1.229	0.709	1.748	1.607	56

Juvenile age 1+ sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	1.210	0.928	1.491	0.883	56
2002	0.455	0.173	0.735	2.349	56
2003	1.141	0.860	1.422	0.936	56
2004	1.073	0.792	1.354	0.996	56
2005	1.122	0.843	1.403	0.952	56

Table 3. GLM results for the fitted model. All F-ratios are based on the residual mean square error.

GLM results for total juveniles

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
year	14.2676	4	3.5669	3.90	0.0043
month	8.5209	1	8.5209	9.32	0.0025
region	81.8082	8	10.2260	11.18	0.0000
depth zone	10.1884	3	3.3962	3.71	0.0121
Residual	240.5430	263	0.9146		
Total (corrected)	351.5750	279			

GLM results for YOY

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
year	2.6867	4	0.6717	1.04	0.3894
month	2.2859	1	2.2859	3.52	0.0616
region	33.4050	8	4.1756	6.44	0.0000
depth zone	14.8525	3	4.9508	7.63	0.0001
Residual	170.6260	263	0.6488		
Total (corrected)	223.0180	279			

GLM results for juveniles age 1+

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
year	13.4020	4	3.3505	4.87	0.0008
month	6.8106	1	6.8106	9.90	0.0018
region	49.2203	8	6.1525	8.94	0.0000
depth zone	3.2506	3	1.0835	1.58	0.1957
Residual	180.9040	263	0.6878		
Total (corrected)	252.6510	279			

Table 4. Multiple Comparisons for total juvenile CPUE by region

Method: 95.0 percent LSD

Region	Count	LS Mean	Homogeneous Groups

SE	20	0.13754	X
SC	40	0.29181	X
NE	20	0.46821	X
NC	20	0.71167	XX
CC	30	1.10971	XX
SW	40	1.32189	XX
NW	40	1.39144	XX
CE	30	1.65461	X
CW	40	1.67518	X

Contrast	Difference	+/- Limits
CC - CE	*-0.544896	0.486211
CC - CW	*-0.565471	0.454809
CC - NC	0.398042	0.543601
CC - NE	*0.641506	0.543601
CC - NW	-0.281729	0.454809
CC - SC	*0.817907	0.454809
CC - SE	*0.972174	0.543601
CC - SW	-0.212182	0.454809
CE - CW	-0.020575	0.454809
CE - NC	*0.942938	0.543601
CE - NE	*1.186400	0.543601
CE - NW	0.263167	0.454809
CE - SC	*1.362800	0.454809
CE - SE	*1.517070	0.543601
CE - SW	0.332714	0.454809
CW - NC	*0.963513	0.515705
CW - NE	*1.206980	0.515705
CW - NW	0.283742	0.421071
CW - SC	*1.383380	0.421071
CW - SE	*1.537650	0.515705
CW - SW	0.353289	0.421071
NC - NE	0.243464	0.595485
NC - NW	*-0.679771	0.515705
NC - SC	0.419865	0.515705
NC - SE	0.574132	0.595485
NC - SW	*-0.610224	0.515705
NE - NW	*-0.923235	0.515705
NE - SC	0.176401	0.515705
NE - SE	0.330668	0.595485
NE - SW	*-0.853688	0.515705
NW - SC	*1.099640	0.421071
NW - SE	*1.253900	0.515705
NW - SW	0.069546	0.421071
SC - SE	0.154267	0.515705
SC - SW	*-1.030090	0.421071
SE - SW	*-1.184360	0.515705

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* denotes a statistically significant difference at the $\alpha = 0.05$ level.

Table 5. Multiple Comparisons for YOY CPUE by region

Method: 95.0 percent LSD

Region Count LS Mean Homogeneous Groups

NE	20	-0.090245	X
SE	20	0.019803	X
SC	40	0.080833	X
NC	20	0.265205	XX
CC	30	0.327681	XX
NW	40	0.696419	XX
CW	40	0.696504	XX
CE	30	0.808685	X
SW	40	0.936819	X

Contrast	Difference	+/- Limits
CC - CE	*-0.481004	0.409497
CC - CW	-0.368823	0.383049
CC - NC	0.062476	0.457832
CC - NE	0.417927	0.457832
CC - NW	-0.368738	0.383049
CC - SC	0.246848	0.383049
CC - SE	0.307878	0.457832
CC - SW	*-0.609138	0.383049
CE - CW	0.112181	0.383049
CE - NC	*0.543480	0.457832
CE - NE	*0.898930	0.457832
CE - NW	0.112266	0.383049
CE - SC	*0.727852	0.383049
CE - SE	*0.788882	0.457832
CE - SW	-0.128134	0.383049
CW - NC	0.431299	0.434337
CW - NE	*0.786749	0.434337
CW - NW	0.000085	0.354635
CW - SC	*0.615671	0.354635
CW - SE	*0.676701	0.434337
CW - SW	-0.240315	0.354635
NC - NE	0.355451	0.501529
NC - NW	-0.431214	0.434337
NC - SC	0.184373	0.434337
NC - SE	0.245402	0.501529
NC - SW	*-0.671614	0.434337
NE - NW	*-0.786665	0.434337
NE - SC	-0.171078	0.434337
NE - SE	-0.110048	0.501529
NE - SW	*-1.027060	0.434337
NW - SC	*0.615587	0.354635
NW - SE	*0.676616	0.434337
NW - SW	-0.240400	0.354635
SC - SE	0.061030	0.434337
SC - SW	*-0.855987	0.354635
SE - SW	*-0.917016	0.434337

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* denotes a statistically significant difference at the $\alpha = 0.05$ level.

Table 6. Multiple Comparisons for juveniles age 1+ CPUE by region

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Method: 95.0 percent LSD

Region	Count	LS Mean	Homogeneous Groups

SE	20	0.131914	X				
SC	40	0.245365	X	X			
NE	20	0.565101	X	X	X		
NC	20	0.667077		X	X		
SW	40	0.707121			X		
CC	30	0.943697			X	X	
NW	40	1.146800				X	X
CW	40	1.284510				X	X
CE	30	1.432350					X

Contrast	Difference	+/- Limits
CC - CE	*-0.488658	0.421651
CC - CW	-0.340811	0.394418
CC - NC	0.276620	0.471420
CC - NE	0.378596	0.471420
CC - NW	-0.203102	0.394418
CC - SC	*0.698332	0.394418
CC - SE	*0.811783	0.471420
CC - SW	0.236576	0.394418
CE - CW	0.147847	0.394418
CE - NC	*0.765278	0.471420
CE - NE	*0.867254	0.471420
CE - NW	0.285555	0.394418
CE - SC	*1.186990	0.394418
CE - SE	*1.300440	0.471420
CE - SW	*0.725234	0.394418
CW - NC	*0.617431	0.447228
CW - NE	*0.719407	0.447228
CW - NW	0.137709	0.365160
CW - SC	*1.039140	0.365160
CW - SE	*1.152590	0.447228
CW - SW	*0.577387	0.365160
NC - NE	0.101976	0.516414
NC - NW	*-0.479722	0.447228
NC - SC	0.421712	0.447228
NC - SE	*0.535163	0.516414
NC - SW	-0.040044	0.447228
NE - NW	*-0.581698	0.447228
NE - SC	0.319736	0.447228
NE - SE	0.433187	0.516414
NE - SW	-0.142020	0.447228
NW - SC	*0.901435	0.365160
NW - SE	*1.014890	0.447228
NW - SW	*0.439678	0.365160
SC - SE	0.113450	0.447228
SC - SW	*-0.461756	0.365160
SE - SW	*-0.575207	0.447228

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* denotes a statistically significant difference at the $\alpha = 0.05$ level.

Table 7. Results of the stepwise procedure for development of the catch rate model for juvenile age 1+ sandbar sharks captured by longline in Delaware Bay. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model. L is the log likelihood.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	279	384.4973	1.3781					
REGION	271	318.0197	1.1735	14.8465	14.8465	-159.0099	66.48	<.0001
YEAR	275	373.5627	1.3584	1.4295		-186.7813	10.93	0.0273
MONTH	278	379.7936	1.3662	0.8635		-189.8968	4.70	0.0301
DEPTH	246	381.0803	1.3807	-0.1887		-190.5401	3.42	0.3317
REGION +								
YEAR	267	303.8540	1.1380	17.4225	2.5760	-151.9270	14.17	0.0068
MONTH	270	311.9419	1.1553	16.1672		-155.9710	6.08	0.0137
DEPTH	268	310.1205	1.1572	16.0293		-155.0603	7.90	0.0481
REGION + YEAR +								
MONTH	266	297.4271	1.1181	18.8666	1.4440	-148.7135	6.43	0.0112
DEPTH	264	295.4705	1.1192	18.7867		-147.7352	8.38	0.0387
REGION + YEAR + MONTH +								
DEPTH	263	288.8211	1.0982	20.3106	1.4440	-144.4106	8.61	0.0350

FINAL MODEL: REGION + YEAR + MONTH + DEPTH

Akaike's information criterion	-656.9
Schwartz's Bayesian criterion	-658.7
(-2) Res Log likelihood	1311.8

Type 3 Test of Fixed Effects

	REGION	YEAR	MONTH	DEPTH
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0098	0.0132	0.0485
DF	8	4	1	3
CHI SQUARE	53.62	13.32	6.14	7.88

Table 7. continued

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	155	1051.4106	6.7833					
REGION	147	961.8941	6.5435	3.5352	3.5352	1611.1794	89.52	<.0001
MONTH	154	1017.9457	6.6100	2.5548		1583.1536	33.46	<.0001
YEAR	151	1005.4245	6.6584	1.8413		1589.4142	45.99	<.0001
DEPTH	152	1029.8094	6.7751	0.1209		1577.2218	21.60	<.0001
REGION +								
MONTH	146	919.3252	6.2967	7.1735	3.6383	1632.4639	42.57	<.0001
YEAR	143	915.6459	6.4031	5.6049		1634.3035	46.25	<.0001
DEPTH	144	935.4449	6.4961	4.2339		1624.4040	26.45	<.0001
REGION + MONTH +								
YEAR	142	867.3226	6.1079	9.9568	2.7833	1658.4652	52.00	<.0001
DEPTH	143	895.5579	6.2626	7.6762		1644.3475	23.77	<.0001
REGION + MONTH + YEAR +								
DEPTH	139	840.1780	6.0444	10.8929	0.9361	1672.0375	27.14	<.0001

FINAL MODEL: REGION + MONTH + YEAR

Akaike's information criterion	-213.3
Schwartz's Bayesian criterion	-214.8
(-2) Res Log likelihood	424.7

	Type 3 Test of Fixed Effects		
Significance (Pr>Chi) of Type 3	REGION	MONTH	YEAR
test of fixed effects for each factor	0.2120	0.0103	0.1392
DF	8	1	4
CHI SQUARE	10.82	6.58	6.94

Table 8. Results of the stepwise procedure for development of the catch rate model for juvenile age 1+ sandbar sharks captured by longline in Delaware Bay. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model. L is the log likelihood.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	279	335.0310	1.2008					
REGION	271	283.9705	1.0479	12.7332	12.7332	-141.9852	51.06	<.0001
DEPTH	276	318.8817	1.1554	3.7808		-159.4409	16.15	0.0011
MONTH	278	333.9095	1.2011	-0.0250		-166.9548	1.12	0.2896
YEAR	275	332.5254	1.2092	-0.6995		-166.2627	2.51	0.6436
REGION +								
DEPTH	268	265.3797	0.9902	17.5383	4.8051	-132.6899	18.59	0.0003
MONTH	270	282.6402	1.0468	12.8248		-141.3201	1.33	0.2488
YEAR	267	281.0114	1.0525	12.3501		-140.5057	2.96	0.5647
REGION + DEPTH +								
MONTH	267	263.9284	0.9885	17.6799	0.1416	-131.9642	1.45	0.2283
YEAR	264	262.1502	0.9930	17.3051		-131.0751	3.23	0.5202

FINAL MODEL: REGION + DEPTH +YEAR

Akaike's information criterion	-631.6
Schwartz's Bayesian criterion	-633.4
(-2) Res Log likelihood	1261.2

Type 3 Test of Fixed Effects

	REGION	DEPTH	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	0.0004	0.0019	0.6139
DF	7	3	4
CHI SQUARE	26.74	14.85	2.67

Table 8. continued

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	79	446.8032	5.6557					
MONTH	78	414.8781	5.3190	5.9533	5.9533	540.6589	31.93	<.0001
YEAR	75	404.3049	5.3907	4.6855		545.9456	42.50	<.0001
DEPTH	76	431.9978	5.6842	-0.5039		532.0991	14.81	0.0020
REGION	72	418.9046	5.8181	-2.8714		538.6457	27.90	0.0002
MONTH +								
YEAR	74	361.5859	4.8863	13.6040	7.6507	567.3051	53.29	<.0001
DEPTH	75	402.7684	5.3409	5.3702		546.7138	12.11	0.0070
REGION	71	394.4080	5.5550	1.7805		550.8940	20.47	0.0046
MONTH + YEAR +								
DEPTH	71	349.2123	4.9185	13.0346	-0.5693	573.4918	12.37	0.0062
REGION	67	337.2981	5.0343	10.9871		579.4489	24.29	0.0010

FINAL MODEL: MONTH +YEAR

Akaike's information criterion	-108.4
Schwartz's Bayesian criterion	-109.5
(-2) Res Log likelihood	214.8

	Type 3 Test of Fixed Effects	
Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	0.0064	0.0520
DF	1	4
CHI SQUARE	7.43	9.39

Table 9. Results of the stepwise procedure for development of the catch rate model for juvenile age 1+ sandbar sharks captured by longline in Delaware Bay. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model. L is the log likelihood.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	279	388.1481	1.3912					
REGION	271	330.2025	1.2185	12.4137	12.4137	-165.1013	57.95	<.0001
YEAR	275	371.5907	1.3512	2.8752		-185.7953	16.56	0.0024
MONTH	278	382.9748	1.3776	0.9776		-191.4874	5.17	0.0229
DEPTH	276	385.9555	1.3984	-0.5175		-192.9777	2.19	0.5334
REGION +								
YEAR	267	309.4712	1.1591	16.6834	4.2697	-154.7356	20.73	0.0004
MONTH	270	323.7675	1.1991	13.8082		-161.8837	6.44	0.0112
DEPTH	268	326.4885	1.2182	12.4353		-163.2442	3.71	0.2940
REGION + YEAR +								
MONTH	266	302.4983	1.1372	18.2576	1.5742	-151.2491	6.97	0.0083
DEPTH	264	305.4384	1.1570	16.8344		-152.7192	4.03	0.2579
REGION + YEAR + MONTH +								
DEPTH	263	298.3500	1.1344	18.4589	0.2013	-149.1750	4.15	0.2459

FINAL MODEL: REGION + YEAR + MONTH

Akaike's information criterion	-644.7
Schwartz's Bayesian criterion	-646.5
(-2) Res Log likelihood	1287.3

	Type 3 Test of Fixed Effects		
Significance (Pr>Chi) of Type 3	REGION	YEAR	MONTH
test of fixed effects for each factor	<.0001	0.0011	0.0100
DF	8	4	1
CHI SQUARE	47.19	18.25	6.64

Table 9. continued

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	138	422.6032	3.0623					
REGION	130	377.7529	2.9058	5.1105	5.1105	608.6143	44.85	<.0001
YEAR	134	406.3083	3.0322	0.9829		594.3366	16.29	0.0026
MONTH	137	416.5225	3.0403	0.7184		589.2295	6.08	0.0137
DEPTH	135	420.0294	3.1113	-1.6001		587.4760	2.57	0.4621
REGION +								
MONTH	129	366.6402	2.8422	7.1874	2.0769	614.1706	11.11	0.0009
YEAR	126	366.4676	2.9085	5.0224		614.2569	11.29	0.0235
DEPTH	127	377.2158	2.9702	3.0075		608.8828	0.54	0.9107
REGION + MONTH +								
YEAR	125	354.5915	2.8367	7.3670	0.1796	620.1950	12.05	0.0170
DEPTH	126	366.2780	2.9070	5.0714		614.3517	0.36	0.9479

FINAL MODEL: REGION + MONTH + YEAR

Akaike's information criterion	-166.1
Schwartz's Bayesian criterion	-167.5
(-2) Res Log likelihood	330.2

	Type 3 Test of Fixed Effects		
Significance (Pr>Chi) of Type 3	REGION	MONTH	YEAR
test of fixed effects for each factor	0.1405	0.0610	0.4738
DF	8	1	4
CHI SQUARE	12.25	3.51	3.53

Table 10. Lo et al. method relative (index/mean) standardized abundance indices for juvenile sandbar sharks in Delaware Bay from 2001-2005. CV = coefficient of variation, N = the number of sets observed.

Total juvenile sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	0.950	0.569	1.331	0.205	56
2002	0.386	0.134	0.637	0.332	56
2003	1.409	0.906	1.912	0.182	56
2004	1.070	0.626	1.514	0.212	56
2005	1.185	0.693	1.678	0.212	56

YOY sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	0.645	0.174	1.117	0.373	56
2002	0.518	0.069	0.968	0.442	56
2003	1.776	0.829	2.724	0.272	56
2004	0.877	0.264	1.490	0.357	56
2005	1.183	0.463	1.903	0.311	56

Juvenile age 1+ sandbar sharks

YEAR	REL INDEX	LCL	UCL	CV	N
2001	1.162	0.744	1.581	0.184	56
2002	0.325	0.085	0.565	0.377	56
2003	1.163	0.722	1.605	0.194	56
2004	1.164	0.691	1.638	0.207	56
2005	1.185	0.722	1.648	0.199	56

Figure 1: Bathymetric map of Delaware Bay showing the nine geographic regions and the four depth strata used during this study

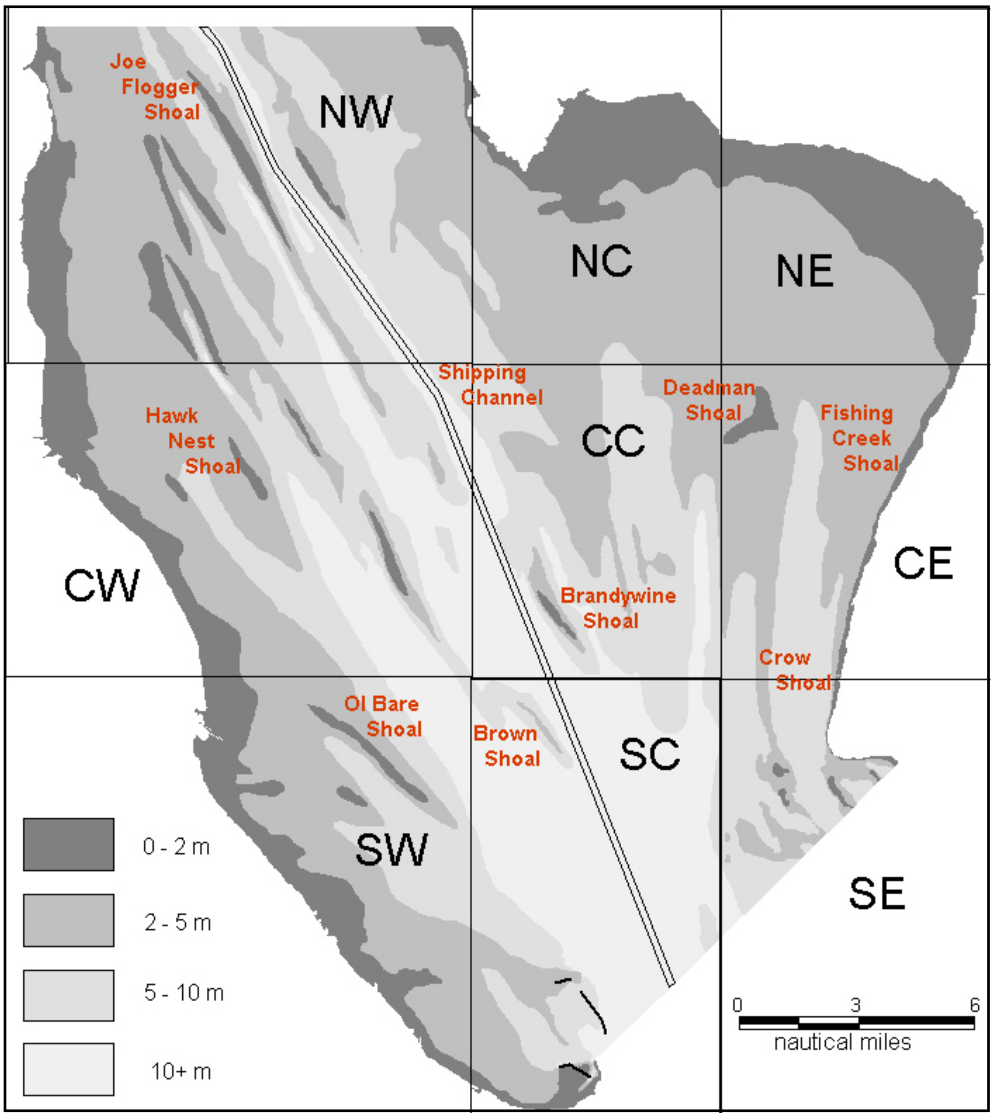

Figure 2: Relative (index/mean) indices of abundance by year for total juvenile sandbar sharks in Delaware Bay from 2001-2005

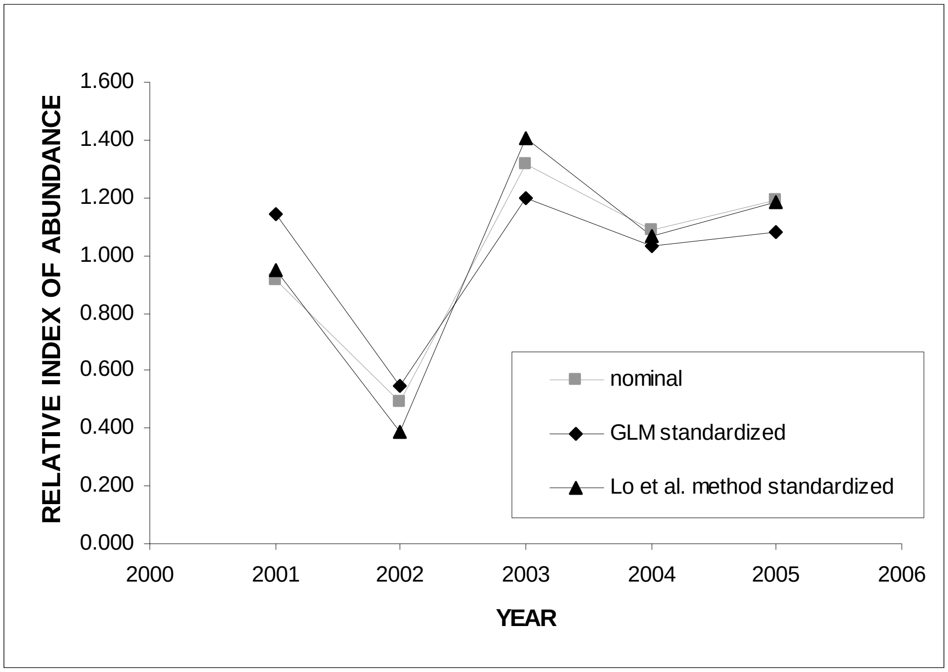

Figure 3: Relative (index/mean) indices of abundance by year for YOY sandbar sharks in Delaware Bay from 2001-2005

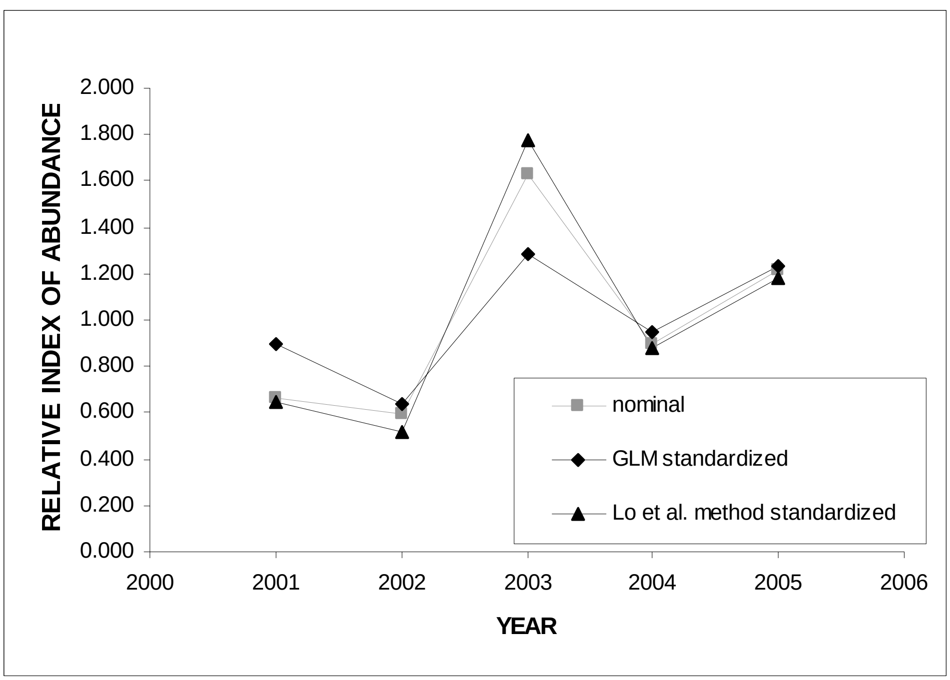

Figure 4: Relative (index/mean) indices of abundance by year for juvenile age 1+ sandbar sharks in Delaware Bay from 2001-2005