The Directed Shark Drift Gillnet Fishery: Characterization of the Small Coastal Shark Catch, Average Size and Standardization of Catch Rates from Observer Data.

John Carlson, Dana Bethea and Ivy Baremore
NOAA/National Marine Fisheries Service, Southeast Fisheries Science Center, 3500 Delwood Beach Road, Panama City, FL 32408

Introduction

The shark drift gillnet fishery developed off the east coast of Florida and Georgia in the late 1980's. Historically, a number of the involved vessels in this fishery strike netted and drift netted for king mackerel, *Scomberomorus cavalla*, Spanish mackerel, *S. maculatus*, bluefish, *Pomotomus saltatrix*, and occasionally for sharks, from November through March. As this fishery developed, some fishers drift gillnetted for sharks from October through April before and after the mackerel seasons (Schaefer et al. 1989). By 1987, many fishers were drift gillnetting for king mackerel during April-September to compensate for their reduction in quotas in their winter fisheries. However, as the king mackerel drift gillnet fishery was further restricted in about 1990, more fishers began drift gillnetting for sharks during all times of the year.

I. Fishery description

Vessels, fishing gear, and fishing techniques have been previously described in Trent et al. (1997). Generally, shark driftnet vessels operate between 4.8 and 14.4 km from shore in areas north of Key West, FL (~24° 37-24° 58' N) and between West Palm Beach, FL (~26° 46'N) and Altamaha Sound, GA (~31° 45' N) (Figure 1). Vessels fish gillnets (both multi and monofilament) ranging in length from 547.2-2,736 m; depths from 9.1-13.7 m and stretched mesh sizes from 12.7-25.4 cm (Trent et al. 1997; Carlson et al. 2005 and references therein). Nets are normally set in a straight line off the stern at night, allowed to drift at the surface for a period of time and then hauled onto the vessel when the catch is adequate. The number of drift gillnet vessels has decreased from about 12 in 1990 to about 6, depending on the market value of sharks and the level of activity in other fisheries.

Shark drift gillnet fisheries are multi-specific and land up to 14 different species of sharks. Depending on season and area, small coastal species are targeted. Data for this fishery was summarized for small coastal species for 1993-1995 and 1998-2005 from that reported in Trent et al. (1997) and Carlson et al. (2005 and references therein).

Information on this fishery was collected using on-board NMFS-approved contract observers. The observer normally left port with the vessel between 1500-1700 hrs; depending on distance to the fishing grounds. Trips are normally 1-3 days in duration. For each set and haul of the net observers recorded: beginning and ending times of setting and hauling; estimated length of net set; latitude and longitude coordinates; and water depth. During haul back, the observer remained about 3-8 m forward of the net reel in an unobstructed view and recorded species, numbers and estimated lengths (±30 cm) of sharks and other species caught as they were suspended in the net just after passing over the power roller.

Estimation of average size

It is difficult to correctly measure all shark catches because generally observers have additional duties while onboard fishing vessels. However, when the haul back is complete observers sometimes have the opportunity to measure sharks when the vessel is returning to port. Sharks were randomly sampled from the entire catch (by set) and measured in fork length (straight line, cm). Weights (in kg) were estimated from these lengths using length-weight relationships provided by Carlson (unpublished data).

Catch rates analysis

A combined data set was developed based on observer programs from Trent el al. (1997) and Carlson et al. (2005 and references therein). Catch rates were standardized in a two-part generalized linear model analysis using the PROC GENMOD procedure in SAS (SAS Inst., Inc.). For the purposes of analysis, several categorical variables were constructed:
-"Year" (10 levels)= 1993-1995, 1998-2005
- "Area" (4 levels)=location of net set (Figure 1).
South Florida=South of 27°51' N Latitude
Central Florida=27°51' N to 30°00' N Latitude
N. Florida/Georgia=North of 30°00' N Latitude
Florida Keys=areas northwest of KeyWest, FL
- "SetBegin" (4 levels)
Dawn=0401-1000 hrs
Day=1001-1600 hrs
Dusk=1601-2200 hrs
Night=2201-0400 hrs
-"Vessel" (10 levels): Specific to a vessel's identification number.
-"Season" (4 levels): corresponds to the level of observer coverage as it pertains to the right whale calving season and the large coastal shark season.
Rightwhale1=Jan-Mar
Nonrightwhale1=Apr-Jun
Nonrightwhale2=Jul-Sep
Rightwhale2=Oct-Dec
-"Meshsize" (3 levels): corresponds to the principal mesh size used in the fishing gear. Small mesh=4"-6" stretched mesh Medium mesh=7"-9" stretched mesh Large mesh=>10" stretched mesh.

The proportion of sets that caught sharks (when at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. The positive catches were modeled assuming a lognormal distribution with a normal link function. Positive catches were modeled using a dependent variable of the log of catch per unit effort (CPUE): sharks kept+sharks released/net length*net depth*soak time.

Initially, a null model was run with no factors entered into the model. Models were then fit in a stepwise forward manner adding one independent variable. Each factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant at $p<0.05$ based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. Regardless of its level of significance, year was kept in all final models. After selecting the set of fixed factors and interactions for each error distribution, all interactions that included the factor year were treated as random interactions (Ortiz and Arocha, 2004). This process converted the basic models from generalized linear models into generalized linear mixed models. The final model determination was evaluated using the Akaike Information Criteria (AIC), and Schwarz's Bayesian Criterion (BIC). Models with smaller AIC and BIC values are preferred to those with larger values. These models were fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute Inc.) and the MIXED procedure in SAS statistical computer software (PROC GLIMMIX). Relative indices of abundance were calculated as the product of the year effect least square means from the two independent models. The standard error of the combined index was estimated with the delta method (Appendix 1 in Lo et al., 1992).

Results and Discussion

Catch

Small coastal sharks dominated the shark catch (by number) for all years since 1998, with the exception of 2000 (Figure 2). In some years, small coastal sharks made up to 95% of the total shark catch. Within the small coastal catch, Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, was the most abundant species caught in most years (Table 1). The second most abundant species varied depending on the year and included bonnethead, *Sphyrna tiburo*, finetooth, *Carcharhinus isodon*, and blacknose shark, *C. acronotus*.

Average size

Average sizes, standard deviation, and number of sharks measured of small coastal sharks caught in the drift gillnet fishery are in Table 2. Length frequency histograms of all sharks measured by species are in Figure 3.

Catch rates

For Atlantic sharpnose shark, the percentage of sets with zero catches was 34.6%. The stepwise construction of the models is summarized in Table 3.
The final binomial model was:
Proportion positive trips = YEAR + SEASON + MESH.
The final lognormal model was:
ln(CPUE) = YEAR + SEASON + VESSEL.
The final mixed models were:
YEAR+SEASON+MESH for the proportion positive, and
YEAR+SEASON+VESSEL YEAR*VESSEL for the positive catch model.
The delta-lognormal abundance index is shown in Figure 4. To allow for visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 8. Due to an error in estimation within the mixed model, a standardized index for 1998 could not be determined.

The percentage of sets with zero catches was 36.3% for blacknose shark. The stepwise construction of the models is summarized in Table 4.
The final binomial model was:
Proportion positive trips = YEAR + AREA.
The final lognormal model was:
ln(CPUE) = YEAR + AREA + VESSEL.

The final mixed models were:

YEAR+AREA YEAR*AREA for the proportion positive, and

YEAR + AREA + VESSEL YEAR*AREA for the positive catch model.

The delta-lognormal abundance index is shown in Figure 4. The index statistics can be found in Table 8.

For bonnetheads, the percentage of sets with zero catches was 44.6%. The stepwise construction of the models is summarized in Table 5.

The final binomial model was:

Proportion positive trips= YEAR + AREA + SEASON.

The final lognormal model was:

ln(CPUE) = YEAR+AREA+VESSEL.

The final mixed models were:

YEAR + AREA + SEASON for the proportion positive, and

YEAR+AREA+VESSEL YEAR*VESSEL for the positive catch model.

The delta-lognormal abundance index is shown in Figure 4. The index statistics can be found in Table 8. Due to an error in estimation within the mixed model, a standardized index for 1993 could not be determined.

The percentage of sets with zero catches was 59.4% for finetooth shark. The stepwise construction of the models is summarized in Table 6.

The final binomial model was:

Proportion positive trips= YEAR + AREA + SEASON + MESH.

The final lognormal model was:

ln(CPUE) =YEAR + VESSEL + AREA.

The final mixed models were:

YEAR+AREA+SEASON+MESH YEAR*SEASON for the proportion positive, and

YEAR+VESSEL+AREA YEAR*AREA for the positive catch model.

The delta-lognormal abundance index is shown in Figure 4. The index statistics can be found in Table 8.

We were unable to run the delta-lognormal model for the small coastal aggregate. Initial runs resulted in the final Hessian not positive definite when year was introduced as a factor in the binomial model. As the proportion of positive trips for the small coastal shark complex was high (92.7%), a single generalized linear model was performed on the natural logarithm of catch per unit effort with the addition of a standard value (0.1) to account for zero values. The same factors were considered and criteria for elimination was utilized, as previously outlined. The stepwise construction of the models is summarized in Table 7.

The final lognormal model was:

ln(CPUE+0.1) = YEAR+AREA+SEASON YEAR*AREA. The index statistics can be found in Table 8. The lognormal abundance index is shown in Figure 5.

Diagnostic plots assessing the fit of the lognormal models were deemed acceptable. The frequency distribution of the natural logarithm of CPUE and residuals approximated a normal distribution. When plotted by year, the residuals were distributed evenly around zero. The quantile-quantile plot of the data from all models tended to fall along the reference line indicating the data are from a normal distribution. In summary, all diagnostic plots met assumptions, and supported an acceptable fit to the selected models.

References

Carlson, J. K., I.E. Baremore, and D.M. Bethea. 2005. The Directed Shark Gillnet Fishery: Catch and Bycatch, 2004. SFD Contribution PCB-05-01.

Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515:2526.

Ortiz, M., and F. Arocha. 2004. Alternative error distribution models for standardization of catch rates of non-target species from a pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery. Fisheries Research 70, 275–294.

Schaefer, H.C., L.E. Barger, and H.E. Kumpf. 1989. The driftnet fishery in the Fort Pierce-Port Salerno area off southeast Florida. Mar. Fish. Rev. 51(1):44-49.

Trent, L., D.E. Parshley and J.K. Carlson. 1997. Catch and bycatch in the shark drift gillnet fishery off Georgia and east Florida. Mar. Fish. Rev. 59(1):19-28.

Table 1. Proportions of individual species within the total small coastal shark catch by year.

1998-1999

	Percent contribution
Atlantic sharpnose	74.4
Blacknose	13.7
Bonnethead	8.9
Finetooth	3.0

2000

	Percent contribution
Atlantic sharpnose	1.3
Blacknose	3.6
Bonnethead	47.0
Finetooth	48.2

2001

	Percent contribution
Atlantic sharpnose	40.7
Blacknose	3.8
Bonnethead	50.5
Finetooth	5.0

2002

	Percent contribution
Atlantic sharpnose	66.2
Blacknose	17.2
Bonnethead	5.1
Finetooth	11.6

2003

	Percent contribution
Atlantic sharpnose	81.3
Blacknose	9.4
Bonnethead	2.0
Finetooth	7.3

2004

	Percent contribution
Atlantic sharpnose	76.9
Blacknose	20.2
Bonnethead	1.4
Finetooth	1.5

2005

	Percent contribution
Atlantic sharpnose	87.9
Blacknose	3.5
Bonnethead	4.9
Finetooth	3.6

Table 2. Average fork length (cm) and estimated weight (kg) of small coastal sharks by species and year.

Atlantic sharpnose shark

Year	Mean	Std. Dev.	n	Estimated weight (kg)
2001	75.5	6.0	40	2.1
2002	77.2	7.3	104	2.2
2003	78.6	5.7	178	2.3
2004	79.2	6.3	216	2.4
2005	76.3	8.0	343	2.2

Blacknose

Year	Mean	Std. Dev.	n	Estimated weight (kg)
2001	101.0	7.5	10	6.88
2002	101.8	6.0	10	7.06
2003	104.6	8.9	10	7.71
2004	102.2	9.8	23	7.14
2005	54.5	3.5	2	0.94

Bonnethead

Year	Mean	Std. Dev.	n	Estimated weight (kg)
2000	63.7	8.4	25	1.37
2001	92.0	4.2	2	3.46
2002	78.0		3	2.28
2003	68.0	10.2	25	1.61
2004				
2005	79.5	8.7	10	2.39

Finetooth

Year	Mean	Std. Dev.	n	Estimated weight (kg)
2000	76.0	19.7	9	2.24
2001	109.0	14.1	10	6.71
2002	107.8	14.7	59	6.48
2003	-	-	-	-
2004	116.5	3.8	8	8.21
2005	130.8	8.8	6	11.67

Table 3. 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 Atlantic sharpnose sharks.

Proportion positive-Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	411	530.721	1.291				
SEASON	408	403.939	0.990	23.329	23.329	126.78	<.0001
YEAR	401	402.840	1.005	22.203		127.88	<.0001
AREA	408	412.122	1.010	21.776		118.60	<.0001
MESH	409	444.901	1.088	15.760		85.82	<.0001
VESSEL	402	449.161	1.117	13.473		Negative of Hessian not positive definite.	
SETBEGIN	408	518.236	1.270	1.634		12.48	0.0059
SEASON +							
AREA	405	314.039	0.775	39.951		Negative of Hessian not positive definite.	
YEAR	398	327.338	0.822	36.307	14.105	76.60	<.0001
MESH	406	342.670	0.844	34.638		61.27	<.0001
SEASON + YEAR							
MESH	396	298.209	0.753	41.682	5.375	29.13	<.0001
FINAL GENMOD							
YEAR + SEASON + MESH	395	298.199	0.755	41.536		29.11	<.0001
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR+SEASON+MESH	2199.5	2203.4	2197.5				
YEAR+SEASON+MESH YEAR*SEASON	2334.0	2336.6	2330.0				
YEAR+SEASON+MESH YEAR*MESH	2444.8	2447.4	2440.8				

Table 3 continued.

Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	268	1082.579	4.039				
SEASON	265	829.383	3.130	22.521	22.521	71.67	<.0001
AREA	265	839.889	3.169	21.539		68.28	<.0001
VESSEL	259	852.662	3.292	18.501		64.22	<.0001
YEAR	258	864.371	3.350	17.062		60.55	<.0001
MESH	266	984.789	3.702	8.349		25.47	<.0001
SETBEGIN	265	1056.452	3.987	1.309		6.57	0.0869
SEASON +							
VESSEL	256	681.819	2.663	34.067	11.546	52.70	<.0001
AREA	262	726.531	2.773	31.352		35.62	<.0001
YEAR	255	707.774	2.776	31.288		42.65	<.0001
MESH	263	759.804	2.889	28.481		23.57	<.0001
SEASON + VESSEL							
YEAR	246	584.004	2.374	41.230	7.163	41.66	<.0001
AREA	253	656.065	2.593	35.805		10.36	0.0158
MESH	254	662.138	2.607	35.466		7.88	0.0195
SEASON + VESSEL + YEAR							
AREA	243	566.719	2.332	42.265	1.035	8.08	0.0444
MESH	244	572.955	2.348	41.869		5.14	0.0766
FINAL GENMOD							
YEAR + SEASON + VESSEL	246	584.004	2.374	41.230		51.71	<.0001
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR+SEASON+VESSEL	971.6	975.1	969.6				
YEAR+SEASON+VESSEL YEAR*SEASON	971.1	973.6	967.1				
YEAR+SEASON+VESSEL YEAR*VESSEL	963.1	966.9	959.1				

Table 4. 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 blacknose sharks.

Proportion positive-Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	410	538.295	1.313				
AREA	407	472.326	1.161	11.608	11.608	65.970	<.0001
VESSEL	401	494.177	1.232	6.135		44.120	<.0001
SEASON	407	509.457	1.252	4.660		28.840	<.0001
YEAR	400	517.157	1.293	1.525		21.140	0.020
MESH	408	533.025	1.306	0.494		5.270	0.072
SETBEGIN	407	536.013	1.317	-0.310		2.280	0.516
AREA+							
VESSEL	398	457.578	1.150	12.432	0.824	14.750	0.098
YEAR	397	457.554	1.153	12.216		14.770	0.141
SEASON	404	467.731	1.158	11.818		4.590	0.204
YEAR + AREA	397	457.554	1.153	12.216	-0.216	59.600	<.0001
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR + AREA	1936.8	1940.8	1934.8				
YEAR + AREA YEAR*AREA	**1931.7**	**1934.5**	**1927.7**				

Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	261	1380.695	5.290				
AREA	258	732.943	2.841	46.298	46.298	165.920	<.0001
VESSEL	252	777.433	3.085	41.682		150.480	<.0001
MESH	259	1076.892	4.158	21.401		65.110	<.0001
YEAR	251	1213.955	4.836	8.574		33.720	0.000
SEASON	258	1358.034	5.264	0.498		4.340	0.227
SETBEGIN	258	1360.420	5.273	0.323		3.880	0.275
AREA+							
VESSEL	249	650.317	2.612	50.629	4.332	31.340	0.000
YEAR	248	671.858	2.709	48.788		22.800	0.012
MESH	256	724.535	2.830	46.499		3.020	0.221
YEAR + AREA + VESSEL	239	596.770	2.497	52.799	2.170	31.050	0.000
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR + AREA + VESSEL	955.8	959.2	953.8				
YEAR + AREA + VESSEL YEAR*AREA	**912.6**	**915.3**	**908.6**				
YEAR + AREA + VESSEL YEAR*VESSEL	956.4	960.1	952.4				

Table 5. 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 bonnetheads.

Proportion positive-Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	410.000	564.830	1.378				
AREA	407.000	483.440	1.188	13.779	13.779	81.390	<.0001
VESSEL	401.000	510.192	1.272	7.646		Negative of Hessian not positive definite.	
MESH	408.000	519.793	1.274	7.522		45.040	<.0001
YEAR	400.000	521.830	1.305	5.303		43.000	<.0001
SEASON	407.000	554.535	1.362	1.099		10.300	0.016
SETBEGIN	407.000	559.272	1.374	0.254		5.560	0.135
AREA +							
SEASON	404.000	436.495	1.080	21.573	7.795	46.940	<.0001
YEAR	397.000	446.256	1.124	18.406		37.180	<.0001
MESH	405.000	463.939	1.146	16.848		19.500	<.0001
AREA + SEASON							
YEAR	394.000	415.412	1.054	23.467	1.894	21.080	0.021
MESH	402.000	434.910	1.082	21.469		1.590	0.453
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR AREA SEASON	**1878.6**	**1882.60**	**1876.6**				
YEAR AREA SEASON YEAR*AREA	2178.8	2181.60	2174.8				
YEAR AREA SEASON YEAR*SEASON	2189.7	2192.30	2185.7				

Table 5 continued.

Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	227	896.712	3.950				
AREA	224	778.907	3.477	11.974	11.974	32.110	<.0001
YEAR	217	775.248	3.573	9.561		33.190	0.000
VESSEL	219	804.719	3.675	6.981		24.680	0.002
SEASON	224	862.859	3.852	2.486		8.770	0.033
MESH	225	875.212	3.890	1.530		5.530	0.063
SETBEGIN	224	877.812	3.919	0.797		4.860	0.183
AREA +							
YEAR	214	652.016	3.047	22.871	10.897	40.540	<.0001
VESSEL	216	695.906	3.222	18.441		25.690	0.001
SEASON	221	721.372	3.264	17.370		17.500	0.001
AREA + YEAR							
VESSEL	206	589.779	2.863	27.524	4.653	22.870	0.004
SEASON	211	625.276	2.963	24.983		9.550	0.023
AREA+YEAR+VESSEL							
SEASON	203	573.131	2.823	28.529	1.005	6.530	0.089
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR+AREA+VESSEL	856.4	859.7	854.4				
YEAR+AREA+VESSEL YEAR*AREA	856.6	859.100	852.6				
YEAR+AREA+VESSEL YEAR*VESSEL	**845.1**	**848.6**	**841.1**				

Table 6. 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 finetooth shark.

Proportion positive- Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	410	555.256	1.354				
AREA	407	460.768	1.132	16.405	16.405	94.490	<.0001
MESH	408	488.859	1.198	11.526		66.400	<.0001
VESSEL	401	500.966	1.249	7.752		Negative of Hessian not positive definite.	
YEAR	400	514.954	1.287	4.940	4.940	40.300	<.0001
SEASON	407	532.149	1.307	3.455		23.110	<.0001
SETBEGIN	407	546.229	1.342	0.901		9.030	0.029
AREA +							
SEASON	404	386.464	0.957	29.365	12.960	74.300	<.0001
MESH	405	420.192	1.038	23.390		40.580	<.0001
YEAR	397	425.222	1.071	20.911		35.550	0.000
AREA + SEASON							
YEAR	394	350.840	0.890	34.249	4.884	35.620	<.0001
MESH	402	376.938	0.938	30.764		9.530	0.009
AREA + SEASON + YEAR							
MESH	392.0	339.932	0.867	35.968	1.719	10.910	0.004
YEAR AREA SEASON MESH	392.0	339.932	0.867	35.968	1.719	10.910	0.004
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR AREA SEASON MESH	2176.2	2180.1	2174.2				
YEAR AREA SEASON MESH YEAR*AREA	2188.7	2191.5	2184.7				
YEAR AREA SEASON MESH YEAR*SEASON	**2094.4**	**2097.0**	**2090.4**				
YEAR AREA SEASON MESH YEAR*MESH	2158.3	2160.8	2154.3				

Table 6 continued.

Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	166	765.604	4.612				
VESSEL	160	621.729	3.886	15.747	15.747	34.760	<.0001
AREA	163	652.554	4.003	13.197		26.680	<.0001
SEASON	163	668.021	4.098	11.140		22.770	<.0001
YEAR	156	654.407	4.195	9.045		26.210	0.004
SETBEGIN	163	724.329	4.444	3.650		9.260	0.026
MESH	164	737.576	4.497	2.486		6.230	0.044
VESSEL+							
YEAR	150	521.254	3.475	24.654	8.907	29.440	0.001
AREA	157	563.112	3.587	22.232		16.540	0.001
SEASON	157	593.337	3.779	18.058		7.810	0.050
SETBEGIN	157	594.920	3.789	17.840		7.360	0.061
MESH	158	620.268	3.926	14.881		0.390	0.822
VESSEL+YEAR							
AREA	147	449.468	3.058	33.704		24.740	<.0001
YEAR VESSEL AREA	**147**	**449.468**	3.058	33.704		24.740	<.0001
Mixed Model	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR VESSEL AREA	626.2	629.2	624.2				
YEAR VESSEL AREA YEAR*VESSEL	625.8	622.8	618.8				
YEAR VESSEL AREA YEAR*AREA	**619.5**	**621.5**	**615.5**				

Table 8. Analysis of deviance of explanatory variables a lognormal generalized linear and mixed model formulations of the catch per unit effort [LN(CPUE+0.1)] for small coastal sharks.

Lognormal error distribution (X+0.1)							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	410	12752.586	31.104				
AREA	407	10693.048	26.273	15.532	15.532	72.39	<.0001
SEASON	407	10890.249	26.757	13.974		64.88	<.0001
VESSEL	401	11456.524	28.570	8.147		44.05	<.0001
MESH	408	11759.825	28.823	7.333		33.31	<.0001
YEAR	400	11859.915	29.650	4.675		29.83	0.0009
SETBEGIN	407	12133.759	29.813	4.151		20.44	0.0001
AREA +							
SEASON	404	10262.622	25.403	18.330	2.798	16.89	0.0007
MESH	405	10319.724	25.481	18.078		14.61	0.0007
SETBEGIN	404	10381.086	25.696	17.387		12.17	0.0068
YEAR	397	10251.114	25.821	16.983		17.35	0.0670
VESSEL	398	10449.063	26.254	15.593		9.49	0.3936
AREA+SEASON							
MESH	402	10146.499	25.240	18.852	0.522	4.68	0.0965
SETBEGIN	401	9939.630	24.787	20.309		13.14	0.0043
YEAR	394	9951.516	25.258	18.796		12.65	0.2438
AREA+SEASON+YEAR							
MIXED MODEL	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR+AREA+SEASON	2448.7	2452.7	2446.7				
YEAR+AREA+SEASON YEAR*AREA	**2432.2**	**2434.9**	**2428.2**				
YEAR+AREA+SEASON YEAR*SEASON	2450.0	2452.6	2446.0				

Table 7. The relative standardized index of abundance, and coefficients of variation (CV) for small coastal sharks.

Atlantic sharpnose

Year	Absolute Index	CV
1993	2.064	0.947
1994	5.389	0.28
1995	1.801	1.092
1996		
1997		
1998		
1999	5.619	0.205
2000	1.245	0.506
2001	6.318	0.119
2002	8.112	0.092
2003	7.554	0.283
2004	7.056	0.41
2005	4.684	0.305

Blacknose

Year	Absolute Index	CV
1993	2.602	1.022
1994	5.469	0.343
1995	3.797	0.748
1996		
1997		
1998	7.622	0.362
1999	7.669	0.203
2000	6.354	0.239
2001	4.984	0.244
2002	7.844	0.146
2003	7.916	0.230
2004	7.875	0.213
2005	8.058	0.171

Bonnethead

Year	Absolute Index	CV
1993		
1994	6.425	0.223
1995	2.468	0.820
1996		
1997		
1998	7.175	0.281
1999	8.199	0.131
2000	6.288	0.148
2001	5.202	0.141
2002	6.002	0.155
2003	3.662	0.434
2004	4.010	0.413
2005	8.401	0.144

Finetooth

YEAR	Absolute Index	CV
1993	9.496	0.366
1994	5.251	0.485
1995	1.557	1.223
1996		
1997		
1998	11.182	0.390
1999	5.266	0.378
2000	7.030	0.237
2001	7.110	0.296
2002	3.016	0.570
2003	3.154	0.637
2004	4.007	0.726
2005	9.555	0.141

Small coastal aggregate

	Absolute Index	CV
1993	3.014	0.879
1994	9.942	0.172
1995	10.934	0.218
1996		
1997		
1998	20.516	0.130
1999	12.287	0.109
2000	9.998	0.140
2001	5.548	0.220
2002	72.233	0.016
2003	11.597	0.133
2004	8.254	0.180
2005	58.842	0.029

Figure 1. Distribution of fishing effort in the directed shark gillnet fishery 1993-1995 and 1998-2005. Fishing areas defined for GLM analysis are area 1: Florida Keys; area 2: South Florida; area 3: Central Florida; area 4: North Florida/Georgia.

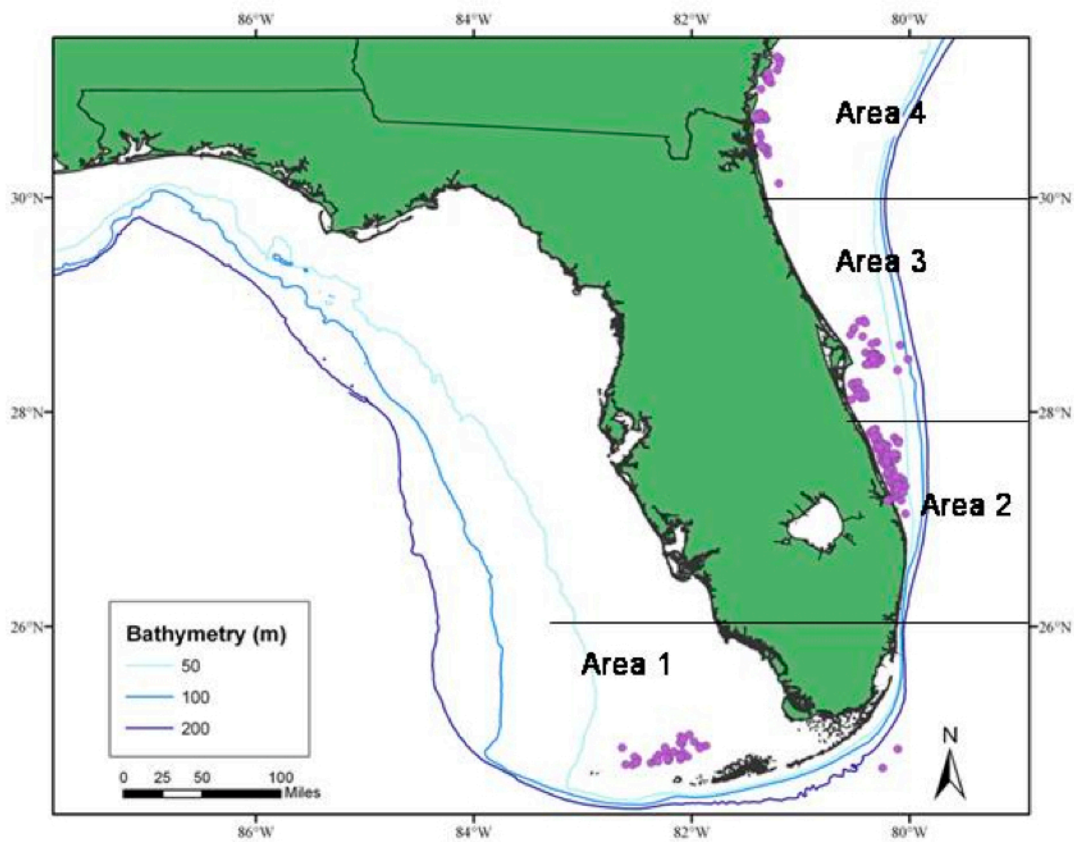


Figure 2. Proportion of small coastal shark catch to overall shark catch by year.

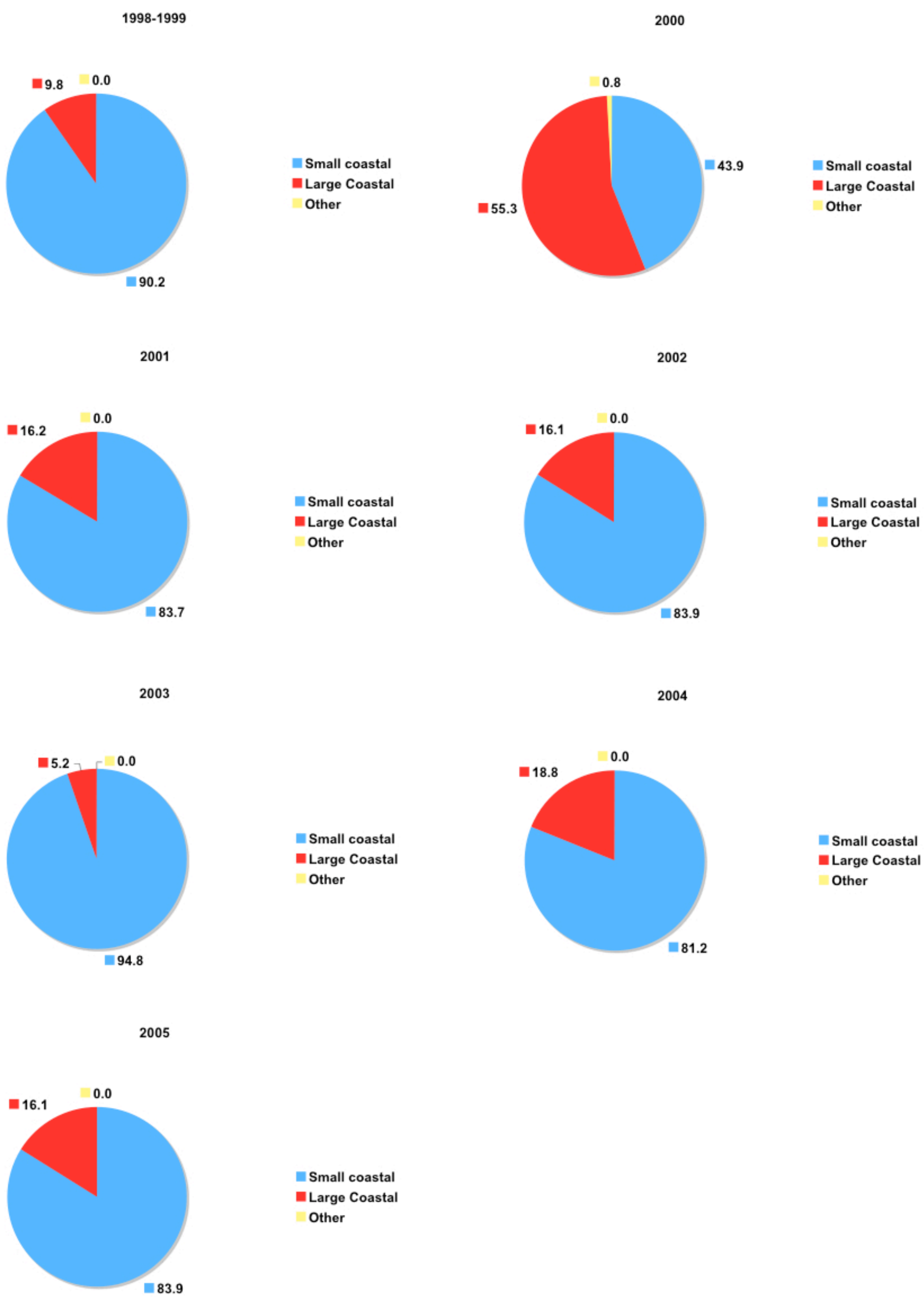


Figure 3. Length-frequency distributions of all small coastal sharks measured by on-board observers.

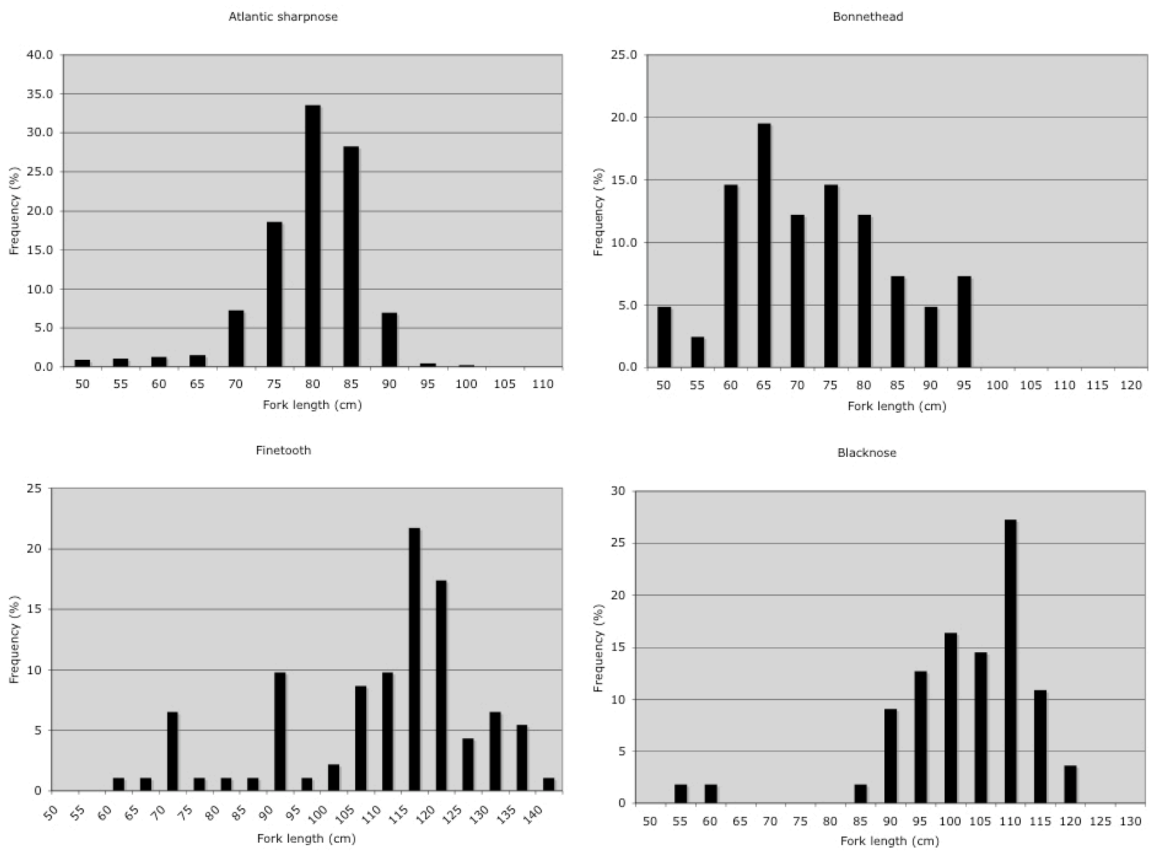


Figure 3. Standardized and nominal catch rates for small coastal sharks by species.

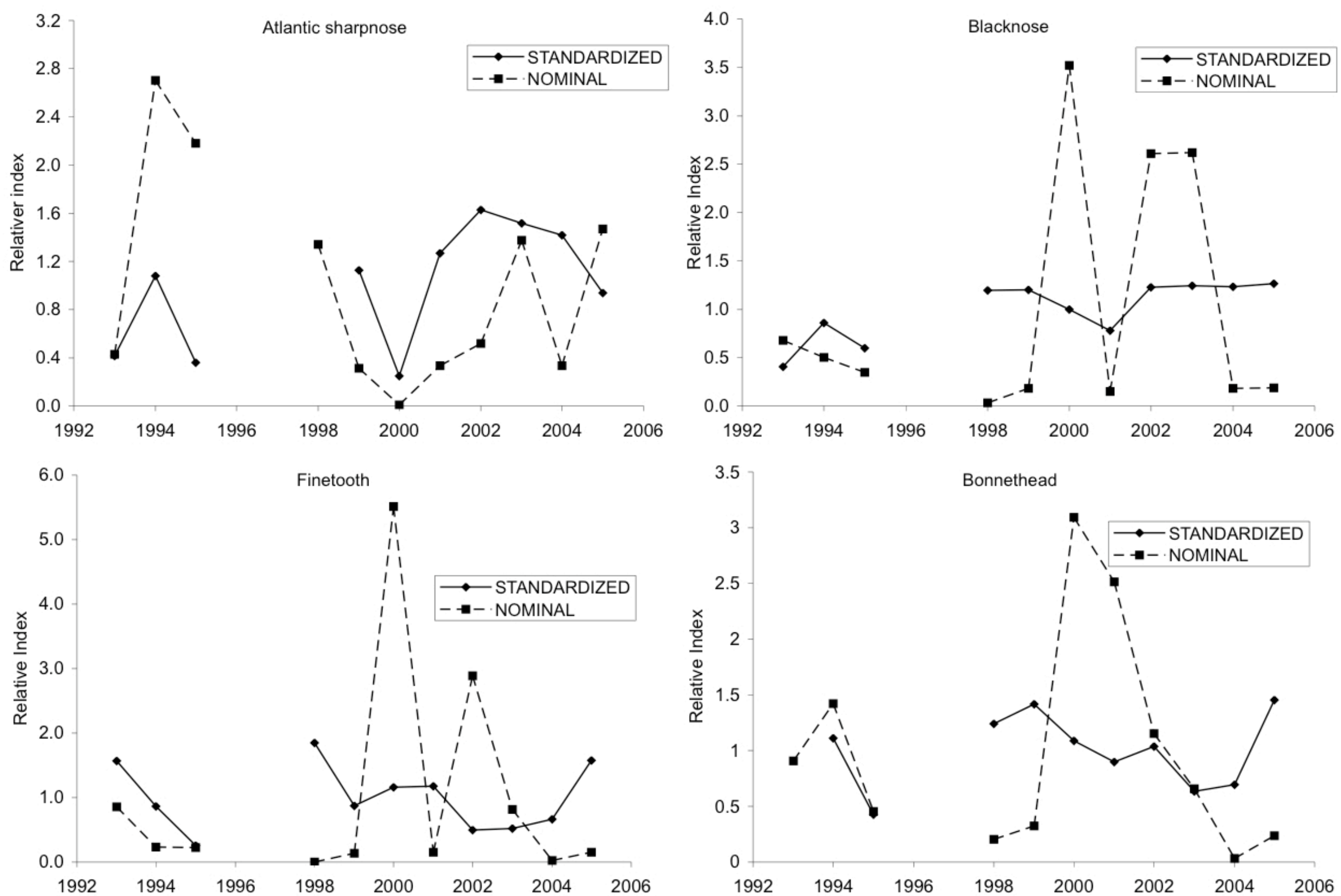
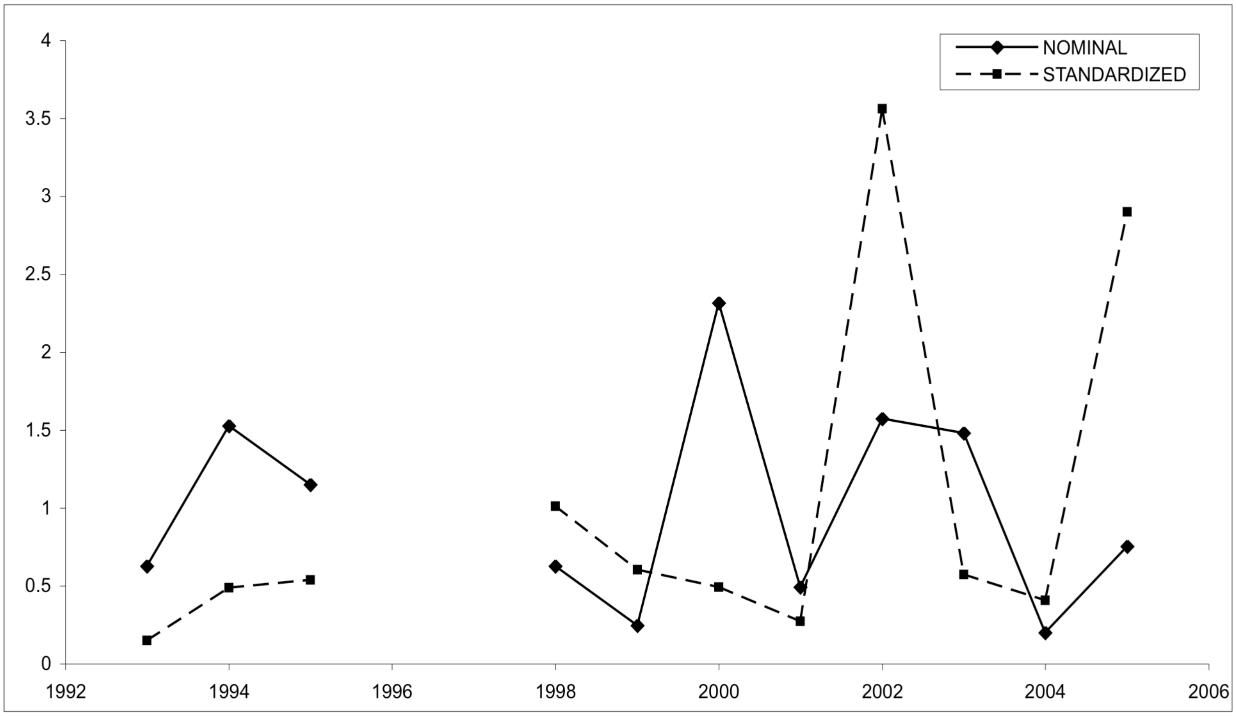


Figure 4. Standardized and nominal catch rates for small coastal sharks aggregate.



ADDENDUM TO SEDAR 13-DW-09
(The Directed Shark Drift Gillnet Fishery: Characterization of the Small Coastal Shark Catch, Average Size and Standardization of Catch Rates from Observer Data**)**

Introduction

Based on discussion at the 2007 Shark SEDAR 13, the present addendum to document **SEDAR 13-DW-09** revises standardized catch rates for all individual small coastal species and provides a new catch rate series for Atlantic sharpnose shark for the Atlantic Ocean stock. There were not enough observations for a Gulf of Mexico index. All analysis followed standardization procedures previously outlined in **SEDAR 13-DW-09** except CPUE is now expressed as the natural logarithm of the number of sharks caught per 10^{-7} net area hours, i.e.:

CPUE=log [(sharks kept+sharks released)/(net length*net depth*soak time/10000000)]

The original estimate of CPUE in **SEDAR 13-DW-09** resulted in negative values of CPUE that caused problems when modeling the mixed procedure. The new estimate of effort allowed for better model convergence. New and revised estimates are listed below:

Table 1. The standardized index of abundance, coefficients of variation (CV), lower (LCI) and upper (UCI) 95% confidence intervals and number of sets observed (N) for small coastal sharks by species and area.

A. Atlantic sharpnose shark, area combined.

YEAR	INDEX	CV	LCI	UCI	N
1993	63.769	1.458	0.008	0.548	5
1994	520.751	0.590	0.177	1.577	39
1995	355.170	1.454	0.043	3.039	7
1996					0
1997					0
1998	*				9
1999	165.327	0.484	0.067	0.420	50
2000	27.340	0.915	0.006	0.132	53
2001	634.326	0.427	0.284	1.461	91
2002	831.673	0.420	0.377	1.890	70
2003	814.365	0.586	0.279	2.450	24
2004	278.853	0.672	0.084	0.960	32
2005	984.790	0.670	0.296	3.382	31

*index could not be computed for 1998 because all observations were positive.

B. Atlantic sharpnose shark, Atlantic Ocean.

YEAR	INDEX	CV	LCI	UCI	N
1993	131.934	1.286	0.010	0.532	5
1994	853.410	0.434	0.208	1.096	39
1995	639.344	1.263	0.051	2.519	7
1996					0
1997					0
1998	*				9
1999	196.219	0.355	0.055	0.218	50
2000	47.828	0.825	0.006	0.113	53
2001	989.642	0.274	0.323	0.948	91
2002	1190.888	0.279	0.385	1.151	70
2003	1496.536	0.404	0.384	1.821	24
2004	403.973	0.446	0.096	0.529	32
2005	1789.160	0.431	0.438	2.285	31

*index could not be computed for 1998 because all observations were positive.

C. Blacknose shark, areas combined.

YEAR	INDEX	CV	LCI	UCI	N
1993	12.832	1.321	0.007	0.381	5
1994	110.912	0.801	0.108	1.802	39
1995	14.734	1.166	0.009	0.374	7
1996					0
1997					0
1998	39.207	0.991	0.030	0.815	9
1999	55.567	0.646	0.068	0.719	50
2000	96.643	0.680	0.112	1.317	53
2001	40.011	0.639	0.049	0.513	91
2002	143.840	0.578	0.195	1.673	70
2003	63.992	0.675	0.075	0.866	24
2004	46.179	0.658	0.055	0.609	32
2005	251.732	0.747	0.264	3.785	31

D. Finetooth shark, areas combined.

YEAR	INDEX	CV	LCI	UCI	N
1993	75.596	1.024	0.015	0.435	5
1994	44.255	0.897	0.010	0.218	39
1995	30.002	1.546	0.003	0.289	7
1996					0
1997					0
1998	0.926	0.999	0.000	0.005	9
1999	44.518	0.764	0.012	0.183	50
2000	945.377	0.707	0.280	3.572	53
2001	68.730	0.718	0.020	0.264	91
2002	77.065	0.888	0.018	0.375	70
2003	57.723	1.096	0.010	0.361	24
2004	8.280	1.115	0.001	0.053	32
2005	370.709	0.766	0.101	1.526	31

E. Bonnethead, areas combined.

YEAR	INDEX	CV	LCI	UCI	N
1993	*				5
1994	196.274	0.619	0.146	1.423	39
1995	12.915	1.359	0.004	0.232	7
1996					0
1997					0
1998	169.757	0.841	0.091	1.700	9
1999	102.106	0.519	0.089	0.629	50
2000	431.009	0.538	0.365	2.741	53
2001	133.159	0.530	0.114	0.835	91
2002	67.460	0.545	0.056	0.434	70
2003	29.868	0.875	0.015	0.313	24
2004	8.594	0.882	0.004	0.091	32
2005	163.588	0.665	0.113	1.272	31

*index could not be computed for 1993 because all observations were positive.