SMALL COASTAL SHARK 2007 SEDAR DATA WORKSHOP DOCUMENT

Standardized catch rates of small coastal sharks from the Georgia COASTSPAN and GADNR penaeid shrimp and blue crab assessment surveys

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Summary

Prior to 1998, Georgia's only sources of data relative to shark species were anecdotal accounts from fishermen, the State's recreation fishing records, and any incidental bycatch reports that identified sharks captured during various projects conducted by Georgia's Department of Natural Resources. In 1998 the NMFS Apex Predators Investigation began the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) program funded through the Highly Migratory Species Management Division's Office of Sustainable Fisheries. This program funded a pilot study through Savannah State University to determine the presence/absence of juvenile sharks in Georgia's estuarine waters. In 2000, the University of Georgia in cooperation with the Georgia Department of Natural Resources (GADNR) developed a coastal shark survey in Georgia's estuarine waters as part of the COASTSPAN program. Data from the first six years of this survey (2000 to 2005) and supplemental shark bycatch data from the GADNR penaeid shrimp and blue crab assessment surveys (2003 to 2005) were used to look at the trends in relative abundance of small coastal sharks in Georgia's coastal waters. Catch per unit effort (CPUE) in number of sharks per hook hour for longline sets and in number of sharks per tow hour for trawl sets were examined from mid April through September. The CPUE was standardized using a modified two-step approach originally proposed by Lo et al (1992) that models the zero catch separately from the positive catch.

Methods

Sampling Gear and Data Collection

Longline sets were made in a maximum of four sound systems (Figure 1) each month from 2000 to 2005 and were restricted to inshore areas. Each of these sound systems were sampled during two days of each month from mid April through the end of September and four longline sets were conducted during each of the days sampling occurred. 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 pieces of squid or fish. Each set contained hooks baited with either squid or a combination of hooks baited with squid and hooks baited with fish. The 50 gangions were placed along the mainline in 4.5 - 6.1 m intervals. Longline soak time varied between 30 and 60 minutes.

Trawl sampling during GADNR monthly penaeid shrimp and blue crab assessment cruises also were used in the study from 2003 to 2005. The *R/V Anna* is outfitted with a single 13.7m (45-foot) flat net, which is towed for 15 minutes at each station. GADNR uses a stratified, fixed-station sampling approach and focuses effort in the state's inshore and nearshore waters. Strata are based on sound system (Wassaw, Ossabaw, Sapelo, St. Simons, St. Andrew and Cumberland) (Figure 1) and area (creeks/rivers, sounds, offshore). The *Anna* samples a total of 36 stations (six per sound; two per area in each sound) each month throughout the year; however, only samples collected during April through September were used for consistency with the COASTSPAN survey.

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

Data Analysis

Catch per unit effort (CPUE) in number of sharks per hook hour for longline sets and in number of sharks per tow hour for trawl sets were used to examine the relative abundance of small coastal sharks in Georgia's coastal waters from 2000 to 2005 (2003 to 2005 for trawls sets). The CPUE was standardized using the Lo et al. (2002) method which models the proportion of positive sets separately from the positive catch. This analysis was done for the following dependent variables: the small coastal shark complex CPUE, Atlantic sharpnose shark *Rhizoprionodon terraenovae* CPUE and bonnethead shark *Sphyrna tiburo* CPUE. After initial exploratory analysis, factors considered as potential influences on the CPUE for these analyses were: year (2000 – 2005), month (April – September) and bait type (squid, squid and fish) for longline sets and year (2003 – 2005), month (April – September) and area (Altamaha, Cumberland, Doboy, Ossabaw, Sapelo, St. Andrew, St. Catherines, St. Simons, and Wassaw) for trawl sets.

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

Small coastal shark complex

A total of 1082 small coastal sharks were caught during 629 longline sets from 2000 to 2005 in Georgia's estuarine waters and 790 small coastal sharks were caught during 690 trawl sets in Georgia's estuarine and nearshore waters from 2003 to 2005 (Tables 1 and 2). In addition to the Atlantic sharpnose and bonnethead sharks (Figures 2 and 3), discussed separately, there were also 14 finetooth sharks (43.0, 46.5, 46.8, 47.5, 48.1, 49.6, 63.0, 66.1, 66.7, 66.7, 69.4, 78.8, 124.5, and 126.5 cm fork length) caught during the longline survey and four blacknose sharks caught during the trawl survey (36.1, 38.6, 39.1 and 103.5 cm fork length) used in the small coastal shark complex analyses. The nominal and relative nominal CPUE by year for each time series are reported in Tables 1 and 2.

The percentage of sets with zero small coastal shark catch was 42.6% for longline sets and 66.2% for trawl sets. The stepwise construction of the binomial model of the probability of catching a small coastal shark and the Poisson model of positive small coastal shark catch sets for both the longline and trawl time series are detailed in Tables 3 and 4, respectively. The final binomial model for the longline series was: proportion positive small coastal shark sets = month + year. The final Poisson model for the longline time series was: positive small coastal shark catch = year + month. The final binomial model for the trawl series was: proportion positive small coastal shark sets = month + area + year. The final Poisson model for the trawl time series was: positive small coastal shark catch = area + month + year. The effect of year was not significant for small coastal sharks in the final Poisson model for the trawl time series, but was retained for calculation of yearly standardized abundance indices (Table 4).

The resulting relative indices of abundance based on the standardized year effects obtained from the Lo et al. method for small coastal sharks for the longline and trawl series are reported in Tables 9 and 10, respectively and are illustrated in Figure 4. Even though the factors of year and month were significant in both the binomial and Poisson models for the small coastal shark longline catch (Table 3), results from this study indicate that any bias associated with these factors did not significantly change the trends between the nominal and standardized small coastal shark longline CPUE (Figure 4). The standardized small coastal shark CPUE data for trawl sets reversed the trend in relative abundance when compared to the nominal CPUE data, which is more representative of the trends seen in the longline nominal and standardized CPUE data.

Atlantic sharpnose sharks

A total of 731 Atlantic sharpnose sharks were caught during 629 longline sets from 2000 to 2005 in Georgia's estuarine waters and 559 Atlantic sharpnose sharks were caught during 690 trawl sets in Georgia's estuarine and nearshore waters from 2003 to 2005 (Tables 1 and 2). Of these Atlantic sharpnose sharks, 693 and 555 were measured during the longline and trawl surveys, respectively. These Atlantic sharpnose sharks ranged in size from 22.5 to 83.0 and 20.3 to 84.0 cm fork length for longline and trawl surveys, respectively (Figure 2). The nominal and relative nominal CPUE by year for each time series are reported in Tables 1 and 2.

The percentage of sets with zero Atlantic sharpnose shark catch was 57.6% for longline sets and 74.9% for trawl sets. The stepwise construction of the binomial model of the probability of catching an Atlantic sharpnose shark and the Poisson model of positive Atlantic sharpnose shark catch sets for both the longline and trawl time series are detailed in Tables 5 and 6, respectively. The final binomial model for the longline series was: proportion positive Atlantic sharpnose shark sets = month + year. The final Poisson model for the longline time series was: positive Atlantic sharpnose shark catch = month + year. The final binomial model for the trawl series was: proportion positive Atlantic sharpnose shark sets = month + area + year. The final Poisson model for the trawl time series was: positive Atlantic sharpnose shark catch = area + month + year.

The resulting relative indices of abundance based on the standardized year effects obtained from the Lo et al. method for Atlantic sharpnose sharks for the longline and trawl series are reported in Tables 9 and 10, respectively and are illustrated in Figure 5. Even though the factors of year and month were significant in the binomial and Poisson models for the Atlantic sharpnose shark longline catch (Table 5), results from this study indicate that any bias associated with these factors did not significantly change the trends between the nominal and standardized Atlantic sharpnose shark longline CPUE (Figure 5). The standardized small coastal shark CPUE data for trawl sets reversed the trend in relative abundance when compared to the nominal CPUE data, which is more representative of the trends seen in the longline nominal and standardized CPUE data.

Bonnethead sharks

A total of 337 bonnethead sharks were caught during 629 longline sets from 2000 to 2005 in Georgia's estuarine waters and 227 bonnethead sharks were caught during 690 trawl sets in Georgia's estuarine and nearshore waters from 2003 to 2005 (Tables 1 and 2). Of these bonnethead sharks, 328 and 227 were measured during the longline and trawl surveys, respectively. These bonnethead sharks ranged in size from 32.2 to 97.0 and 21.3 to 97.0 cm fork length for longline and trawl surveys, respectively (Figure 3). The nominal and relative nominal CPUE by year for each time series are reported in Tables 1 and 2.

The percentage of sets with zero bonnethead shark catch was 70.0% for longline sets and 82.9% for trawl sets. The stepwise construction of the binomial model of the probability of catching a bonnethead shark and the Poisson model of positive small coastal shark catch sets for both the longline and trawl time series are detailed in Tables 7 and 8, respectively. The final binomial model for the longline series was: proportion positive bonnethead shark sets = year + month. The final Poisson model for the longline time series was: positive bonnethead shark catch = year. The final binomial model for the trawl series was: proportion positive bonnethead shark sets = month + area + year. The final Poisson model for the trawl time series was: positive bonnethead shark catch = year. The effect of year was not significant for bonnethead sharks in the final Poisson model for the trawl time series, but was retained for calculation of yearly standardized abundance indices (Table 8).

The resulting relative indices of abundance based on the standardized year effects obtained from the Lo et al. method for bonnethead sharks for the longline and trawl series are reported in Tables 9 and 10, respectively and are illustrated in Figure 6. Even though several factors included in the binomial and Poisson models for both the longline and trawl catch were significant, results from this study indicate that any bias associated with the factors included did not significantly change the trends between the nominal and standardized Atlantic sharpnose shark longline CPUE (Figure 6).

References

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Table 1. Nominal and nominal relative (CPUE/mean) abundance indices for small coastal sharks caught by longline in Georgia's estuarine waters from 2000-2005. CPUE of a set = sharks/(hooks*soak time). LCL = lower confidence limit, UCL = upper confidence limit, CV = coefficient of variation, and N = the number of sets observed for the nominal relative abundance indices.

Small coastal complex

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2000	113	0.029	0.462	0.365	0.559	1.955	87
2001	294	0.060	0.973	0.876	1.071	1.254	157
2002	125	0.068	1.096	0.949	1.242	1.150	74
2003	180	0.075	1.211	1.060	1.362	1.221	96
2004	255	0.099	1.592	1.440	1.744	0.973	104
2005	115	0.041	0.666	0.537	0.795	2.047	111

Atlantic sharpnose sharks

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2000	85	0.022	0.541	0.404	0.677	2.349	87
2001	249	0.050	1.257	1.116	1.397	1.402	157
2002	81	0.044	1.099	0.910	1.288	1.478	74
2003	133	0.056	1.382	1.174	1.590	1.477	96
2004	112	0.044	1.088	0.925	1.250	1.524	104
2005	71	0.025	0.634	0.463	0.805	2.839	111

Bonnethead sharks

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2000	26	0.006	0.305	0.228	0.382	2.353	87
2001	41	0.009	0.438	0.351	0.525	2.497	157
2002	43	0.023	1.101	0.909	1.294	1.506	74
2003	46	0.019	0.909	0.736	1.081	1.863	96
2004	137	0.053	2.497	2.221	2.773	1.128	104
2005	44	0.016	0.750	0.576	0.923	2.436	111

Table 2. Nominal and nominal relative (CPUE/mean) abundance indices for small coastal sharks caught by trawl in Georgia's estuarine and nearshore waters from 2003-2005. N = the number of sets observed. CPUE of a set = sharks/tow time. LCL = lower confidence limit, UCL = upper confidence limit, CV = coefficient of variation, and N = the number of sets observed for the nominal relative abundance indices.

Small coastal complex

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2003	242	4.481	0.980	0.852	1.107	1.912	216
2004	248	4.593	1.004	0.861	1.147	2.094	216
2005	300	4.651	1.017	0.810	1.223	3.264	258

Atlantic sharpnose sharks

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2003	153	2.833	0.883	0.741	1.024	2.356	216
2004	166	3.074	0.958	0.802	1.114	2.398	216
2005	240	3.721	1.159	0.890	1.429	3.739	258

Bonnethead sharks

YEAR	CATCH	INDEX	REL INDEX	LCL	UCL	CV	N
2003	88	1.630	1.213	0.998	1.427	2.605	216
2004	82	1.519	1.130	0.917	1.342	2.765	216
2005	57	0.884	0.658	0.510	0.805	3.598	258

Table 3. Results of the stepwise procedure for development of the catch rate model for small coastal sharks caught during longline sets. %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	628	858.1782	1.3665					
MONTH	623	747.1712	1.1993	12.2356	12.2356	-373.5856	111.01	<.0001
YEAR	623	810.3113	1.3007	4.8152		-405.1557	47.87	<.0001
BAIT TYPE	627	857.7567	1.368	-0.1098		-428.8783	0.42	0.5162
MONTH +								
YEAR	618	699.9805	1.1327	17.1094036	4.8738	-349.9903	47.19	<.0001

FINAL MODEL: MONTH + YEAR

Akaike's information criterion 2896.0

Schwartz's Bayesian criterion 2900.4

(-2) Res Log likelihood 2894.0

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	<.0001	<.0001
DF	5	5
CHI SQUARE	87.63	41.90

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	360	647.3916	1.7983					
YEAR	355	568.1841	1.6005	10.9993	10.9993	85.3930	79.21	<.0001
MONTH	355	571.0394	1.6086	10.5489		83.9654	76.35	<.0001
BAIT TYPE	359	626.0861	1.7440	3.0195		56.4420	21.31	<.0001
YEAR +								
MONTH	350	491.9665	1.4056	21.8373	10.8380	123.5018	76.22	<.0001
BAIT TYPE	354	567.4939	1.6031	-0.1624		85.7381	0.69	0.4061

FINAL MODEL: YEAR + MONTH

Akaike's information criterion 843.4

Schwartz's Bayesian criterion 847.2

(-2) Res Log likelihood 841.4

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	YEAR	MONTH
test of fixed effects for each factor	<.0001	<.0001
DF	5	5
CHI SQUARE	46.76	43.30

Table 4. Results of the stepwise procedure for development of the catch rate model for small coastal sharks caught during trawl sets. %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	689	882.4899	1.2808					
MONTH	684	706.6456	1.0331	19.3395	19.3395	-353.3228	175.84	<.0001
AREA	684	864.2430	1.2635	1.3507		-432.1215	18.25	0.0027
YEAR	687	869.1303	1.2651	1.2258		-434.5652	13.36	0.0013
MONTH +								
AREA	679	682.6472	1.0054	21.5021861	2.1627	-341.3236	24.00	0.0002
YEAR	682	689.0518	1.0103	21.1196127		-344.5259	17.59	0.0002
MONTH + AREA +								
YEAR	677	664.2517	0.9812			-332.1258	18.40	0.0001

FINAL MODEL: MONTH + AREA + YEAR

Akaike's information criterion 3417.2

Schwartz's Bayesian criterion 3421.7

(-2) Res Log likelihood 3415.2

Type 3 Test of Fixed Effects

	MONTH	AREA	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0007	0.0004
DF	5	5	2
CHI SQUARE	120.06	21.23	16.10

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	232	721.8856	3.1116					
AREA	227	623.0613	2.7448	11.7881	11.7881	223.9978	98.82	<.0001
MONTH	227	664.3687	2.9267	5.9423		203.3441	57.52	<.0001
YEAR	230	686.2481	2.9837	4.1104		192.4044	35.64	<.0001
AREA +								
MONTH	222	562.5269	2.5339	18.5660	6.7779	254.2650	101.84	<.0001
YEAR	225	600.0101	2.6667	14.2981		235.5234	23.05	<.0001
AREA + MONTH +								
YEAR	220	546.4455	2.4838	20.1761	1.6101	262.3057	16.08	0.0003

FINAL MODEL: AREA + MONTH + YEAR

Akaike's information criterion 683.5

Schwartz's Bayesian criterion 686.9

(-2) Res Log likelihood 681.5

Type 3 Test of Fixed Effects

	AREA	MONTH	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0054	0.0820
DF	5	5	2
CHI SQUARE	27.92	16.58	5.00

Table 5. Results of the stepwise procedure for development of the catch rate model for Atlantic sharpnose sharks caught during longline sets. %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	628	857.5759	1.3656					
MONTH	623	700.0892	1.1237	17.7138	17.7138	-350.0446	157.49	<.0001
YEAR	623	814.6375	1.3076	4.2472		-407.3187	42.94	<.0001
BAIT TYPE	627	853.3791	1.3611	0.3295		-426.6896	4.20	0.0405
MONTH +								
YEAR	618	660.0628	1.0681	21.7853	4.0715	-330.0314	40.03	<.0001

FINAL MODEL: MONTH + YEAR

Akaike's information criterion 3039.2

Schwartz's Bayesian criterion 3043.6

(-2) Res Log likelihood 3037.2

	Type 3 Test of Fixed Effects	
Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	<.0001	<.0001
DF	5	5
CHI SQUARE	87.29	32.94

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	266	442.0568	1.6619					
MONTH	261	384.0660	1.4715	11.4568	11.4568	-1.5368	57.99	<.0001
YEAR	261	408.1644	1.5638	5.9029		-13.5861	33.89	<.0001
BAIT TYPE	265	425.8585	1.6070	3.3034		-22.4331	16.20	<.0001
MONTH +								
YEAR	256	359.2848	1.4035	15.5485	4.0917	10.8537	24.78	0.0002
BAIT TYPE	260	407.7080	1.5681	5.6441		-13.3579	0.46	0.4993

FINAL MODEL: MONTH + YEAR

Akaike's information criterion 650.3

Schwartz's Bayesian criterion 653.9

(-2) Res Log likelihood 648.3

	Type 3 Test of Fixed Effects	
Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	<.0001	0.0124
DF	5	5
CHI SQUARE	25.90	14.56

Table 6. Results of the stepwise procedure for development of the catch rate model for Atlantic sharpnose sharks caught during trawl sets. %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	689	777.1192	1.1279					
MONTH	684	588.4367	0.8603	23.7255	23.7255	-294.2183	188.68	<.0001
AREA	684	757.1927	1.1070	1.8530		-378.5964	19.93	0.0013
YEAR	687	767.6522	1.1174	0.9309		-383.8261	9.47	0.0088
MONTH +								
AREA	679	561.1941	0.8265	26.7222271	2.9967	-280.5970	27.24	<.0001
YEAR	682	575.9055	0.8444	25.135207		-2879527	12.53	0.0019
MONTH + AREA +								
YEAR	677	547.1975	0.8083	28.3358	1.6136	-273.5988	14.00	0.0009

FINAL MODEL: MONTH + AREA + YEAR

Akaike's information criterion 3855.3

Schwartz's Bayesian criterion 3859.8

(-2) Res Log likelihood 3853.3

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	MONTH	AREA	YEAR
test of fixed effects for each factor	<.0001	0.0006	0.0051
DF	5	5	2
CHI SQUARE	90.19	21.54	10.55

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	172	521.9452	3.0346					
AREA	167	443.7468	2.6572	12.4366	12.4366	135.7268	78.20	<.0001
MONTH	167	451.8441	2.7057	10.8383		131.6781	70.10	<.0001
YEAR	170	462.6001	2.7212	10.3276		126.3001	59.35	<.0001
AREA +								
MONTH	162	365.6895	2.2573	25.6146	13.1780	174.7554	78.06	<.0001
YEAR	165	409.8468	2.4839	18.1474		152.6768	33.90	<.0001
AREA + MONTH +								
YEAR	160	338.4474	2.1153	30.2939	4.6794	188.3765	27.24	<.0001

FINAL MODEL: AREA + MONTH + YEAR

Akaike's information criterion 491.5

Schwartz's Bayesian criterion 494.5

(-2) Res Log likelihood 489.5

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	AREA	MONTH	YEAR
test of fixed effects for each factor	0.0009	0.0001	0.0064
DF	5	5	2
CHI SQUARE	20.81	25.10	10.09

Table 7. Results of the stepwise procedure for development of the catch rate model for bonnethead sharks caught during longline sets. %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	628	768.975	1.2245					
YEAR	623	708.2020	1.1368	7.1621	7.1621	-354.1010	60.77	<.0001
MONTH	623	753.6771	1.2098	1.2005		-376.8386	15.30	0.0092
BAIT TYPE	627	768.8662	1.2263	-0.1470		-384.4331	0.11	0.7415
YEAR + MONTH	618	691.2436	1.1185	8.6566	1.4945	-345.6218	16.96	0.0046

FINAL MODEL: YEAR +MONTH

Akaike's information criterion 2892.0

Schwartz's Bayesian criterion 2896.5

(-2) Res Log likelihood 2890.0

Type 3 Test of Fixed Effects		
Significance (Pr>Chi) of Type 3	YEAR	MONTH
test of fixed effects for each factor	<.0001	0.0078
DF	5	5
CHI SQUARE	56.89	15.68

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	188	135.2535	0.7194					
YEAR	183	101.8975	0.5568	22.6022	22.6022	-139.8660	33.36	<.0001
MONTH	183	128.4950	0.7022	2.3909		-153.1648	6.76	0.2392
BAIT TYPE	187	135.0199	0.7220	-0.3614		-156.4272	0.23	0.6288

FINAL MODEL: YEAR

Akaike's information criterion 358.6

Schwartz's Bayesian criterion 361.8

(-2) Res Log likelihood 356.6

Type 3 Test of Fixed Effects	
Significance (Pr>Chi) of Type 3	YEAR
test of fixed effects for each factor	<.0001
DF	5
CHI SQUARE	48.03

Table 8. Results of the stepwise procedure for development of the catch rate model for bonnethead shark caught during trawl sets. %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	689	631.3378	0.9163					
MONTH	684	599.1126	0.8759	4.4090	4.4090	-299.5563	32.23	<.0001
AREA	684	612.8502	0.8960	2.2154		-306.4251	18.49	0.0024
YEAR	687	623.7443	0.9079	0.9167		-311.8722	7.59	0.0224
MONTH +								
AREA	679	579.8940	0.8540	6.79908327	2.3900	-289.9470	19.22	0.0018
YEAR	682	591.1980	0.8669	5.39124741		-295.5990	7.91	0.0191
MONTH + AREA +								
YEAR	677	572.0046	0.8449			-286.0023	7.89	0.0194

FINAL MODEL: MONTH + AREA + YEAR

Akaike's information criterion	3521.9
Schwartz's Bayesian criterion	3526.4
(-2) Res Log likelihood	3519.9

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	MONTH	AREA	YEAR
test of fixed effects for each factor	0.0002	0.0091	0.0255
DF	5	5	2
CHI SQUARE	24.16	15.32	7.34

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CHI
NULL	117	110.1457	0.9414					
AREA	112	103.1125	0.9206	2.2095	2.2095	-74.9652	7.03	0.2182
MONTH	112	104.2619	0.9309	1.1154		-75.5398	5.88	0.3177
YEAR	115	109.1051	0.9487	-0.7754		-77.9615	1.04	0.5943

FINAL MODEL: YEAR

Akaike's information criterion	292.7
Schwartz's Bayesian criterion	295.5
(-2) Res Log likelihood	290.7

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3	YEAR
test of fixed effects for each factor	0.6638
DF	2
CHI SQUARE	0.82

Table 9. Relative (index/mean) standardized abundance indices for small coastal sharks caught during the GA COASTSPAN longline survey based on the standardized year effects obtained from the Lo et al. analyses. LCL = lower confidence limit, UCL = upper confidence limit, CV = coefficient of variation, and N = the number of sets observed.

Small coastal complex

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2000	2.498	0.388	-0.024	0.801	0.542	87
2001	5.508	0.856	0.517	1.195	0.202	157
2002	7.579	1.178	0.594	1.762	0.253	74
2003	7.958	1.237	0.644	1.830	0.245	96
2004	10.941	1.700	1.172	2.228	0.158	104
2005	4.121	0.640	0.125	1.156	0.410	111

Atlantic sharpnose sharks

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2000	2.234	0.486	-0.032	1.004	0.544	87
2001	5.103	1.111	0.687	1.534	0.195	157
2002	5.693	1.239	0.490	1.987	0.308	74
2003	6.480	1.410	0.698	2.123	0.258	96
2004	5.316	1.157	0.507	1.807	0.287	104
2005	2.744	0.597	-0.039	1.233	0.543	111

Bonnethead sharks

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2000	0.602	0.280	-0.793	1.353	1.955	87
2001	0.804	0.374	-0.564	1.311	1.279	157
2002	2.398	1.115	-0.434	2.664	0.709	74
2003	2.024	0.941	-0.471	2.354	0.765	96
2004	5.412	2.517	1.184	3.850	0.270	104
2005	1.660	0.772	-0.622	2.166	0.921	111

Table 10. Relative (index/mean) standardized abundance indices for small coastal sharks caught during the GADNR trawl survey based on the standardized year effects obtained from the Lo et al. analyses. LCL = lower confidence limit, UCL = upper confidence limit, CV = coefficient of variation, and N = the number of sets observed.

Small coastal complex

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2003	648.908	1.124	0.787	1.461	0.153	216
2004	580.957	1.006	0.682	1.330	0.164	216
2005	502.532	0.870	0.574	1.167	0.174	258

Atlantic sharpnose sharks

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2003	526.649	1.043	0.652	1.434	0.191	216
2004	511.770	1.014	0.644	1.384	0.186	216
2005	476.209	0.943	0.564	1.322	0.205	258

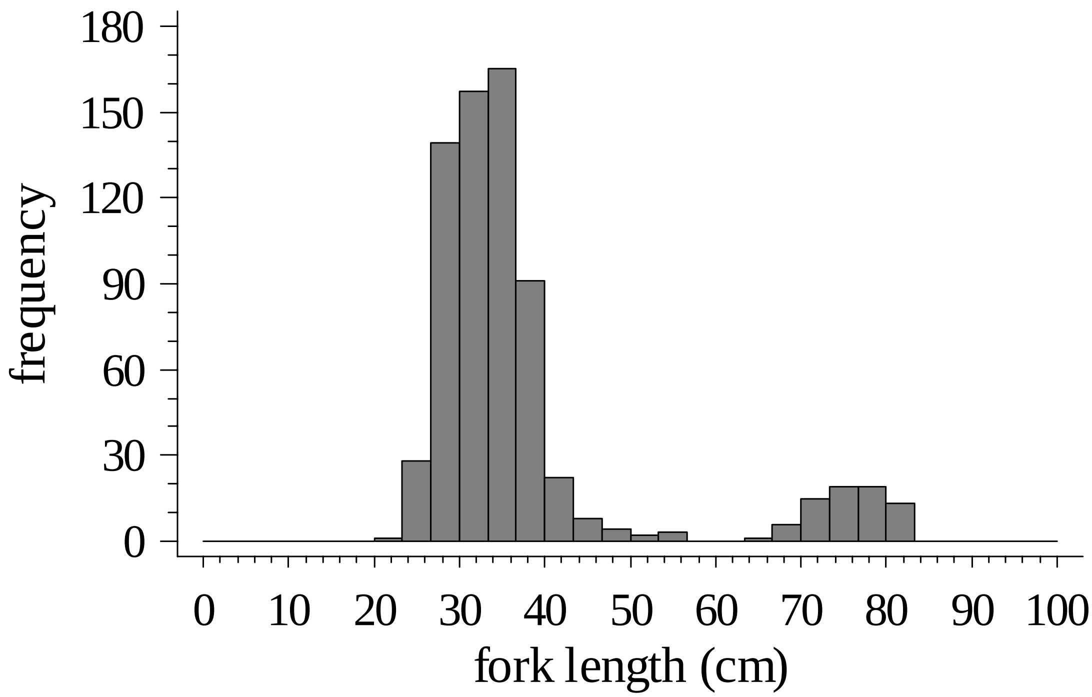
Bonnethead sharks

YEAR	INDEX	REL INDEX	LCL	UCL	CV	N
2003	191.430	1.220	0.776	1.664	0.186	216
2004	176.985	1.128	0.680	1.576	0.203	216
2005	102.319	0.652	0.340	0.964	0.244	258

Figure 1. Georgia's coastline with the labeled sound systems that are used to designate sampling areas for COASTSPAN longline and GADNR trawl sets.

Figure 2. Length frequency histograms for Atlantic sharpnose sharks caught during (A) longline sets and (B) trawl sets

A



B

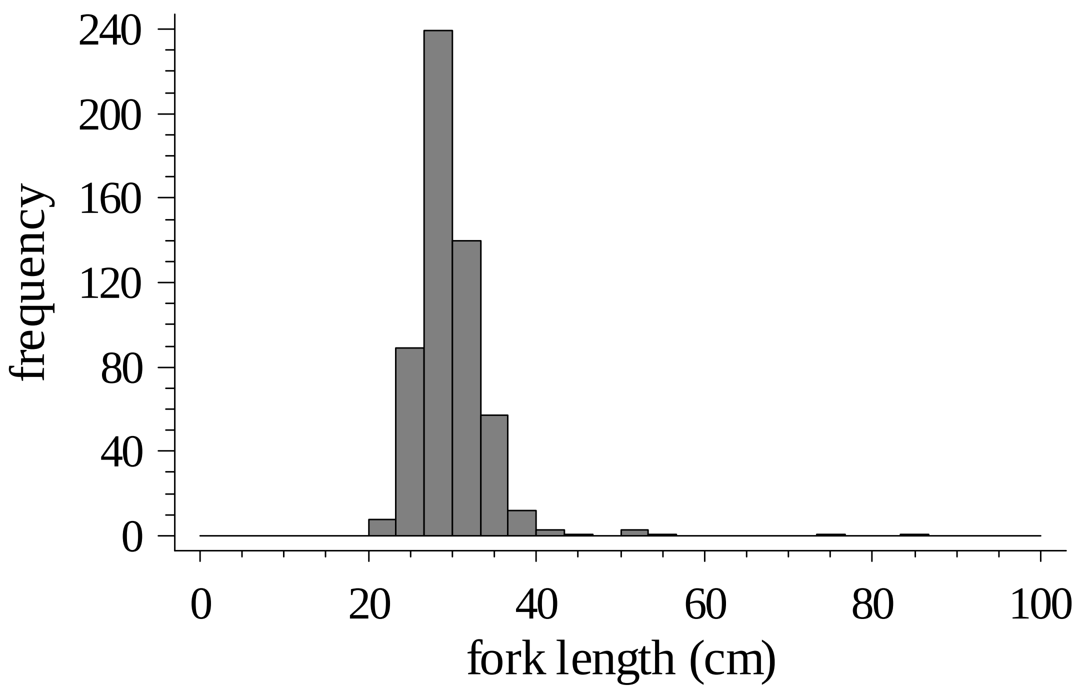
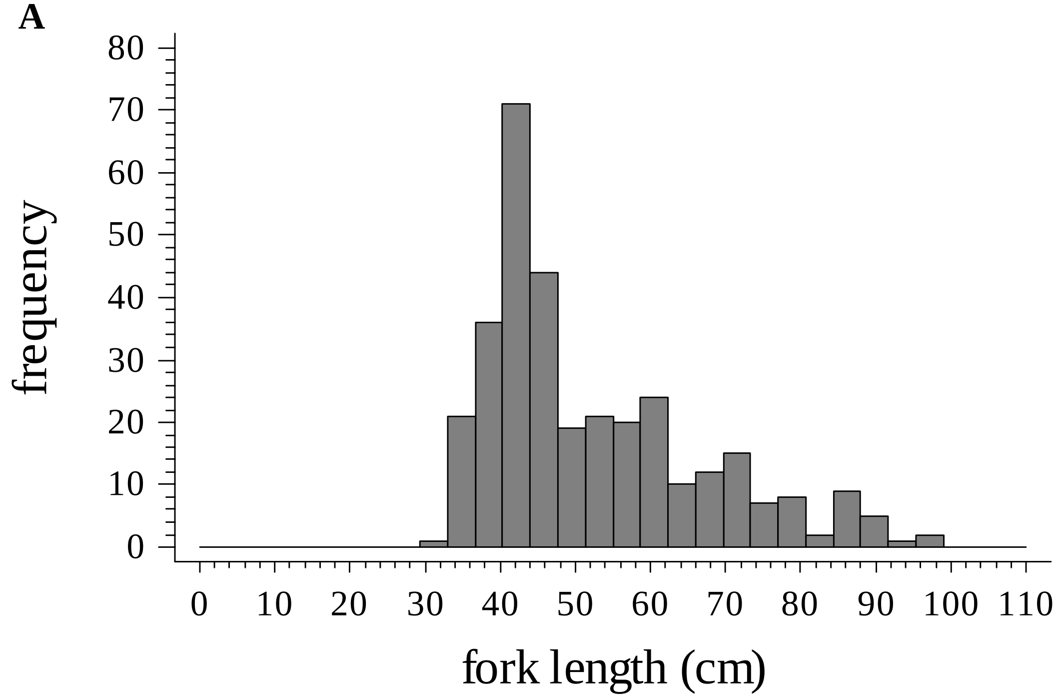


Figure 3. Length frequency histograms for bonnethead sharks caught during (A) longline sets and (B) trawl sets

A



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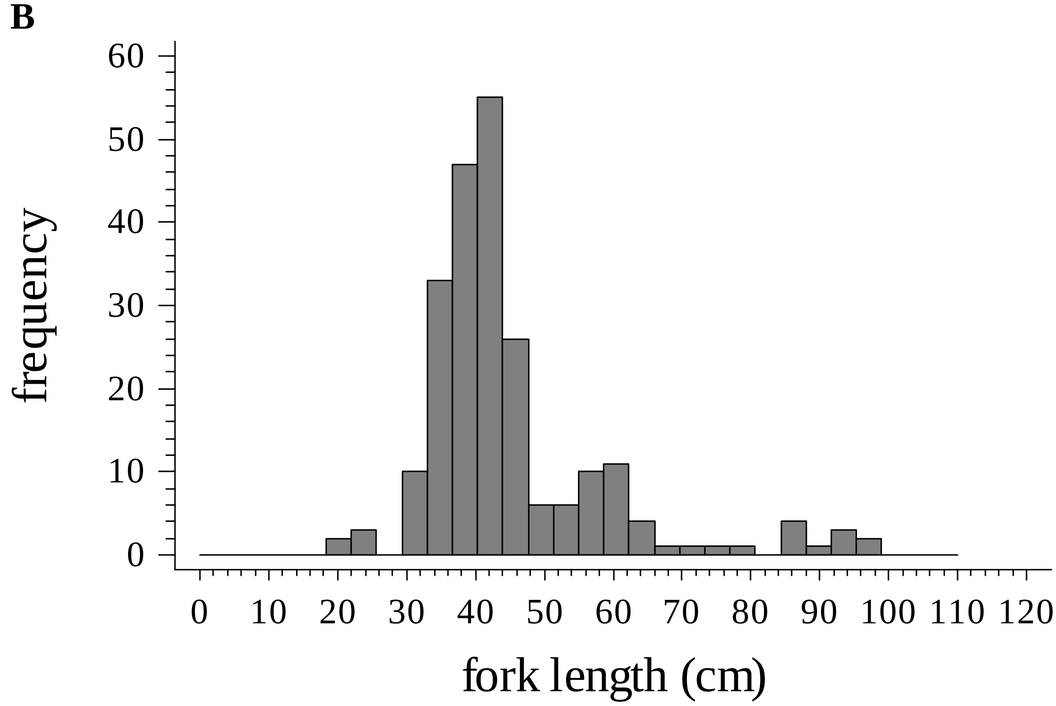
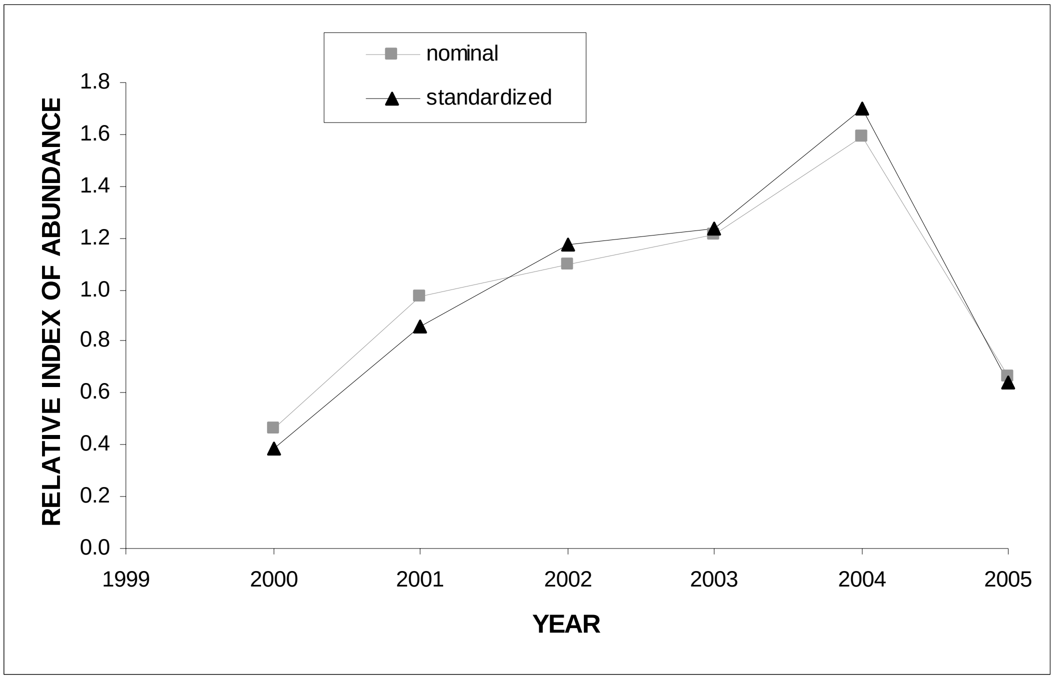


Figure 4. Relative (index/mean) indices of abundance by year for the small coastal shark complex CPUE for (A) longline data and (B) trawl survey data

A



B

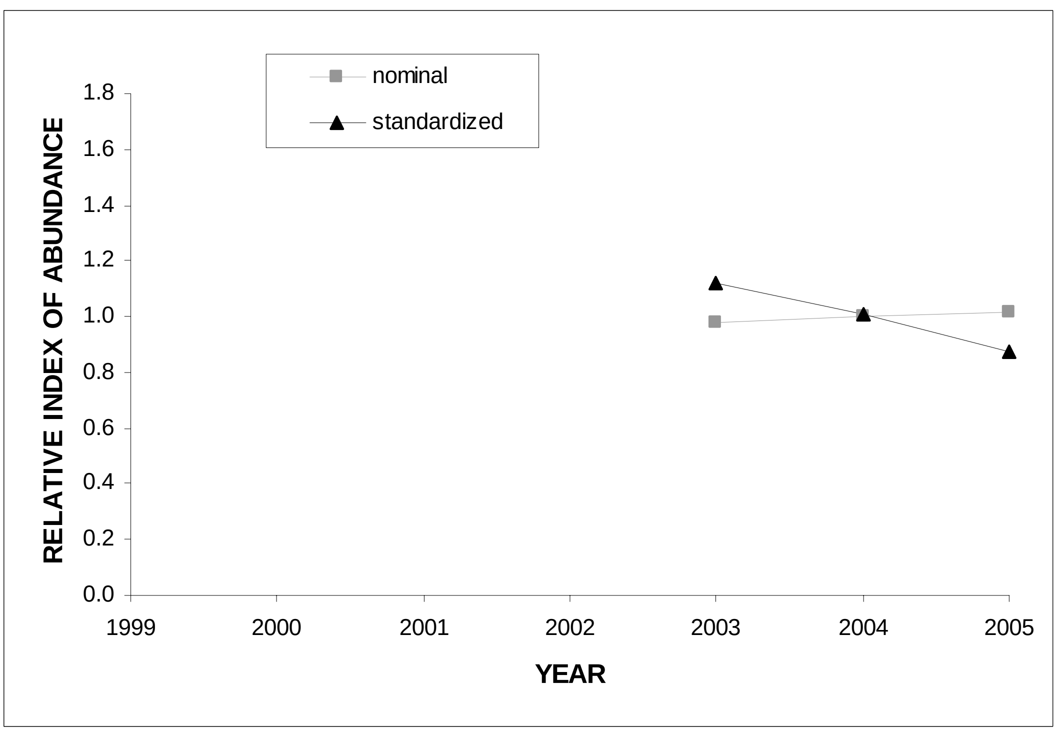
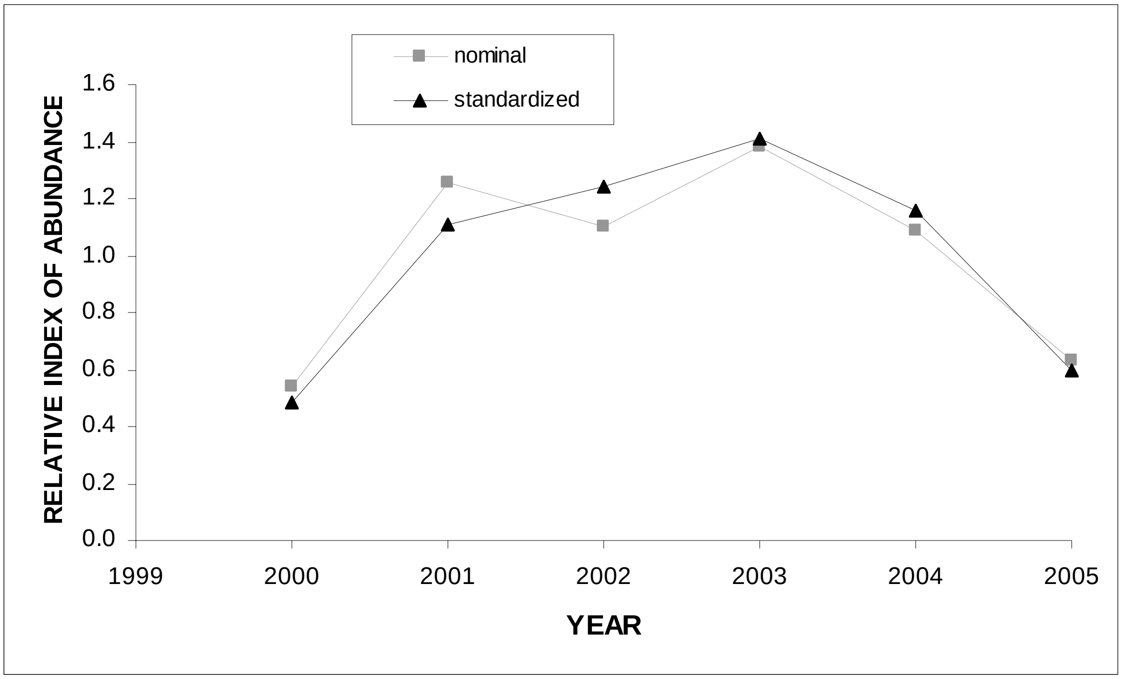


Figure 5. Relative (index/mean) indices of abundance by year for Atlantic sharpnose shark CPUE for (A) longline data and (B) trawl survey data

A



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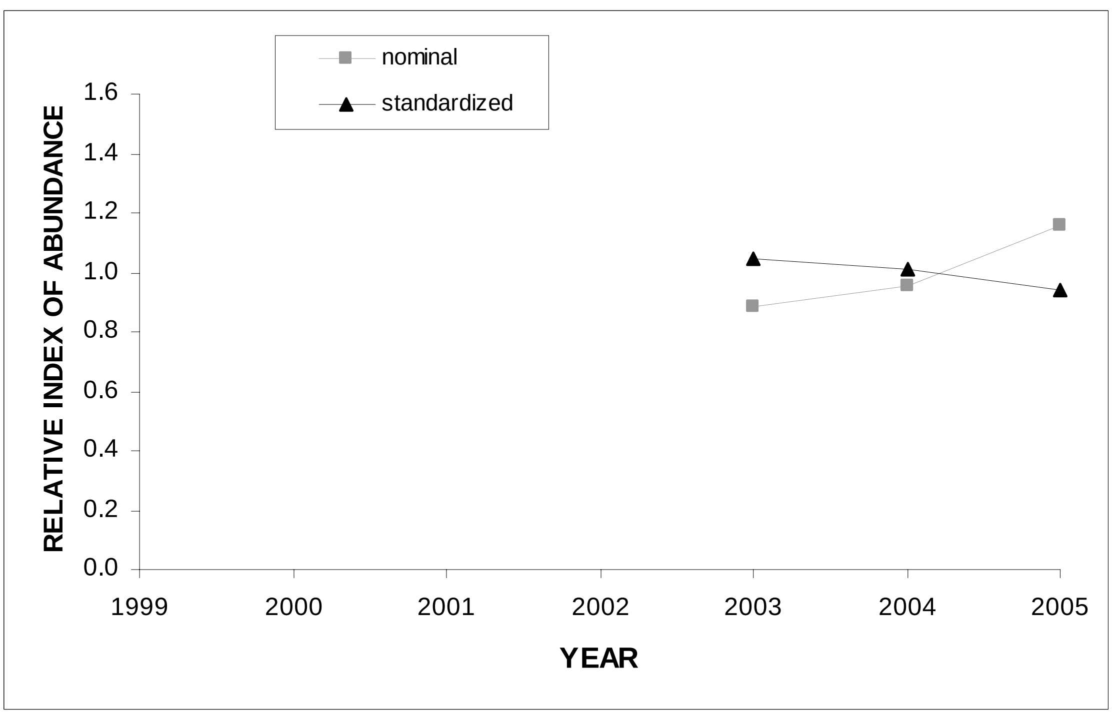
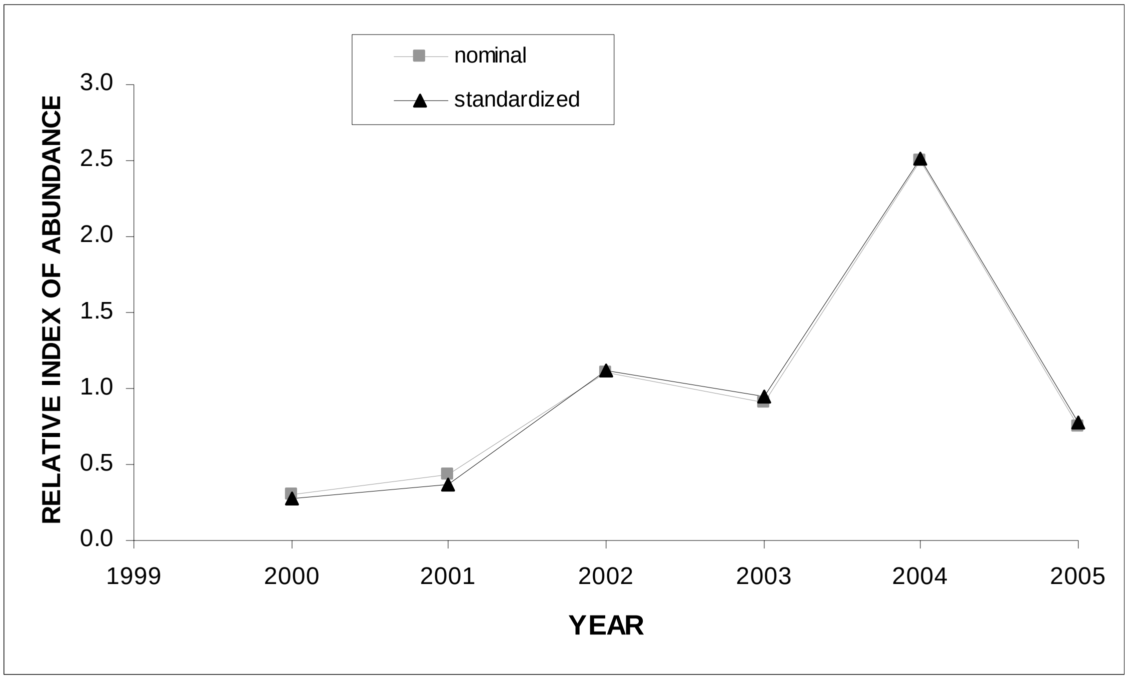


Figure 6. Relative (index/mean) indices of abundance by year for bonnethead shark CPUE for (A) longline data and (B) trawl survey data

A



B