STANDARDIZED CATCH RATES OF LARGE COASTAL SHARKS FROM A FISHERY-INDEPENDENT SURVEY IN NORTHWEST FLORIDA

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INTRODUCTION

A fishery-independent survey of large and small coastal shark populations in coastal nursery areas of the northeast Gulf of Mexico has been conducted using gillnets from 1996-2004 and longlines from 1993-2000. Although field methods were standardized, some bias associated with factors such as spatial-temporal distributions could not be controlled which could cause changes in catch rates not directly related to abundance. The present study attempts to standardize catch rates using a modified two-step approach originally proposed by Lo et al. (1992). Catch rate series are developed for the large coastal species-aggregate, and blacktip shark, *Carcharhinus limbatus* from the longline survey. From the gillnet survey, catch rates are standardized for the large coastal species-aggregate, all blacktip sharks, and all sandbar sharks. Two additional catch rate series are also developed by age for the blacktip shark; young-of-the year (age 0+) and juvenile (age 1-5).

MATERIAL AND METHODS

Field data collection

Gillnets

A 186-m long gill net consisting of six different mesh size panels was utilized for sampling. Stretched mesh sizes (SM) ranged from 8.9 cm (3.5”) to 14.0 cm (5.5”) in steps of 1.27 cm (0.5”), with an additional size of 20.3 cm (8.0”). Panel depths when fishing were 3.1 m. Webbing for all panels, except for 20.3-cm, was of clear monofilament, double knotted and double selvaged. The 20.3-cm SM webbing was made of #28 multifilament nylon, single knotted, and double selvage. The nets when set were anchored at both ends.

Longline

The longline was constructed of a mainline made of two 152-m lengths of 425.8 kg-test monofilament line. Each 152-m length was connected by a 15.2-m length of 0.79-cm diameter braided polypropylene line so that the entire line when fished was 319.2 m long. Polyethylene floats made of 1.5-m lengths of 136-kg test monofilament line with a snap were attached to the mainline every 30.4 m. A standard longline consisted of 10-20 gangions placed at 15.2-m intervals along the mainline. Gangions were 0.9 m long and composed of snaps, aluminum sleeves, hooks (Mustad #12/0, no 2888), and monofilament lines (136-kg test). Bait was either menhaden (*Brevoortia* spp.) or Atlantic mackerel (*Scomber scombrus*). The mainline, when set, was tethered to an anchor on each end with a 30.4-m, 0.79-cm polypropylene rope between the anchor and the end of the mainline. A buoy (3.6-m aluminum pole with 1.8-kg weight and 50.8-cm poly float), with a strobe light and flag extended 2.4 m above the float, was attached at each end of the mainline.

Survey design

Surveys were conducted monthly from April-October, occasionally March-November. The sampling gear was set at fixed stations or randomly set within each area based on depth strata and GPS location. For gillnets, the nets were checked and cleared of catch, or pulled and reset every 1.0-2.0 hr. For longlines, soak time ranged from 1.0-1.5 hr. Following each soak period, the longline was checked and all gangions that had caught sharks, been broken or damaged, or had damaged or lost baits, were removed from the mainline and a fresh-baited gangion attached. Sharks captured using either method were measured to the nearest cm for body lengths (precaudal, fork, total, and stretch total length) and data for sex and life history stage (neonate, young-of-the-year, juvenile, adult) were recorded. Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged with a nylon-head dart tag and released. Environmental data were collected prior to sampling. Mid-water temperature (°C), salinity (ppt), and dissolved oxygen (mg l^{-1}) was measured with a YSI Model 55 oxygen meter and light transmission (cm) was determined using a secci disk. Further details can be found in Carlson and Brusher (1999).

Index Development

Longline

Several categorical variables were constructed for analysis of longline data:

“Year” (8 levels): 1993-2000

“Area” (2 levels): location of longline set (Figure 1).

“SetBegin” (4 levels):

- Dawn=0401-1000 hrs
- Day=1001-1600 hrs
- Dusk=1601-2200 hrs
- Night=2201-0400 hrs

“Season” (3 levels):

- Spring=Mar-May
- Summer=Jun-Aug
- Fall=Sep-Nov

Gillnet

Several categorical variables were constructed for analysis of gillnet data:

“Year” (9 levels): 1996-2004

“Area” (4 levels): location of gillnet set (Figure 1).

“SetBegin” (4 levels):

- Dawn=0401-1000 hrs
- Day=1001-1600 hrs

Dusk=1601-2200 hrs
Night=2201-0400 hrs
"Season" (3 levels):
Spring=Mar-May
Summer=Jun-Aug
Fall=Sep-Nov
"Setdepth" (2 levels):
Shallow=less than 5 meters
Deep=greater than 5 meters

The proportion of sets that caught any sharks (at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. Positive catches were modeled assuming a poisson distribution with a log link. For longlines, an offset of the natural log of the number of hooks*soak time of the gear was used for the poisson model while for gillnets the offset was the natural log of the soak time of the net. 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 selection of the final model, the SAS GLIMMIX macro was run to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Inst., Inc.). The final mixed model calculates relative indices of abundance as the result of the year effect least square means from the combined binomial and poisson components using bias correction terms to calculate confidence intervals. Goodness-of-fit criteria for the final model included (-2) Residual Log Likelihood, Akaike's Information Criterion, and Schwarz's Bayesian Criterion. Relative indices of abundance were calculated as the product of the year effect least square means from the binomial and poisson models. The standard error of the combined index was estimated with the Delta Method (Lo et al. 1992). To facilitate visual comparison, a relative index and relative nominal index were calculated by dividing each value in the series by the mean value of the series.

RESULTS AND DISCUSSION

<u>Longline</u>

Large Coastal Sharks

A total of 348 longline sets were made from 1993-2000. The percentage of sets with zero catches was 64.4% for the large coastal aggregate. The stepwise construction of the binomial model of the probability of catching a large coastal shark and the poisson model on positive sets is in Table 1. The final binomial model was *Proportion positive sets=Area + Year.* Year was not significant in the final model but was kept in the glimmix model to allow for calculation of indices. The final poisson model was *Positive large coastal sets =Year + Area*. The frequency distribution of positive large coastal sets is in Figure 2 and the distribution of residuals by year is in Figure 3.

The standardized 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 2.

Blacktip Sharks

For blacktip shark, the percentage of sets with zero catches was 76.1%. Most blacktip sharks caught on longlines were juveniles and the average size did not change considerable over the survey period (79 cm FL ±0.87 S.D.). The stepwise construction of the binomial model of the probability of catching a blacktip shark and the poisson model on positive sets is in Table 3. The final binomial model was *Proportion positive trips=Area + Year.* The final poisson model was *Positive blacktip shark sets=Year*. Year was not significant in the final binomial model but was kept in the glimmix model to allow for calculation of indices. The frequency distribution of Positive blacktip shark sets is in Figure 5 and the distribution of residuals by year is in Figure 6. The standardized abundance index is shown in Figure 7. 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 2.

<u>Gillnet</u>

Large Coastal Sharks

A total of 712 gillnet sets were made from 1996-2004. The percentage of sets with zero catches was 57.1% for the large coastal aggregate. The stepwise construction of the binomial model of the probability of catching a large coastal shark and the poisson model on positive sets is in Table 4. The final binomial model was *Proportion positive sets=Area + Season + Year.* The final poisson model was *Positive large coastal sets =Area + Year + Season.* The frequency distribution of positive large coastal sets is in Figure 8 and the distribution of residuals by year is in Figure 9. Although some interactions were significant (i.e. year*season), the increased number of degrees of freedom in the interaction precluded estimation of the least square means in the glimmix model. Thus, all final models were run without interactions.

The standardized abundance index is shown in Figure 10. 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 5.

All Blacktip Sharks

For blacktip sharks regardless of age, the percentage of sets with zero catches was 67.1%. The stepwise construction of the binomial model of the probability of catching any blacktip shark and the poisson model on positive sets is in Table 6. The final binomial model was *Proportion positive trips=Area + Season + Year.* The final poisson model was *Positive blacktip shark sets= Setbegin + Area + Year Year* Setbegin.* The frequency distribution of positive blacktip shark sets is in Figure 11 and the distribution of residuals by year is in Figure 12. The standardized abundance index is shown in Figure 13. 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 7.

Juvenile blacktip sharks

For juvenile blacktip sharks, the percentage of sets with zero catches was 72.1%. The average size of all juvenile blacktip sharks collected from 1996-2004 was 79.7 cm FL (±12.5 S.D.). The stepwise construction of the binomial model of the probability of catching any blacktip shark and the poisson model on positive sets is in Table 8. The final binomial model was *Proportion positive trips=Area + Season + Year.* The final poisson model was *Positive blacktip shark sets= Setbegin + Area + Year Year* Setbegin*. The frequency distribution of positive juvenile blacktip shark sets is in Figure 14 and the distribution of residuals by year is in Figure 15. The standardized abundance index is shown in Figure 16. 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 7.

Age 0 blacktip sharks

For age 0 blacktip sharks, the percentage of sets with zero catches was 72.1%. The average size of all age 0 blacktip sharks collected from 1996-2004 was 54.1 cm FL (±5.4 S.D.). The stepwise construction of the binomial model of the probability of catching any blacktip shark and the poisson model on positive sets is in Table 9. The final binomial model was *Proportion positive trips=Area + Season + Year.* The final poisson model was *Positive blacktip shark sets= Year+ Area + Season*. The frequency distribution of positive age 0 blacktip shark sets is in Figure 17 and the distribution of residuals by year is in Figure 18. The standardized abundance index is shown in Figure 19. 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 7.

Sandbar sharks

For all sandbar sharks, the percentage of sets with zero catches was 95.6%. The average size of all sandbar sharks collected from 1996-2004 was 79.1 cm FL (±20.6 S.D.). The stepwise construction of the binomial model of the probability of catching any sandbar shark and the poisson model on positive sets is in Table 10. The final binomial model was *Proportion positive trips=Area + Season + Year.* The final poisson model was *Positive sandbar shark sets= Year+ Area + Season*. The frequency distribution of positive sandbar shark sets is in Figure 20 and the distribution of residuals by year is in Figure 21. The standardized abundance index is shown in Figure 22. 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 11.

LITERATURE CITED

Carlson, J.K., Brusher, J.H., 1999. An index of abundance for coastal species of juvenile sharks from the northeast Gulf of Mexico. Mar. Fish. Rev. 61:37-45.

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.

Table 1. Results of the stepwise procedure for development of the fishery independent longline catch rate model for the large coastal shark aggregate. %DIFF 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	CHISQUARE	PR>CHI
NULL	347	453.286	1.306			-226.643		
AREA	346	396.172	1.145	12.347	12.347	-198.086	57.110	<.0001
YEAR	340	437.114	1.286	1.582		-218.557	16.170	0.0236
TIME	344	444.932	1.293	0.987		-222.466	8.350	0.0392
SEASON	345	446.586	1.294	0.907		-223.293	6.700	0.0351
AREA +								
YEAR	339	388.474	1.146	12.276	-0.072	-194.237	7.7	0.36
FINAL MODEL: AREA + YEAR	339	388.474	1.146	12.276	-0.072	-194.237	7.7	0.36

Akaike's information criterion	1586.1
Schwartz's Bayesian criterion	1589.9
(-2) Res Log Likelihood	1584.1

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	AREA	YEAR
test of fixed effects for each factor	<.0001	0.5147
DF	1	7
CHI SQUARE	41.47	6.220

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	123	274.937	2.235			-120.663		
YEAR	116	146.206	1.260	43.613	43.613	-56.297	128.73	<.0001
AREA	122	214.434	1.758	21.367		-90.412	60.5	<.0001
TIME	120	267.022	2.225	0.451		-116.706	7.92	0.0478
SEASON	121	270.763	2.238	-0.110		-118.576	4.17	0.1241
YEAR +								
AREA	115	134.749	1.172	47.580	3.967	-50.569	11.46	0.0007
YEAR + AREA	115	134.749	1.172	47.580	3.967	-50.569	11.46	0.0007
YEAR*AREA	110	128.926	1.172	47.565	-0.015	-47.657	5.82	0.3238
FINAL MODEL: YEAR + AREA	115	134.7485	1.172	47.580	3.967	-50.569	11.46	0.0007

Akaike's information criterion	326.0
Schwartz's Bayesian criterion	330.7
(-2) Res Log Likelihood	326.0

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	YEAR	AREA
test of fixed effects for each factor	<.0001	0.0085
DF	7	1
CHI SQUARE	49.68	6.930

Table 2. The relative standardized index of abundance from fishery independent longline catches, coefficients of variance (CV), and number of sets (N) for large coastal sharks and blacktip sharks, 1993-2000.

		Large coastal sharks		Blacktip sharks	
YEAR	**N**	**RELATIVE INDICES**	**CV**	**RELATIVE INDICES**	**CV**
1993	9	0.816	0.73	0.768	1.288
1994	66	0.386	0.894	0.133	3.244
1995	38	1.272	0.61	1.018	1.244
1996	69	0.858	0.583	0.758	1.087
1997	60	0.926	0.539	1.299	0.704
1998	29	0.725	0.967	0.974	1.328
1999	42	1.174	0.564	1.136	1.011
2000	35	1.844	0.508	1.914	0.92

Table 3. Results of the stepwise procedure for development of the fishery independent longline catch rate model for blacktip sharks. %DIFF 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	CHISQUARE	PR>CHI
NULL	347	382.349	1.102			-191.174		
AREA	346	340.008	0.983	10.817	10.817	-170.004	42.340	<.0001
YEAR	340	365.105	1.074	2.544		-182.552	17.240	0.0159
SEASON	345	377.450	1.094	0.709		-188.725	4.900	0.0864
TIME	344	378.058	1.099	0.260		-189.029	4.290	0.2318
AREA +								
YEAR	339	334.9397	0.988	10.332	-0.485	-167.470	5.07	0.6517
FINAL MODEL: AREA + YEAR	339	334.9397	0.988	10.332	-0.485	-167.470	5.07	0.6517
Akaike's information criterion	1668.5							
Schwartz's Bayesian criterion	1672.3							
(-2) Res Log Likelihood	1666.5							

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3		
test of fixed effects for each factor	<.0001	0.690
DF	1	7
CHI SQUARE	26.09	4.760

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	82	169.850	2.071			-100.143		
YEAR	75	66.525	0.887	57.177	57.177	-48.480	103.32	<.0001
AREA	81	128.611	1.588	23.345		-79.523	41.24	<.0001
TIME	79	148.314	1.877	9.364		-89.374	21.54	<.0001
SEASON	80	162.321	2.029	2.044		-96.378	7.53	0.0232
YEAR +								
TIME	72	60.4255	0.839	59.483	2.306	-45.430	6.1	0.1069
AREA	74	63.160	0.854	58.794		-46.797	3.37	0.0666
SEASON	73	65.9174	0.903	56.406		-48.176	0.61	0.7379
FINAL MODEL: YEAR	75	66.525	0.887	57.177	57.177	-48.480	103.32	<.0001
Akaike's information criterion	207.9							
Schwartz's Bayesian criterion	210.2							
(-2) Res Log Likelihood	205.9							

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	YEAR
test of fixed effects for each factor	<.0001
DF	7
CHI SQUARE	65.81

Table 4. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for the large coastal shark aggregate. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	972.379	1.368			-486.189		
AREA	708	741.023	1.047	23.470	23.470	-370.512	231.360	<.0001
YEAR	703	911.459	1.297	5.198		-455.730	60.920	<.0001
SEASON	709	952.863	1.344	1.731		-476.432	19.520	<.0001
TIME	708	957.115	1.352	1.153		-478.557	15.260	0.0016
SETDEPTH	710	966.411	1.361	0.474		-483.206	5.97	0.0146
AREA +								
SEASON	706	721.1693	1.021	25.309	1.839	-360.585	19.85	<.0001
TIME	705	724.3675	1.027	24.872		-362.184	16.66	0.0008
YEAR	700	719.259	1.028	24.869		-359.630	21.76	0.0054
AREA + SEASON +								
YEAR	698	696.035	0.997	27.086	1.777	-348.018	25.130	0.0015
TIME	703	704.8017	1.003	26.693		-352.401	16.37	0.001
AREA + SEASON + YEAR								
TIME	695	687.386	0.989	27.681	0.595	-343.693	8.650	0.0343
AREA + SEASON + YEAR	698	696.035	0.997	27.086	1.777	-348.018	25.130	0.0015
AREA*SEASON	692	673.3444	0.973	28.852	1.765	-336.672	22.69	0.0009
AREA*YEAR	678	650.0308	0.959	29.897		-325.015	Negative of Hessian not positive definite.	
SEASON*YEAR	682	666.4462	0.977	28.548		-333.223	Negative of Hessian not positive definite.	

FINAL MODEL: AREA + SEASON + YEAR

Akaike's information criterion	3425.6
Schwartz's Bayesian criterion	3430.1
(-2) Res Log Likelihood	3423.6

Type 3 Tests of Fixed Effects

	AREA	SEASON	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	<.0001	0.031
DF	3	2	8.000
CHI SQUARE	136.33	21.450	16.910

Table 4 (cont)

Positive catches-Poisson error distribution								
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**L**	**CHISQUARE**	**PR>CHI**
NULL	304	2369.678	7.795			2516.616		
AREA	301	1895.765	6.298	19.202	19.202	2753.573	473.91	<.0001
YEAR	296	1882.563	6.360	18.409		2760.174	487.12	<.0001
TIME	301	2090.596	6.946	10.898		2656.157	279.08	<.0001
SEASON	302	2163.348	7.163	8.102		2619.781	206.33	<.0001
SETDEPTH	303	2357.026	7.779	0.206		2522.942	12.65	0.0004
AREA +								
YEAR	293	1473.308	5.028	35.493	16.291	2964.801	422.46	<.0001
TIME	298	1676.946	5.627	27.808		2862.982	218.82	<.0001
SEASON	299	1737.589	5.811	25.448		2832.661	158.18	<.0001
AREA + YEAR +								
SEASON	291	1342.822	4.615	40.802	5.309	3030.044	130.49	<.0001
TIME	290	1440.987	4.969	36.255		2980.962	32.32	<.0001
AREA + YEAR + SEASON +								
TIME	288	1311.976	4.555	41.559	0.757	3045.467	30.85	<.0001
AREA + YEAR + SEASON	291	1342.822	4.615	40.802	5.309	3030.044	130.49	<.0001
YEAR*SEASON	276	906.475	3.284	57.866	17.065	3248.218	436.35	<.0001
AREA*SEASON	286	1320.924	4.619	40.749		3040.993	21.9	0.0005
AREA*YEAR	274	1269.177	4.632	40.577		3066.867	73.64	<.0001
FINAL MODEL: AREA + YEAR + SEASON								
Akaike's information criterion	896.9							
Schwartz's Bayesian criterion	900.5							
(-2) Res Log Likelihood	894.9							
	Type 3 Tests of Fixed Effects							
Significance (Pr>Chi) of Type 3	AREA	YEAR	SEASON					
test of fixed effects for each factor	<.0001	<.0001	<.0001					
DF	3	8	2.000					
CHI SQUARE	53.6500	59.3900	21.680					

Table 5. The relative standardized index of abundance from fishery independent gillnet catches, coefficients of variance (CV), and number of sets (N) for large coastal sharks, 1996-2004.

YEAR	N	RELATIVE INDICES	CV
1996	26	0.511	0.241
1997	27	1.637	0.132
1998	68	0.607	0.310
1999	48	0.969	0.297
2000	54	0.811	0.326
2001	91	1.549	0.211
2002	130	0.936	0.201
2003	150	1.072	0.186
2004	117	0.908	0.220

Table 6. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for all blacktip sharks. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	901.705	1.268			-450.852		
AREA	708	724.381	1.023	19.325	19.325	-362.190	177.320	<.0001
YEAR	703	871.448	1.240	2.256		-435.724	30.260	0.0002
SEASON	709	889.820	1.255	1.040		-444.910	11.880	0.0026
SETDEPTH	710	896.375	1.263	0.451		-448.188	5.330	0.0210
TIME	708	895.277	1.265	0.292		-447.638	6.430	0.0925
AREA +								
SEASON	706	712.1129	1.009	20.467	1.142	-356.056	12.27	0.0022
YEAR	700	715.252	1.022	19.431		-357.626	9.13	0.3315
AREA + SEASON +								
YEAR	698	699.7346	1.002	20.953	0.487	-349.867	12.38	0.1351

FINAL MODEL: AREA + SEASON + YEAR

Akaike's information criterion 3405.9

Schwartz's Bayesian criterion 3410.5

(-2) Res Log Likelihood 3403.9

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	AREA	SEASON	YEAR
test of fixed effects for each factor	<.0001	0.0007	0.1615
DF	3	2	8
CHI SQUARE	124.22	14.40	11.78

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	233	1154.614	4.955			911.009		
TIME	230	977.904	4.252	14.200		999.364	176.71	<.0001
AREA	230	1007.900	4.382	11.568	11.568	984.366	146.71	<.0001
YEAR	225	1006.557	4.474	9.723		985.037	148.06	<.0001
SEASON	231	1139.567	4.933	0.449		918.532	15.05	0.0005
SETDEPTH	232	1153.211	4.971	-0.309		911.710	1.4	0.2363
TIME +								
AREA	227	857.950	3.780	23.730	9.530	1059.341	119.95	<.0001
YEAR	222	939.666	4.233	14.584		1018.483	38.24	<.0001
TIME + AREA +								
YEAR	219	825.608	3.770	23.924	0.194	1075.512	32.34	<.0001
TIME + AREA + YEAR								
YEAR*TIME	208	778.282	3.742	24.492	0.568	1099.175	47.33	<.0001
YEAR*AREA	202	787.513	3.899	21.327		1094.559	38.09	0.0024

FINAL MODEL: TIME + AREA + YEAR YEAR*TIME

Akaike's information criterion 703.0

Schwartz's Bayesian criterion 705.2

(-2) Res Log Likelihood 699.0

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	TIME	AREA	YEAR
test of fixed effects for each factor	0.3291	0.0002	0.5180
DF	3	3	8
CHI SQUARE	3.44	19.9900	5.38

Table 7. The relative standardized index of abundance from fishery independent gillnet catches, coefficients of variance (CV), and number of sets (n) for all blacktip sharks, juvenile blacktip sharks, and age-0 blacktip sharks, 1996-2004.

		ALL BLACKTIP		JUVENILE BLACKTIP		AGE 0 BLACKTIP	
YEAR	**N**	**RELATIVE INDICES**	**CV**	**RELATIVE INDICES**	**CV**	**RELATIVE INDICES**	**CV**
1996	26	0.695	0.475	0.980	0.427	0.152	1.063
1997	27	1.397	0.287	1.513	0.279	0.782	0.397
1998	68	0.565	0.451	0.639	0.455	0.654	0.586
1999	49	1.209	0.359	1.068	0.412	2.101	0.388
2000	54	0.769	0.484	0.649	0.632	0.676	0.737
2001	91	1.583	0.286	1.408	0.312	2.130	0.350
2002	130	0.872	0.283	0.854	0.305	1.260	0.293
2003	150	0.909	0.283	0.790	0.318	1.012	0.334
2004	117	1.001	0.307	1.098	0.294	0.232	0.823

Table 8. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for juvenile blacktip sharks. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	843.685	1.187			-421.842		
AREA	708	708.850	1.001	15.626	15.626	-354.425	134.830	<.0001
YEAR	703	812.648	1.156	2.583		-406.324	31.040	0.0001
SEASON	709	832.116	1.174	1.093		-416.058	11.570	0.0031
SETDEPTH	710	835.351	1.177	0.848		-417.676	8.330	0.0039
TIME	708	834.998	1.179	0.610		-417.499	8.690	0.0338
AREA +								
SEASON	706	696.6109	0.987	16.848	1.222	-348.305	12.24	0.0022
YEAR	700	695.4136	0.993	16.279		-347.707	13.44	0.0977
AREA + SEASON +								
YEAR	698	679.7895	0.974	17.925	1.078	-339.895	16.82	0.032
AREA + SEASON + YEAR								
YEAR*AREA	678	647.262	0.955	19.547	1.622	-323.631	Negative of Hessian not positiv	
YEAR*SEASON	682	654.216	0.959	19.160		-327.108	25.57	0.0603
AREA*SEASON	692	673.155	0.973	18.022		-336.577	6.640	0.3559

FINAL MODEL: AREA + SEASON + YEAR

Akaike's information criterion 3469.1

Schwartz's Bayesian criterion 3473.6

(-2) Res Log Likelihood 3467.1

Type 3 Tests of Fixed Effects

	AREA	SEASON	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0009	0.0496
DF	3	2.000	8.000
CHI SQUARE	94.11	13.970	15.530

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	198	920.743	4.650			582.723		
TIME	195	769.083	3.944	15.186	15.186	658.553	151.66	<.0001
YEAR	190	798.021	4.200	9.679		644.084	122.72	<.0001
AREA	195	866.039	4.441	4.494		610.075	54.7	<.0001
SEASON	196	913.262	4.660	-0.200		586.463	7.48	0.0237
SETDEPTH	197	918.783	4.664	-0.294		583.703	1.96	0.1616
TIME +								
AREA	192	730.850	3.807	18.143	2.957	677.670	38.23	<.0001
YEAR	187	743.549	3.976	14.494		671.320	25.53	0.0013
TIME + AREA +								
YEAR	184	707.360	3.844	17.330	-0.814	689.415	23.49	0.0028
AREA*TIME	178	653.897	3.674	21.002	3.672	716.146	53.46	<.0001
YEAR*TIME	174	673.299	3.870	16.788		706.445	34.06	0.0002
YEAR*AREA	167	668.929	4.006	13.863		708.630	38.43	0.0021

FINAL MODEL: TIME + AREA + YEAR AREA*TIME

Akaike's information criterion 603.2

Schwartz's Bayesian criterion 606.3

(-2) Res Log Likelihood 601.2

Type 3 Tests of Fixed Effects

	TIME	AREA	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	0.9174	0.0777	0.6267
DF	3	3	8
CHI SQUARE	0.51	6.8200	6.18

Table 9. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for age 0 blacktip sharks. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	492.098	0.692			-246.049		
AREA	708	372.114	0.526	24.062	24.062	-186.057	119.980	<.0001
SEASON	709	470.878	0.664	4.042		-235.439	21.220	<.0001
YEAR	703	473.594	0.674	2.665		-236.797	18.500	0.0177
TIME	708	490.064	0.692	-0.009		-245.032	2.030	0.5654
SETDEPTH	710	491.488	0.692	-0.017		-245.744	0.610	0.4346
AREA +								
SEASON	706	353.1638	0.500	27.725	3.663	-176.582	18.95	<.0001
YEAR	700	360.9913	0.516	25.490		-180.496	11.12	0.1948
AREA + SEASON +								
YEAR	698	339.9495	0.487	29.632	1.907	-169.975	13.21	0.1047

FINAL MODEL: AREA + SEASON + YEAR

Akaike's information criterion

Schwartz's Bayesian criterion

(-2) Res Log Likelihood

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	AREA	SEASON	YEAR
test of fixed effects for each factor	<.0001	<.0001	0.05
DF	2	2.000	8.000
CHI SQUARE	72.01	18.780	15.330

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	77	212.082	2.754			-63.525		
YEAR	69	95.374	1.382	49.816	49.816	-5.171	116.71	<.0001
SEASON	75	179.857	2.398	12.933		-47.413	32.22	<.0001
TIME	74	179.533	2.426	11.916		-47.251	32.55	<.0001
AREA	75	191.905	2.559	7.101		-53.437	20.18	<.0001
SETDEPTH	76	212.056	2.790	-1.304		-63.512	0.03	0.8724
YEAR +								
AREA	67	88.610	1.323	51.983	2.167	-1.789	6.76	0.0340
SEASON	67	89.972	1.343	51.245		-2.470	5.4	0.0671
TIME	66	94.311	1.429	48.119		-4.640	1.060	0.7861
YEAR + AREA +								
SEASON	65	81.941	1.261	54.230	2.248	1.545	6.67	0.0356
YEAR* AREA	57	75.686	1.328	51.791	-2.439	4.673	6.26	0.6186
YEAR* SEASON	57	78.585	1.379	49.944		3.223	3.36	0.9100

FINAL MODEL: YEAR + AREA + SEASON

Akaike's information criterion 180.3

Schwartz's Bayesian criterion 182.5

(-2) Res Log Likelihood 178.3

Type 3 Tests of Fixed Effects

Significance (Pr>Chi) of Type 3	YEAR	AREA	SEASON
test of fixed effects for each factor	<.0001	0.0180	0.0356
DF	8	2	2
CHI SQUARE	72.37	8.0300	0.04

Table 10. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for juvenile sandbar sharks. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	254.944	0.359			-127.472		
AREA	708	188.622	0.266	25.701	25.701	-94.311	66.320	<.0001
YEAR	703	224.604	0.319	10.898		-112.302	30.340	0.0002
TIME	708	242.005	0.342	4.673		-121.003	12.940	0.0048
SETDEPTH	710	251.656	0.354	1.151		-125.828	3.290	0.0698
SEASON	709	253.784	0.358	0.174		-126.892	1.160	0.5600
AREA +								
YEAR	700	162.6653	0.232	35.193	9.492	-81.333	25.96	0.0011
TIME	705	174.4811	0.247	30.979		-87.241	Negative of Hessian not positive definite.	
AREA + YEAR								
AREA * YEAR	680	157.1029	0.231	35.568	0.375	-78.551	Negative of Hessian not positive definite.	

FINAL MODEL: AREA + YEAR

Akaike's information criterion 2834.3

Schwartz's Bayesian criterion 2838.4

(-2) Res Log Likelihood 2832.3

	Type 3 Tests of Fixed Effects	
Significance (Pr>Chi) of Type 3	AREA	YEAR
test of fixed effects for each factor	<.0001	<.0001
DF	1	8
CHI SQUARE	32.76	45.000

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	30	81.149	2.705			-14.471		
YEAR	22	18.777	0.854	68.447	68.447	16.714	62.37	<.0001
TIME	28	43.824	1.565	42.138		4.191	37.32	<.0001
SETDEPTH	29	47.704	1.645	39.187		2.251	33.44	<.0001
AREA	29	73.353	2.529	6.489		-10.574	7.8	0.0052
SEASON	28	77.958	2.784	-2.930		-12.876	3.19	0.2029
YEAR +								
TIME	20	16.614	0.831	69.289	0.843	17.796	2.16	0.3391
SETDEPTH	21	18.286	0.871	67.808		16.960	0.49	0.4835
AREA	21	18.7761	0.894	66.946		16.7148	0	0.9745

FINAL MODEL: YEAR

Akaike's information criterion 56.1

Schwartz's Bayesian criterion 57.2

(-2) Res Log Likelihood 54.1

	Type 3 Tests of Fixed Effects
Significance (Pr>Chi) of Type 3	TIME
test of fixed effects for each factor	<.0001
DF	8
CHI SQUARE	50.57

Table 11. The relative standardized index of abundance from fishery independent gillnet catches, coefficients of variance (CV), and number of sets (N) for all sandbar sharks, 1996-2004.

YEAR	N	RELATIVE INDICES	CV
1996	26	0.485	0.653
1997	27	1.167	0.563
1998	68	3.424	0.456
1999	49	0.459	2.283
2000	54	0.769	1.603
2001	91	1.075	0.808
2002	130	0.388	1.137
2003	150	0.76	0.721
2004	117	0.472	1.441

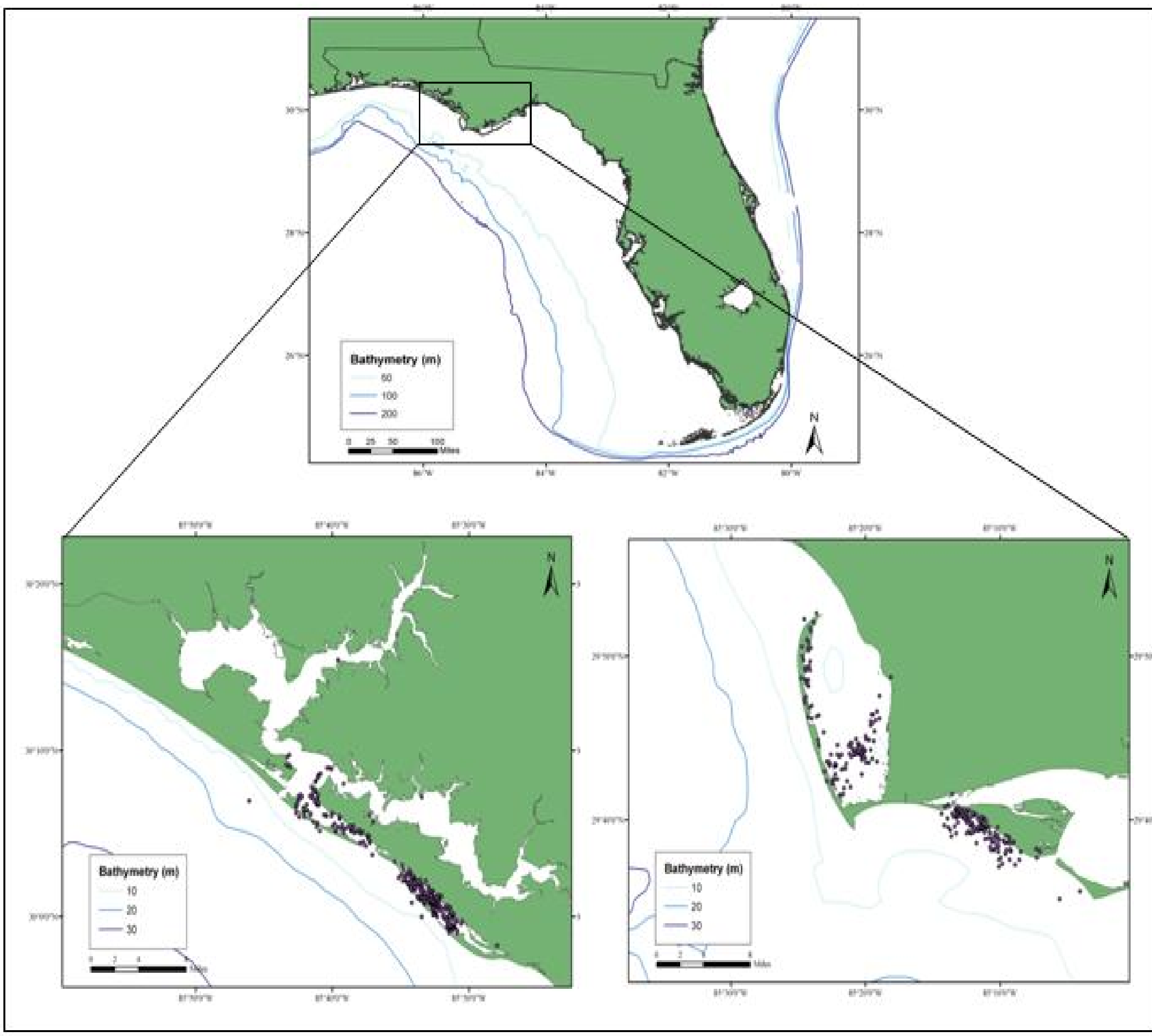

Figure 1. Location of study site in northwest Florida near latitude 30° 00’ N and longitude 85° 35’ W. Locations of sets of fishing gear are represented by dots.

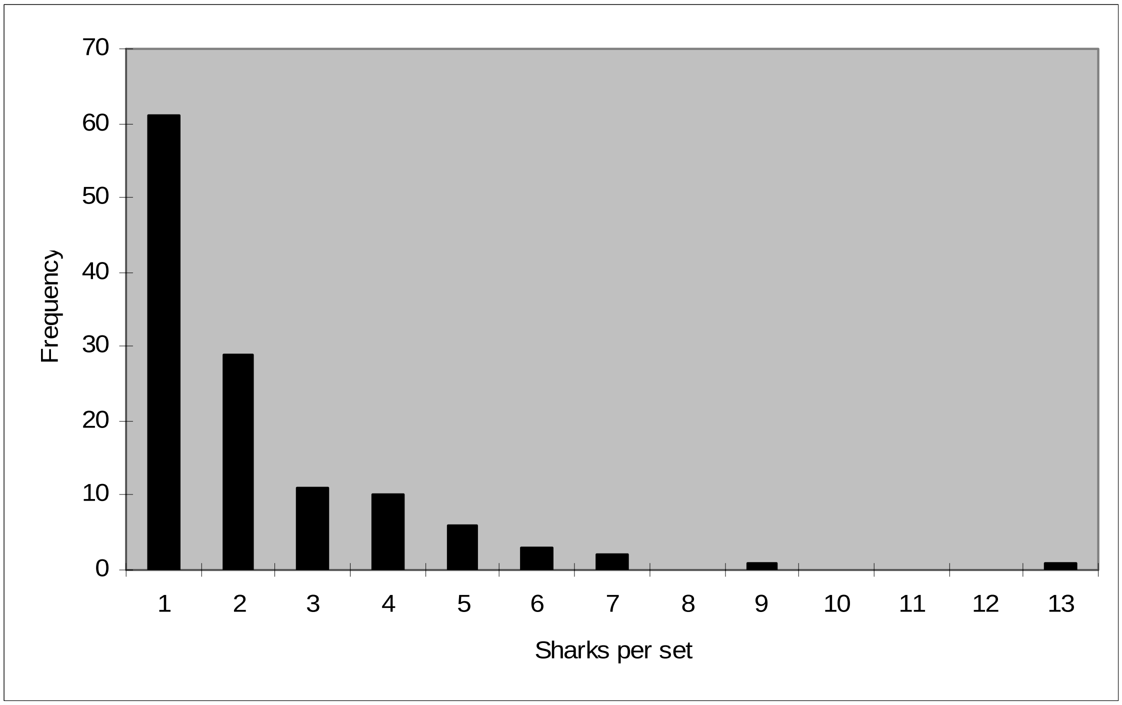

Figure 2. Frequency distribution of positive sets for the large coastal shark aggregate caught using longlines.

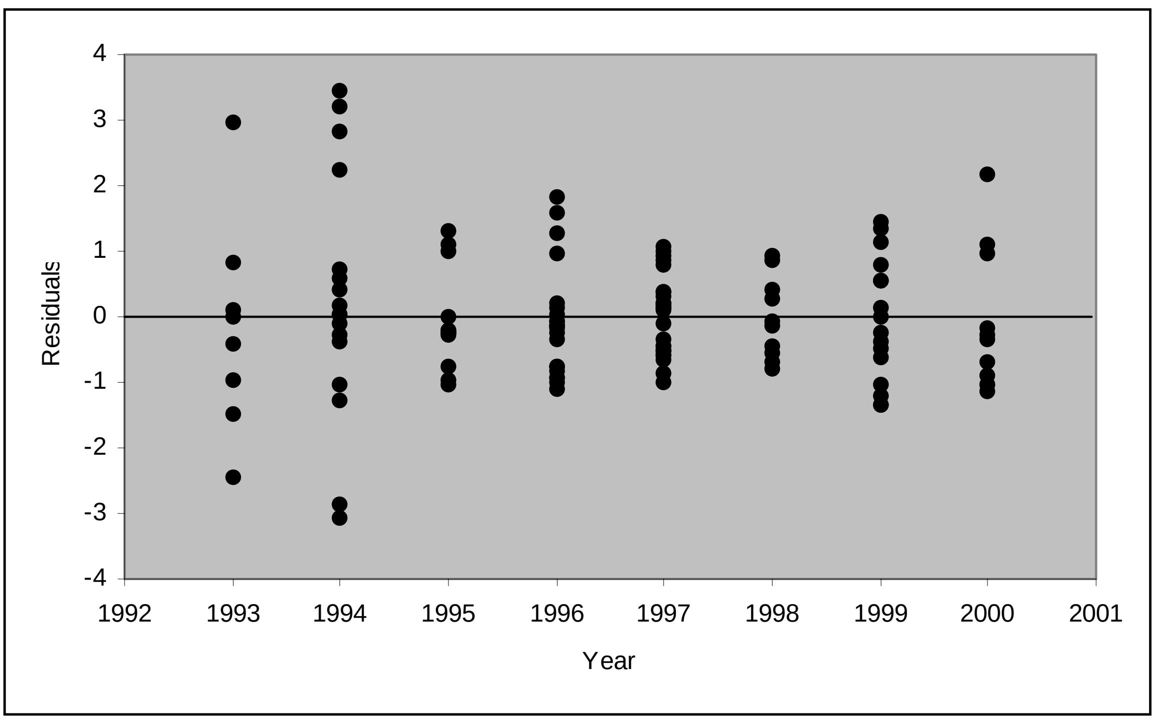

Figure 3. Residuals for the poisson model on positive catch rates by year for the large coastal shark aggregate caught using longlines.

Figure 4. Standardized and nominal relative abundance trends for the large coastal shark aggregate caught using longlines.

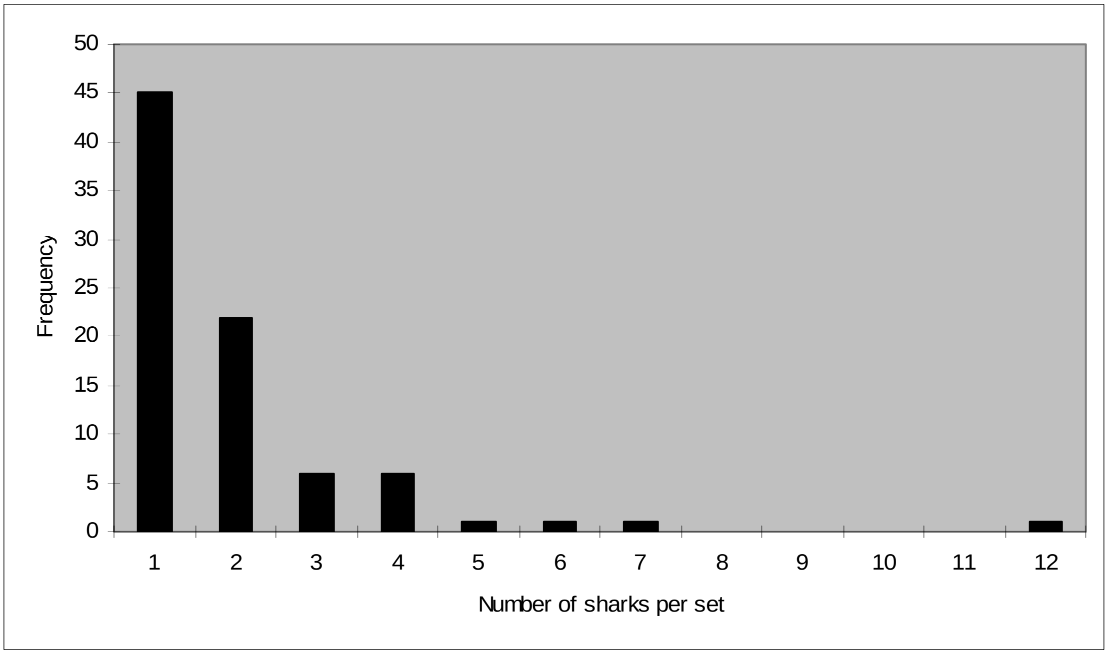

Figure 5. Frequency distribution of positive sets for blacktip sharks caught using longlines.

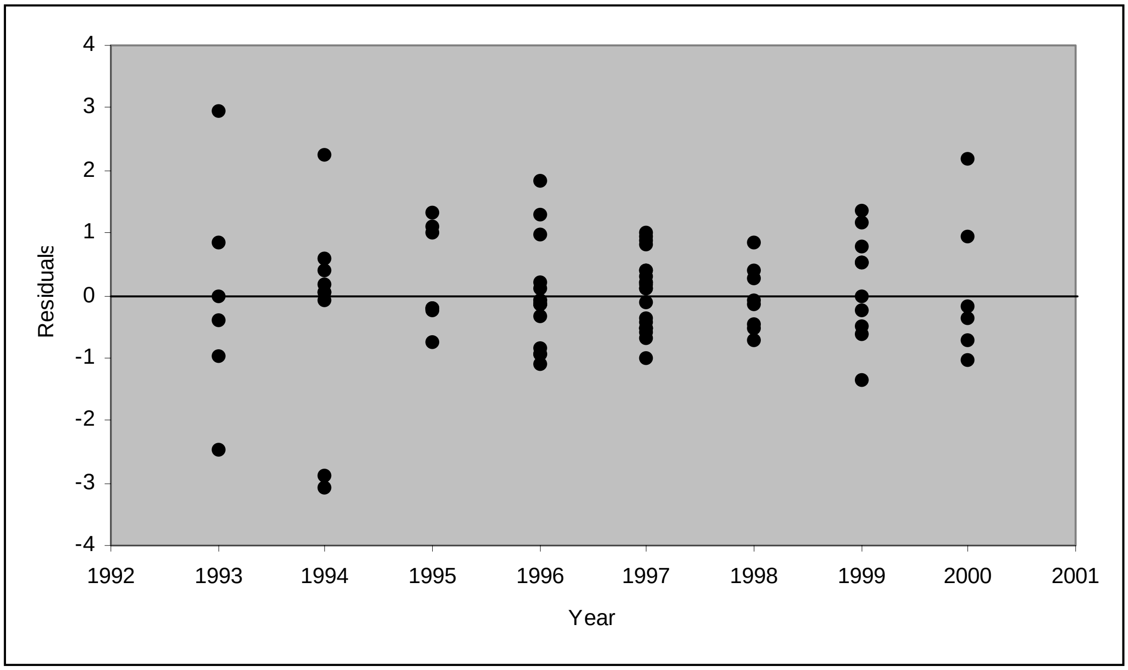

Figure 6. Residuals for the poisson model on positive catch rates by year for blacktip sharks caught using longlines.

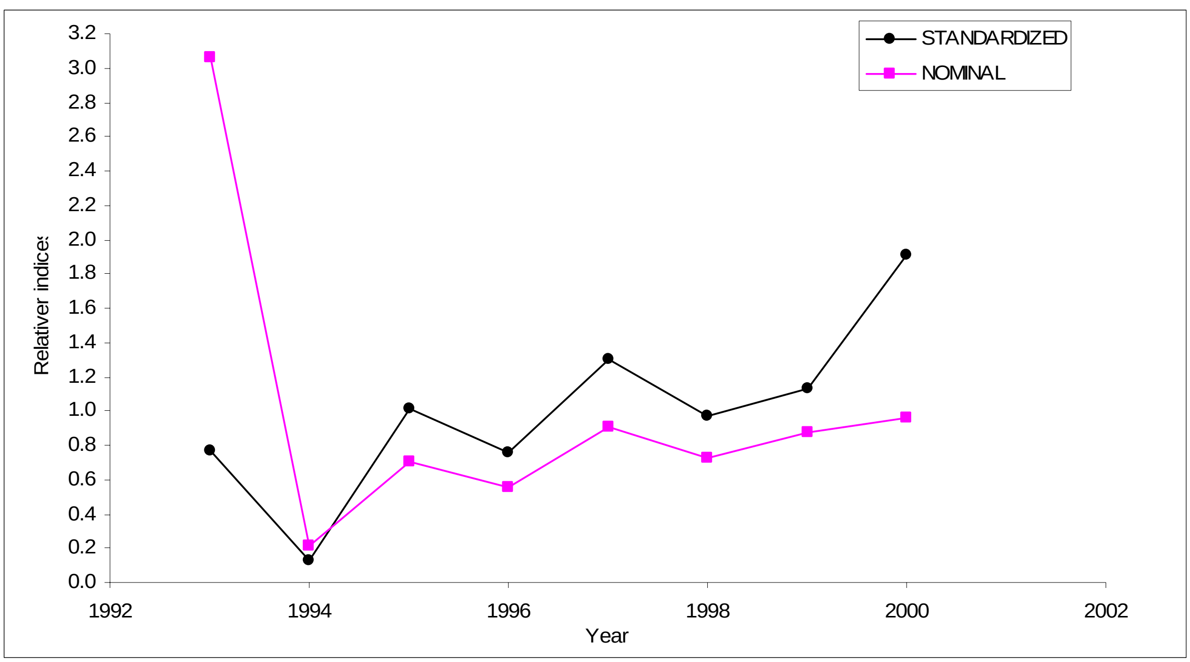

Figure 7. Standardized and nominal relative abundance trends for blacktip sharks caught using longlines.

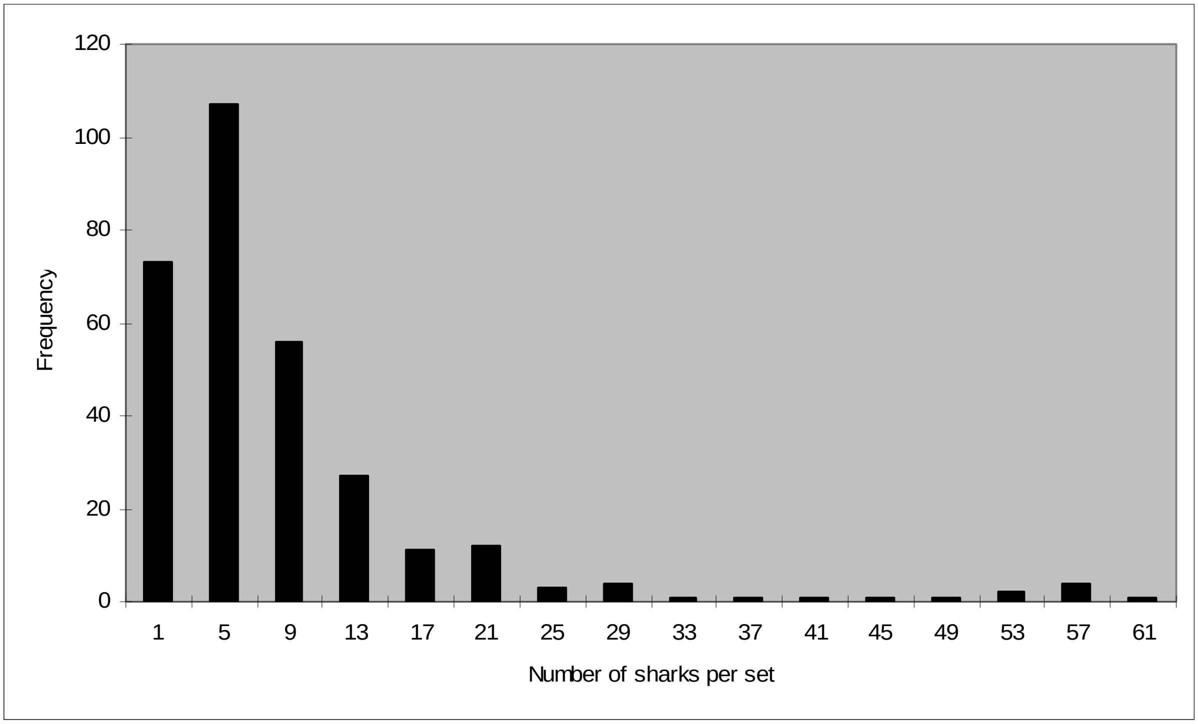

Figure 8. Frequency distribution of positive sets for the large coastal shark aggregate caught using gillnets.

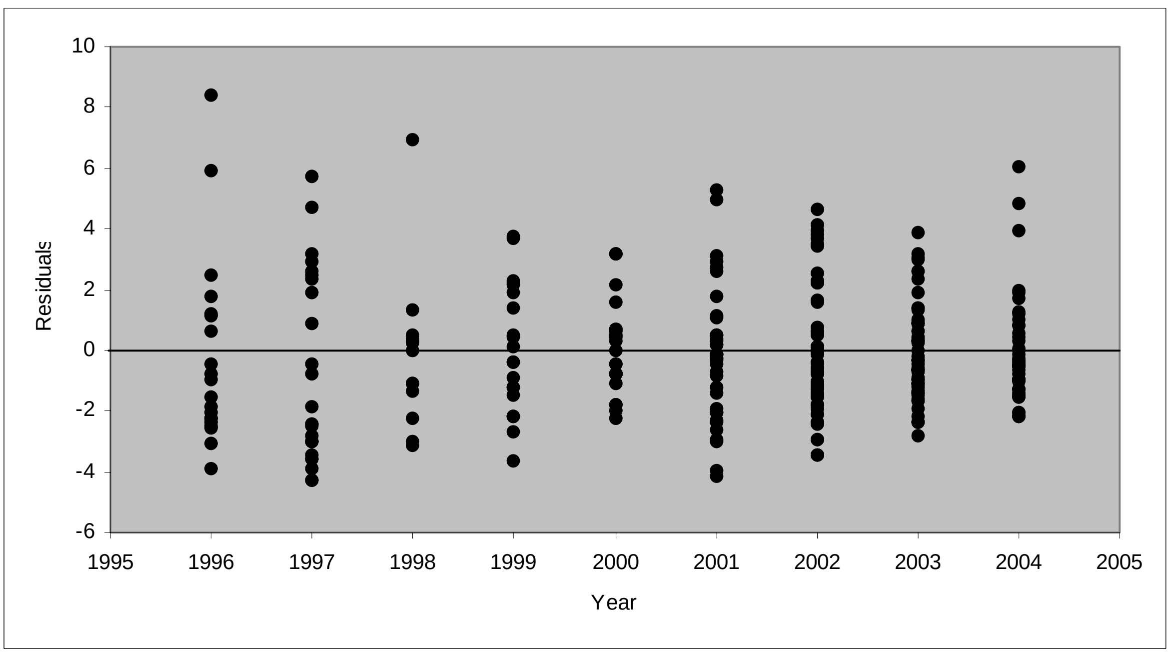

Figure 9. Residuals for the poisson model on positive catch rates by year for the large coastal shark aggregate caught using gillnets.

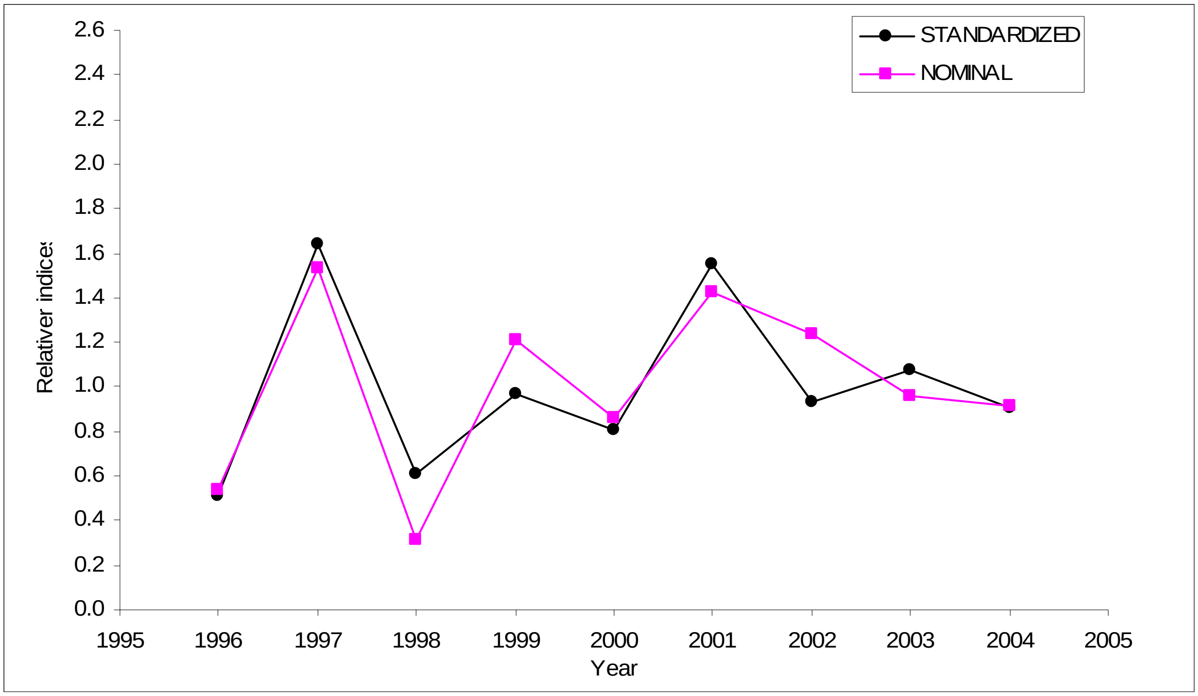

Figure 10. Standardized and nominal relative abundance trends for large coastal sharks caught using gillnets.

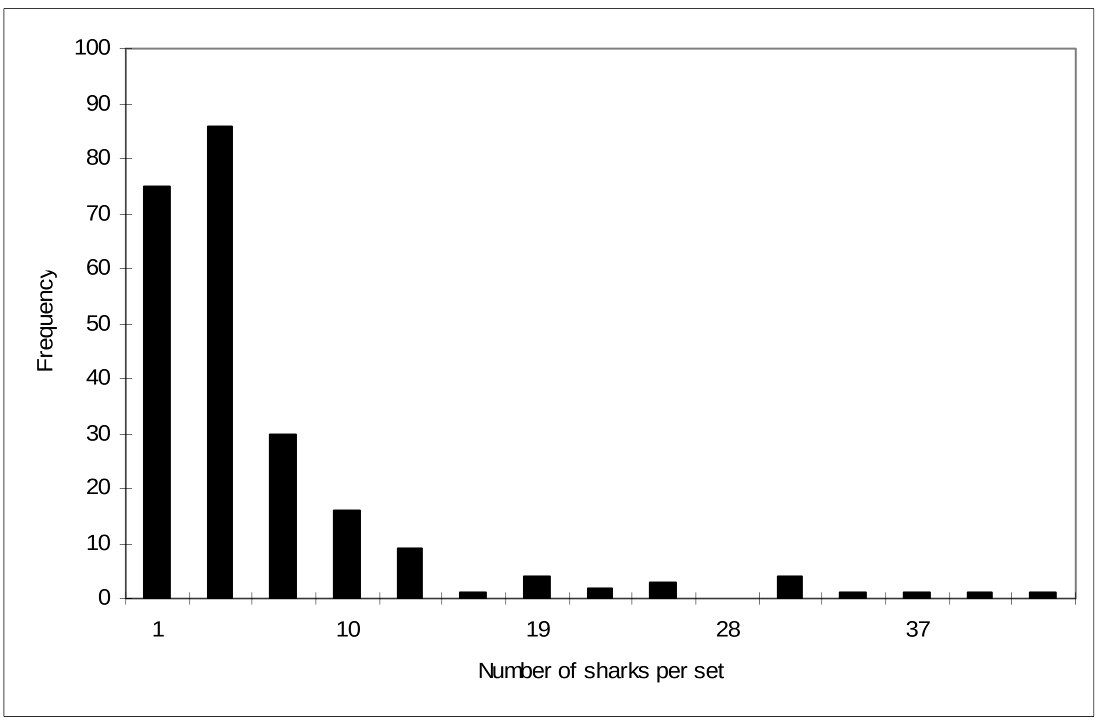

Figure 11. Frequency distribution of positive sets for all blacktip sharks caught using gillnets.

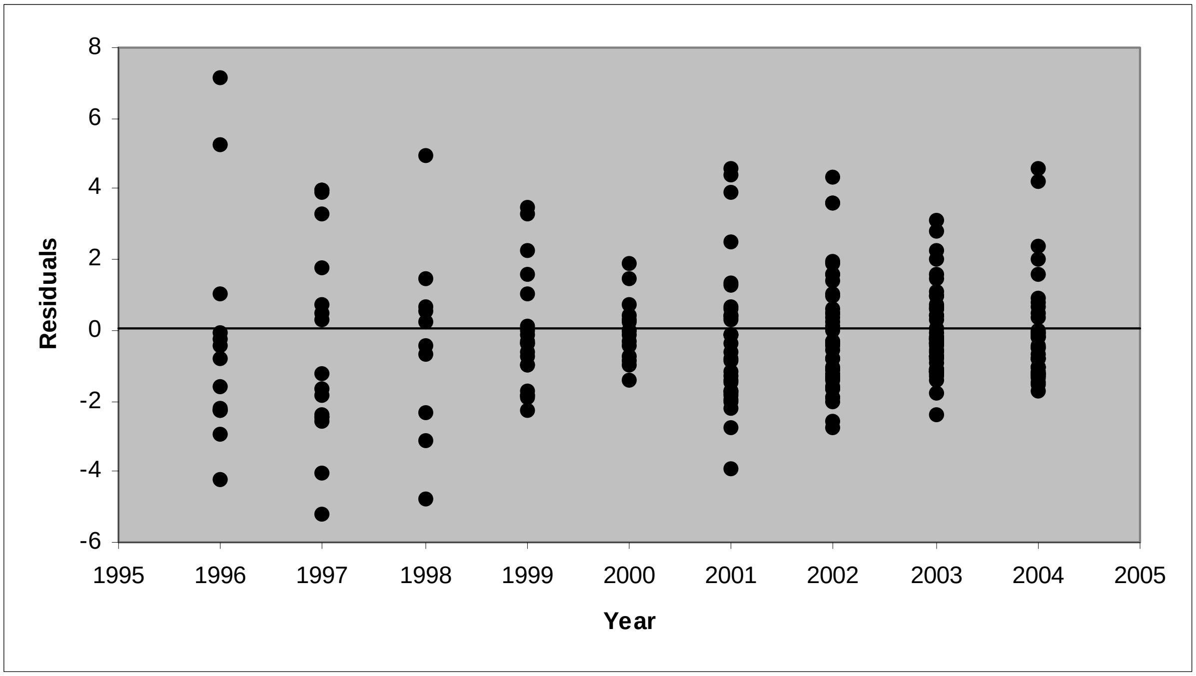

Figure 12. Residuals for the poisson model on positive catch rates by year for all blacktip sharks caught using gillnets.

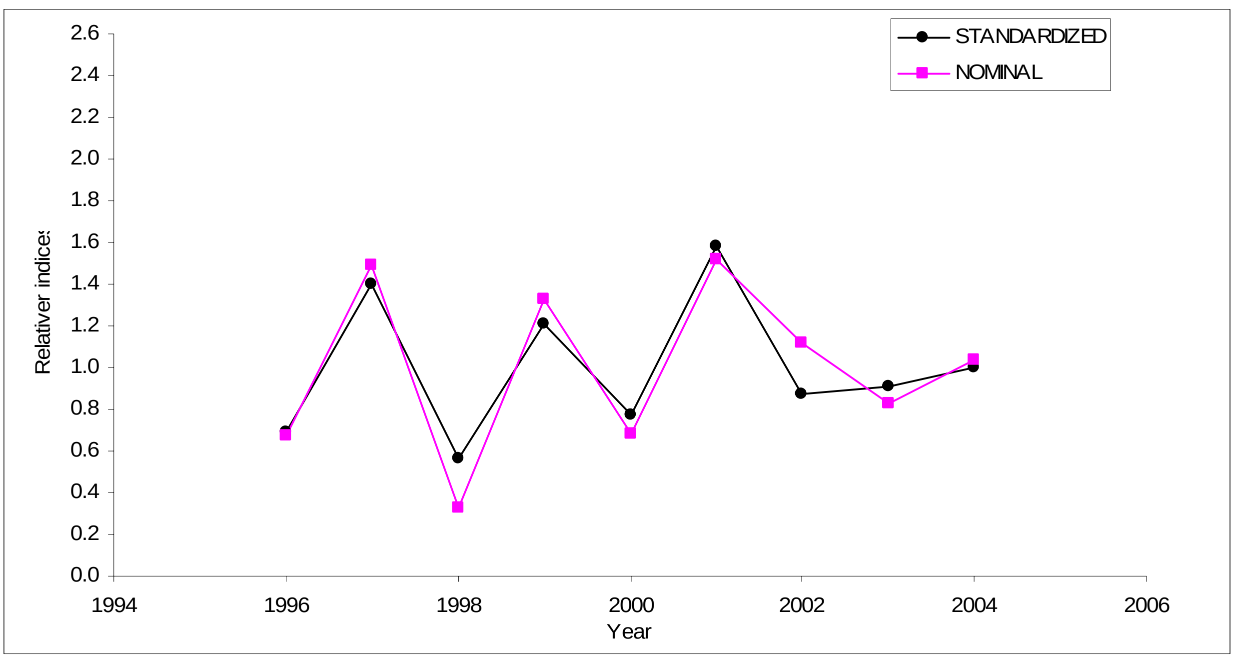

Figure 13. Standardized and nominal relative abundance trends for all blacktip sharks caught using gillnets.

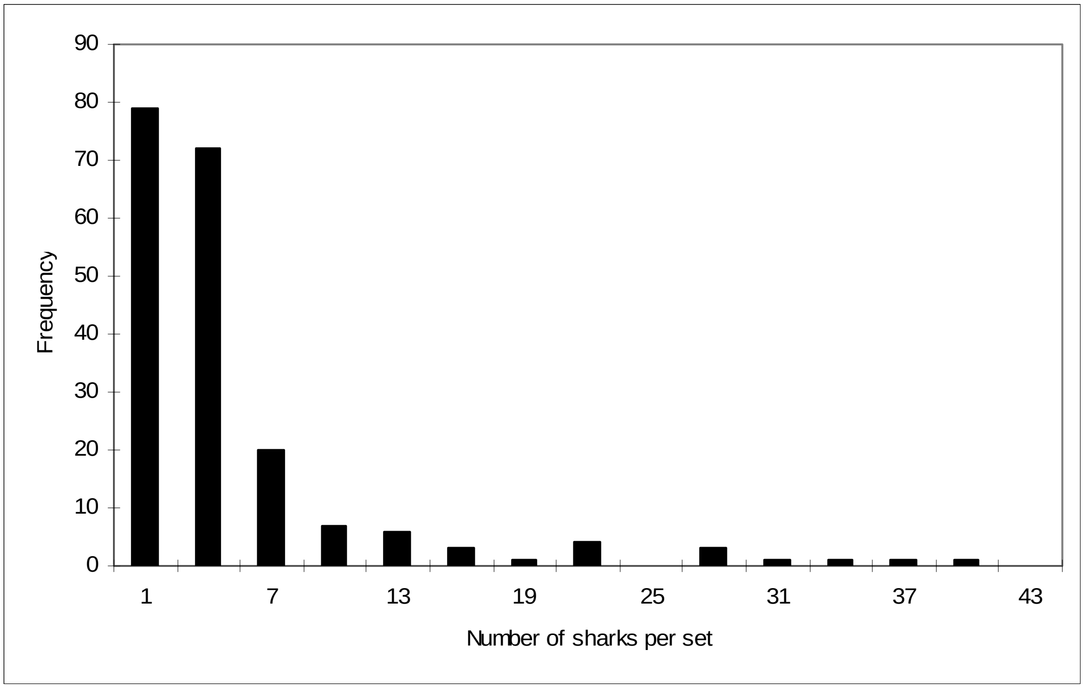

Figure 14. Frequency distribution of positive sets for juvenile blacktip sharks caught using gillnets.

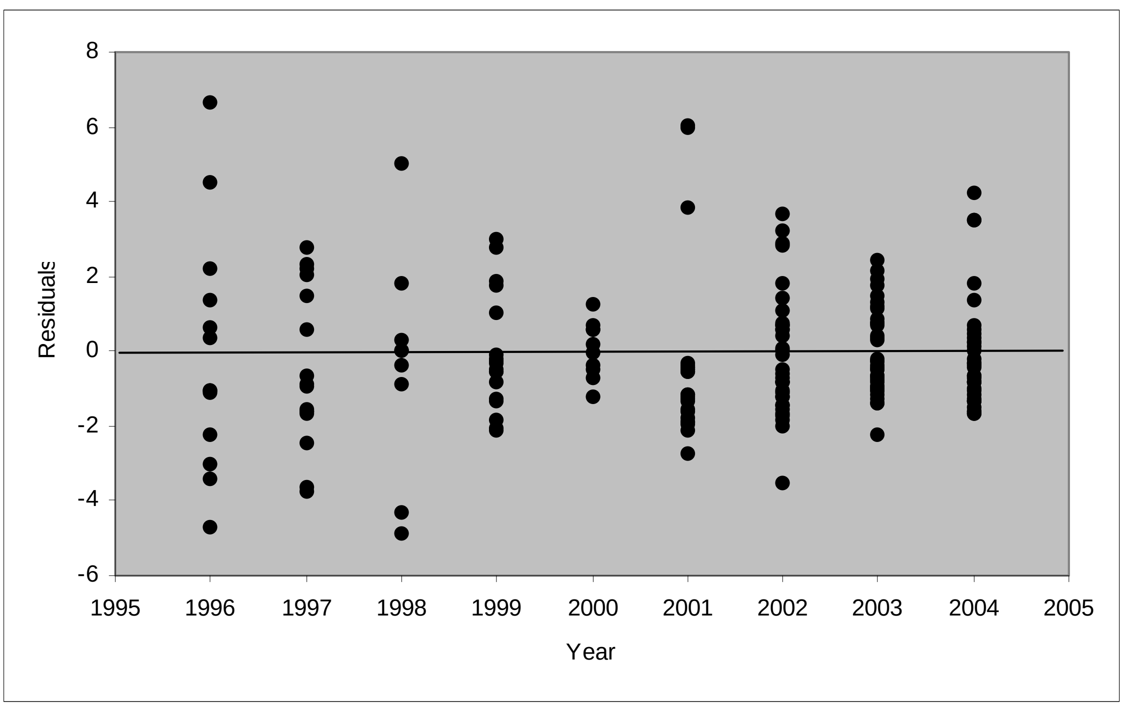

Figure 15. Residuals for the poisson model on positive catch rates by year for juvenile blacktip sharks caught using gillnets.

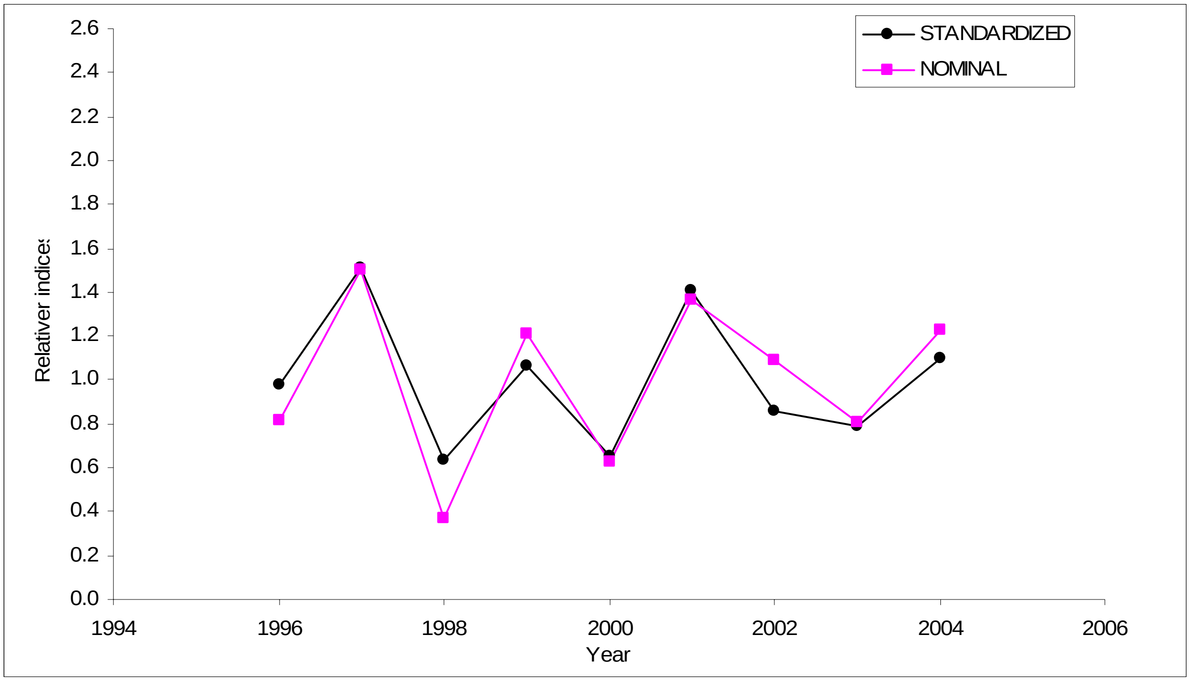

Figure 16. Standardized and nominal relative abundance trends for juvenile blacktip sharks caught using gillnets.

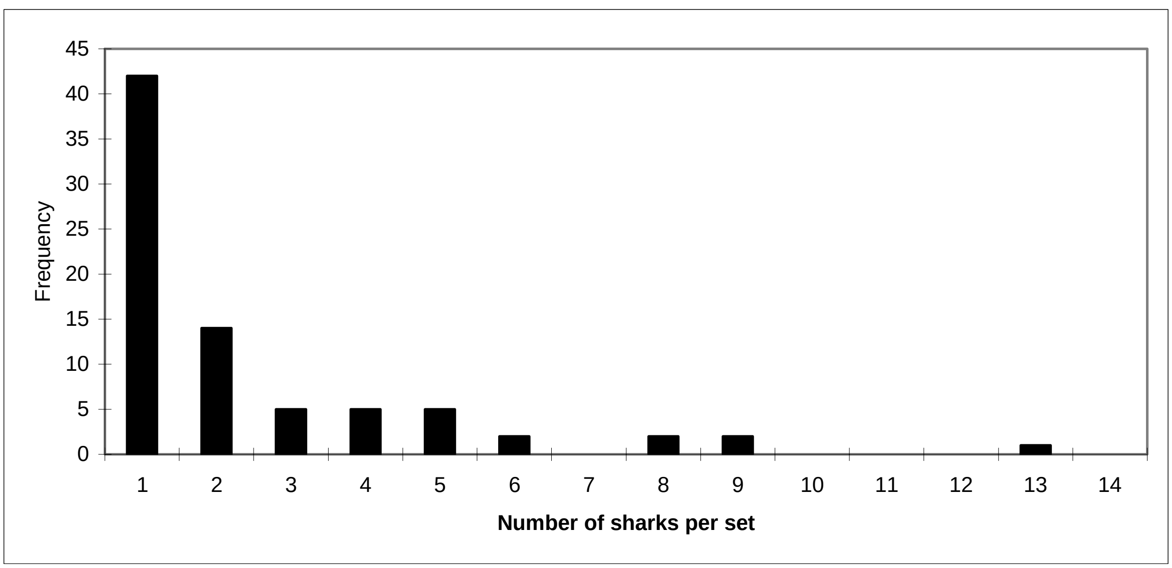

Figure 17. Frequency distribution of positive sets for age 0 blacktip sharks caught using gillnets.

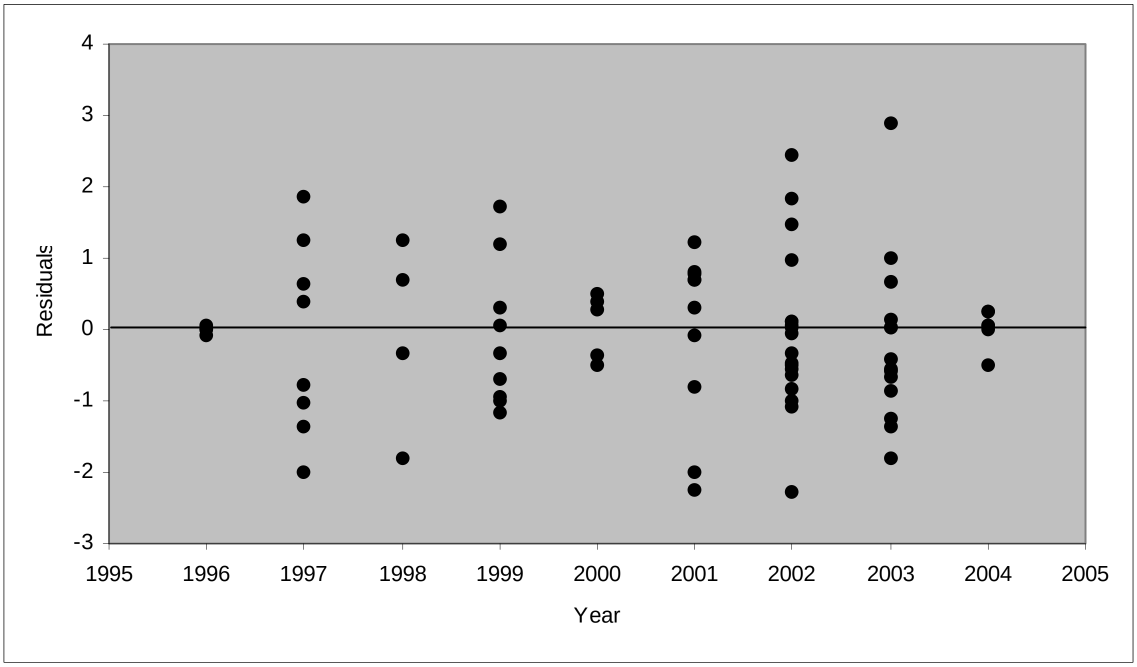

Figure 18. Residuals for the poisson model on positive catch rates by year for age 0 blacktip sharks caught using gillnets.

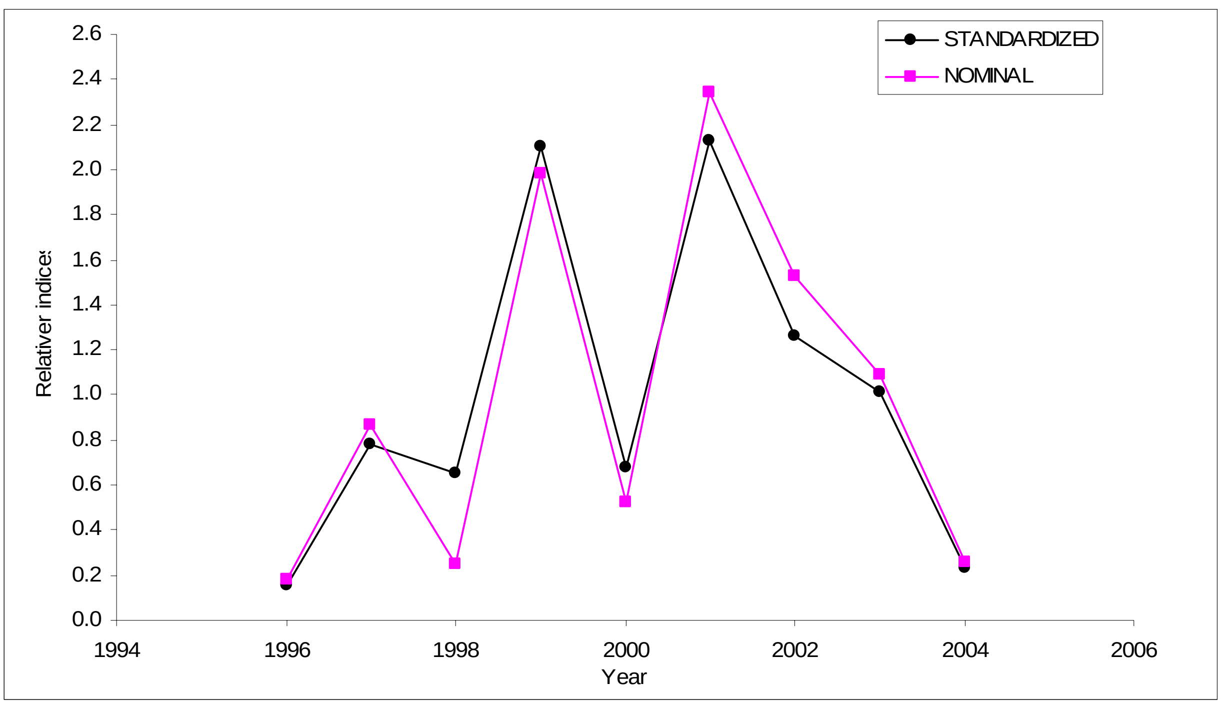

Figure 19. Standardized and nominal relative abundance trends for age 0 blacktip sharks caught using gillnets.

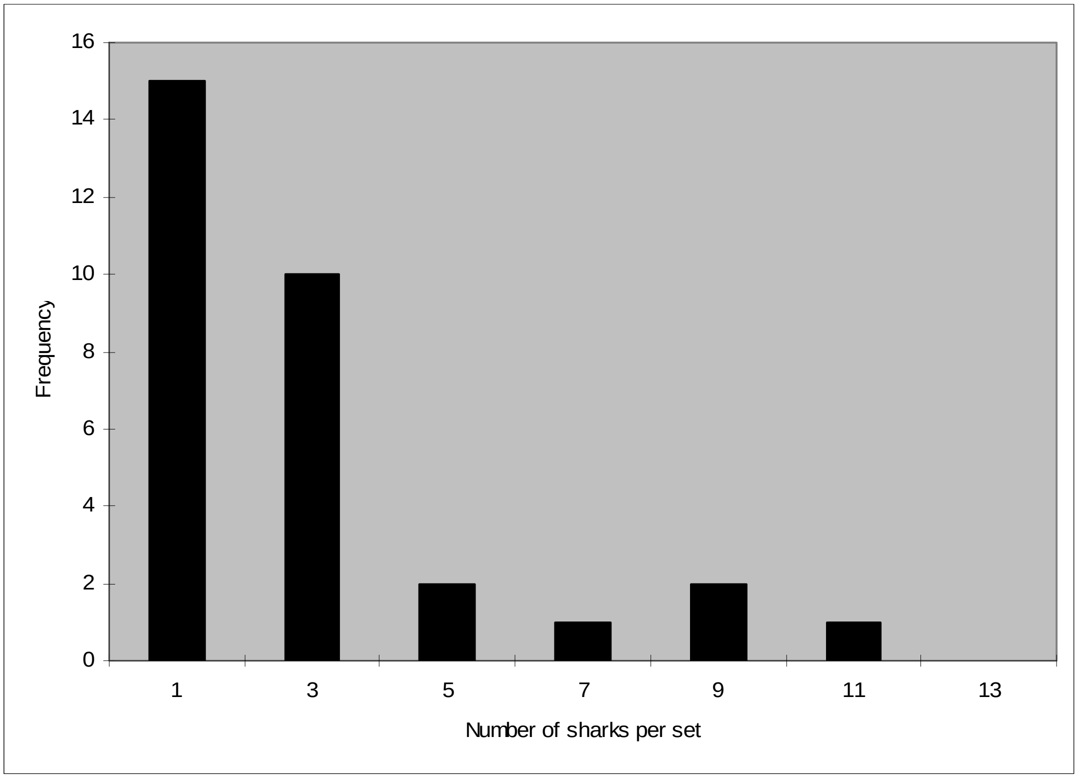

Figure 20. Frequency distribution of positive sets for sandbar sharks caught using gillnets.

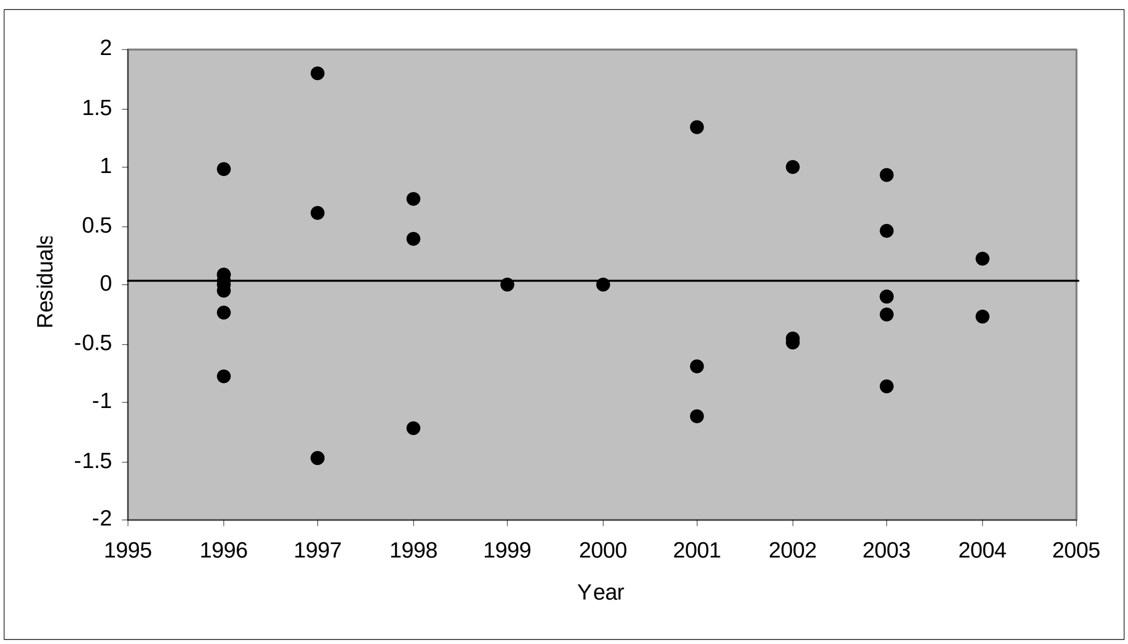

Figure 21. Residuals for the poisson model on positive catch rates by year for sandbar sharks caught using gillnets.

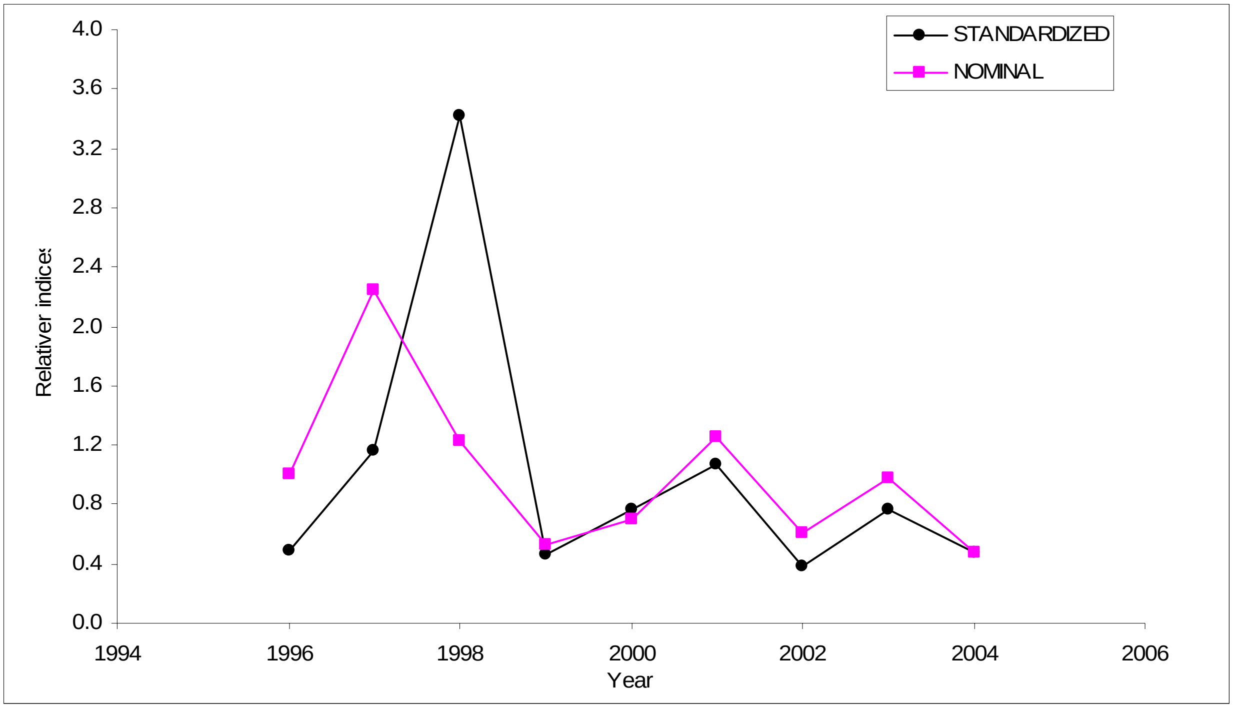

Figure 22. Standardized and nominal relative abundance trends for sandbar sharks caught using gillnets.

DRAFT-DO NOT REFERENCE

APPENDIX TO LCS05/06-DW-12
(STANDARDIZED CATCH RATES OF LARGE COASTAL SHARKS FROM A FISHERY-INDEPENDENT SURVEY IN NORTHWEST FLORIDA)

Introduction

Based on discussion at the 2005 Shark SEDAR Data workshop, the present appendix to document **LCS05/06-DW-12** attempts to standardize catch rates for the large coastal species-aggregate minus prohibited species minus blacktip shark minus sandbar shark. All analysis followed standardization procedures outline in **LCS05/06-DW-12.** No other series were attempted to be modeled because of low sample size. In addition, because of the small sample size associated with the juvenile sandbar shark series and the GLM model overcompensating in some years, the catch rate group suggested presenting this time series as a nominal series only.

Results

<u>Gillnet</u>

Large coastal species-aggregate (minus prohibited species minus blacktip shark minus sandbar shark)

The percentage of sets with zero catches was 71.3% for this group. The stepwise constructions of the models are in Table 1a. The final binomial model was *Proportion positive sets=Area + Season + Time + Year.* The final poisson model was *Positive large coastal sets =Year + Season + Setdepth*. First order interactions were run but found not to be significant. The standardized abundance index is shown in Figure 1a. 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 2a.

Sandbar sharks

The nominal series for juvenile sandbar shark is in Table 3a.

Table 1a. Results of the stepwise procedure for development of the fishery independent gillnet catch rate model for the large coastal shark aggregate minus prohibited species minus blacktip shark minus sandbar shark. %DIFF 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	CHISQUARE	PR>CHI
NULL	711	852.981	1.200			-426.490		
AREA	708	684.694	0.967	19.389	19.389	-342.347	168.290	<.0001
YEAR	703	808.497	1.150	4.137		-404.248	44.48	<.0001
SEASON	709	821.550	1.159	3.413		-410.775	31.430	<.0001
TIME	708	831.966	1.175	2.050		-415.983	21.010	0.0001
SETDEPTH	710	849.040	1.196	0.322		-424.520	3.940	0.0471
AREA +								
SEASON	706	654.9893	0.928	22.668	3.279	-327.495	29.7	<.0001
TIME	705	660.7737	0.937	21.874		-330.387	23.92	<.0001
YEAR	700	666.564	0.952	20.627		-333.282	18.13	0.0203
AREA + SEASON +								
TIME	703	631.046	0.898	25.177	2.509	-315.523	23.940	<.0001
YEAR	698	633.888	0.908	24.301		-316.944	21.1	0.0069
AREA + SEASON + TIME								
YEAR	695	621.782	0.895	25.427	0.250	-310.891	9.260	0.3205
AREA + SEASON + TIME + YEAR								
AREA*SEASON	689	612.9436	0.890	25.847		-306.472	8.84	0.1829
AREA*TIME	687	604.3879	0.880	26.669		-302.194	Negative of Hessian not positive definite.	
AREA*YEAR	675	584.7926	0.866	27.785		-292.396	Negative of Hessian not positive definite.	
SEASON*TIME	689	611.7257	0.888	25.994		-305.863	10.06	0.1223
TIME*YEAR	680	603.7493	0.888	25.992		-301.875	Negative of Hessian not positive definite.	

FINAL MODEL: AREA + SEASON + TIME + YEAR

Akaike's information criterion	3709.8
Schwartz's Bayesian criterion	3714.3
(-2) Res Log Likelihood	3707.8

Table 1a continued.

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	203	1128.792	5.561			555.772		
YEAR	195	729.427	3.741	32.729	32.729	755.454	399.36	<.0001
SEASON	201	1006.763	5.009	9.923		616.786	122.03	<.0001
TIME	200	1013.320	5.067	8.883		613.508	115.47	<.0001
SETDEPTH	202	1034.408	5.121	7.908		602.964	94.38	<.0001
AREA	200	1057.049	5.285	4.951		591.644	71.74	<.0001
YEAR +								
SEASON	193	631.635	3.273	41.144	8.415	804.350	97.79	<.0001
AREA	192	678.319	3.533	36.465		781.008	51.11	<.0001
SETDEPTH	194	725.960	3.742	32.703		757.188	3.47	0.0626
TIME	192	718.487	3.742	32.702		760.924	10.94	0.0121
YEAR + SEASON								
SETDEPTH	190	588.323	3.096	44.314	3.170	826.006	43.31	<.0001
AREA	190	621.9818	3.274	41.128		809.1769	9.65	0.0218
TIME	192	628.692	3.274	41.113		805.822	2.94	0.0862
YEAR + SEASON + SETDEPTH +								
AREA	189	580.5045	3.071	44.764	0.449	829.9155	48.19	<.0001
TIME	189	619.670	3.279	41.037		810.333	9.02	0.0290
YEAR + SEASON + SETDEPTH								
YEAR*SEASON	177	565.3409	3.194	42.559	-2.204	837.4974	63.35	<.0001
YEAR*SETDEPTH	185	597.417	3.229	41.925		821.459	31.27	<.0001
SEASON*SETDEPTH	190.0	628.5294	3.308	40.509		805.903	0.16	0.9218

FINAL MODEL: YEAR + SEASON + SETDEPTH

Akaike's information criterion	588.9
Schwartz's Bayesian criterion	592.2
(-2) Res Log Likelihood	586.9

Table 2a. The relative standardized index of abundance from fishery independent gillnet catches, coefficients of variance (CV), and number of sets (N) for the large coastal shark aggregate minus prohibited species minus blacktip shark minus sandbar shark, 1996-2004

YEAR	RELATIVE INDICES	LCL	UCL	CV	N
1996	0.328	-0.014	0.67	0.532	26
1997	1.197	0.558	1.836	0.272	27
1998	0.521	0.016	1.027	0.494	68
1999	0.973	0.09	1.856	0.463	48
2000	1.112	0.215	2.008	0.411	54
2001	1.682	0.662	2.703	0.309	91
2002	1.129	0.51	1.748	0.28	130
2003	1.022	0.47	1.574	0.276	150
2004	1.034	0.399	1.67	0.314	117

Table 3a. The nominal index (# sharks/net/hr) of abundance from fishery independent gillnets catches and standard deviation (S.D.) for the sandbar shark, 1996-2004.

YEAR	RELATIVE	S.D.
1996	1.00	0.06
1997	2.25	0.24
1998	1.22	0.21
1999	0.53	0.12
2000	0.69	0.18
2001	1.25	0.3
2002	0.61	0.16
2003	0.97	0.19
2004	0.47	0.12

Figure 1A. Standardized and nominal relative abundance trends for the large coastal shark aggregate minus prohibited species minus blacktip shark minus sandbar shark using gillnets.