Standardized catch rates of sandbar sharks and dusky sharks in the VIMS Longline Survey: 1975-2009

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Summary

The Virginia Institute of Marine Science has conducted a fishery-independent longline survey during summer months since 1974. Data for sandbar sharks and dusky sharks captured in the survey between 1975 and 2009 are presented. Most of the sandbar sharks encountered by the survey were immature, with females composing almost all of the mature sandbar catch. Almost all dusky sharks captured were immature. Most of the catch since the early 1990's has been composed of 0-4 year age classes. Nominal and standardized catch rates are presented. CPUE for both species decreased from the early 1980's to minima in 1992. CPUE then slightly increased and has oscillated since.

Materials and Methods

Sampling

The VIMS longline survey is a depth-stratified station-oriented field survey of the Chesapeake Bay and coastal waters from Cape Hatteras, NC to Cape Henlopen, DE with most effort taking place in Virginia waters (Figure 1). The gear used was the standard for the commercial longline industry at the beginning of the VIMS program in 1974. Gear characteristics have remained constant throughout. We used commercial-style longlines consisting of 4.8-mm tarred, nylon mainline that was anchored at each end and marked by buoys equipped with radar reflectors. Three-meter gangions were spaced approximately 18 m apart along the mainline and a large inflatable buoy was attached to the mainline following every 20th gangion. Standard gangions were composed of a stainless-steel tuna clip (quick snap) attached to a 2-m section of 3.2-mm tarred nylon trawl line, the end of which was attached to an 8/0 barrel swivel. We crimped one end of a 1-m section of 1.6-mm stainless-steel aircraft cable to the swivel and the other end to a Mustad-9/0, J-hook. All coastal stations are in water depths between five and 30 meters, therefore nearly all gangions rest on the bottom during a set. Bait consisted of various coastal teleosts including Atlantic menhaden (*Brevoortia tyrranus*) until 1995. Only Atlantic menhaden and Atlantic mackerel (*Scomber scombrus*) were used from 1995 to 2009. A standard set consisted of 100 hooks and was approximately 2 km in length. Standard soak times were four hours long. Data recorded for each set included 1) location, 2) start and finish times for setting and hauling, 3) maximum and minimum water depth, 4) surface and bottom water temperature (to 30 meters maximum), 5) number of hooks and hook type, 6) bait species. Beginning in 1996, temperature, dissolved oxygen, and salinity were recorded from surface to the bottom at two-meter intervals. Animals that were lost once brought to the side of the vessel were counted as catch, but broken gangions and “bite-offs” were not included in catch. All species captured were recorded and measured. Pre-caudal length, fork length, and stretch total length were measured for all sharks.

Data Analyses

We calculated length frequencies and plotted males and females separately for all sharks caught within the survey. Catch per unit of effort (CPUE) was calculated for each set as the number of sharks per 100 standard hooks fished per hour. Monthly CPUE was calculated for each species for all months and sets where standard gear was used. Monthly mean CPUE was calculated from standard stations and standard gear from all months. Only the five standard coastal stations and standard gear (steel leader with 9/0 J-hook) were used in catch analyses. The nominal CPUE index for each year was calculated as mean CPUE for all standard stations fished from June to September in a given year divided by the mean index value.

CPUE data were standardized following the delta lognormal approach (Lo et al. 1992). Both proportion of positive catch sets and positive catch rates were modeled using generalized linear models. Models were fit to the data using GENMOD procedure in SAS (Version 9.1 of the SAS, SAS Institute Inc. Cary, NC, USA). Fixed effects factors were added to a null base model in stepwise fashion to determine best fit. The factor with the greatest reduction in deviance was added to the model if the factor was significant at $p<0.05$ estimated from a Chi-Square test and the deviance per degree of freedom was reduced by 1% or more. This process was repeated until no factors met the criteria for incorporation into the model. If year was not a significant factor in the model it was included in the final model. Interactions with the year factor were treated as random interactions and analyzed using the MIXED procedure. Mixed model fits were evaluated using the Akaike Information Criteria (AIC) and Schwarz’s Bayesian Criteria (BIC). Models with lower AIC and BIC values were selected. Proportion of Positive Catch Sets (PPCS) were modeled assuming a binomial distribution with a log link function. Positive Catch Rates (PCR) were modeled assuming a Poisson distribution with the log link function. The product of the yearly mean standardized proportion of positive catches and mean standardized positive catch rates were used to produce the catch index. Factors used in model development for both indices were YEAR, MONTH, and STATION. Only stations C, T, W, V, and L (Figure 2) and sets occurring in June through September were used in index development. Two years were not used in the index development. In 1985 no standard stations were fished. In 1994 no coastal stations were fished as the survey was limited to sampling within Chesapeake Bay.

Results

Length Frequencies

Length data were available for 1453 sandbar sharks comprising 484 males and 923 females (Figure 3), and 445 dusky sharks comprising 192 males and 246 females (Figure 4). Average total length (TL) of male sandbar sharks was 103 cm (S.D. = 20.05) and average TL of females was 132.64 (S.D. = 36.55) cm. Sminkey and Musick (1995) suggested that most males and females reach maturity at >135 cm pre-caudal length (PCL). We estimate that 11% of female and less than 1% of male sandbar sharks sampled were mature.

Average TL of male dusky sharks was 116.21 (S.D = 21.86) cm and average TL of females was 130.33 (S.D. = 44.37) cm. Natanson et al. (1995) used samples from the western North Atlantic to estimate male dusky shark maturity at 231 cm fork length (FL) and 19 years of age, and females mature at 235 cm FL and 21 years of age. Cortés et al. (2006) estimated median size at maturity for dusky sharks in the region to be 226 cm FL for females (273 cm TL) and 224 FL for males (271 cm TL). Based on these estimates only a small proportion of female dusky sharks sampled were possibly mature (3%), while no adult males have been sampled at standard stations.

Index Development

Sandbar shark

Catches of sandbar sharks were highest in September and lowest in May (Figure 5). For initial model fits, 542 sets were used. Years 1976,1982,1983,1986 and 1988 were removed from the sandbar shark analysis either because no sandbar sharks were captured or sharks were captured on all sets during that year. This reduced the data set to 419 sets. Of these, sandbar sharks were captured on 253 sets.

Model development for Proportion of positive catch sets (PPCS) is summarized in Table 1a. The final model for PPCS for sandbar sharks was *PPCS=Month+Year+Station+Year*Station*. The interaction term was treated as a random effect. Variation in PPCS across years is depicted in Figure 6. Model development for positive catch rate is depicted in Table 1b. The final model was *log(CPUE)=Year*. Combined model fit to the data was reasonable; with residuals being approximately normally distributed (Table 2, Figure 7).

The highest nominal catches of sandbar sharks occurred in 1980 and 1981 (Figure 8a). The lowest nominal catch rates occurred in the early 1990’s with 1992 being the lowest nominal value. Nominal values increased until 1998 then decreased to 2007.

Dusky sharks

Catches of dusky sharks were highest in June and lowest in May (Figure 9). Data used for model development were limited to standard hooks, standard coastal stations (C, V, T, L, W), and months May through September. Years 1976,1979,1982,1983,1984,1986,1988 and 1997 were removed from the analysis because no dusky sharks were captured during that year. This reduced the number of sets to 393. Of these, dusky sharks were encountered on 114 sets.

Model development for Proportion of positive catch sets (PPCS) is summarized in (Table 3a). The final model for PPCS for dusky sharks was *PPCS=Month+Year+Station+Year*Station.* The interaction term was treated as a random effect. Variation in PPCS across years is depicted in Figure 10. Model development for positive catch rates is summarized in Table 3b. The final model for PCR for dusky sharks was *log(CPUE)=Year*. Combined model fit to the data was reasonable; with residuals being approximately normally distributed (Table 4, Figure 11). Nominal positive set CPUE is depicted in Figure 12. The highest nominal catches of dusky shark occurred in 1975 and 1977. Nominal values reached their lowest values in the early 1990's. The removal of years where less than five standard stations were sampled did not change explanatory factors in the model (Figure 12b).

References

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Cortés, E., E. Brooks, P. Apostolaki, C.A. Brown. 2006. Stock assessment of dusky shark in the U.S. Atlantic and Gulf of Mexico. Sustainable Fisheries Division Contribution SFD-2006-014.

Sminkey, T.R. and J.A. Musick. 1995. Age and growth of the sandbar shark, *Carcharhinus plumbeus*, before and after population depletion. Copeia 1995(4): 871-883.

Table 1. (a) Proportion positive binomial model and (b) positive catch rate model development for sandbar shark.

a)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	418	562.7	1.3461		-281.3		
YEAR	391	517.1	1.3226	1.74	-258.6	45.51	0.01435
STATION	414	530.5	1.2814	4.8	-265.3	32.14	0
MONTH	415	518.7	1.2499	7.14	-259.4	43.93	0

The explanatory factors in the base model are: MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	415	518.7	1.2499		-259.4		
YEAR	388	473.7	1.2209	2.33	-236.8	45.03	0.01613
STATION	411	481.1	1.1706	6.35	-240.6	37.6	0

The explanatory factors in the base model are: MONTH STATION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
Base	411	481.1	1.1706		-240.6		
Year	384	428.8	1.1166	4.61	-214.4	52.34	0.00241

Mixed Model	**AIC**	**BIC**	**-LL**
Base Month Station Year	553.3	557.3	551.3
Year*station	548.1	553.8	544.1

Final
Month+Year+Station Year*Station

b)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	248	213.2	0.8598		-240.9		
YEAR	221	178.4	0.8072	6.11	-223.4	34.82	0.14346
MONTH	245	212	0.8653	-0.65	-240.3	1.21	0.75076
STATION	244	210.2	0.8613	-0.18	-239.3	3.07	0.54697

Mixed Model	**AIC**	**BIC**	**-LL**
Base Year	643.0	646.4	641.0
Year*station	644.5	650.2	640.5

Final
Log(CPUE)=Year

Table 2. Results for standardized index for sandbar sharks. (CV=coefficient of variation, LCI and UCI=Lower and upper 95% confidence intervals)

YEAR	N	Proportion positive	Observed Index	Standardized Index	CV	LCI	UCI
1975	8	0.875	3.33351	1.880482	0.357349	0.940063	3.761677
1977	7	0.571429	1.662448	1.70367	0.511381	0.649738	4.46717
1978	3	0.666667	1.045883	0.716878			
1979	2	0.5	0.747483	1.159219	1.258888	0.165092	8.139628
1980	16	0.875	2.317664	2.38519	0.259545	1.431361	3.974631
1981	20	0.9	2.666271	2.494284	0.222968	1.605545	3.874977
1984	3	0.666667	0.402466	0.775913	0.803784	0.189068	3.184258
1987	3	0.666667	1.015551	0.519068	1.059669	0.09154	2.943326
1989	4	0.75	0.739961	0.901274	0.672833	0.265506	3.059427
1990	24	0.458333	0.393483	0.404125	0.568605	0.140213	1.164775
1991	20	0.4	0.469279	0.57986	0.600339	0.191181	1.758739
1992	18	0.277778	0.136208	0.235906	0.809711	0.057015	0.976083
1993	14	0.428571	0.5331	0.774253	0.570132	0.267966	2.237103
1995	21	0.666667	0.730902	0.928231	0.280792	0.535027	1.610412
1996	26	0.576923	0.835256	0.912976	0.363983	0.450909	1.848544
1997	21	0.619048	0.795357	0.852917	0.352939	0.429833	1.69244
1998	21	0.666667	1.225872	1.395592	0.301326	0.773919	2.516643
1999	17	0.411765	0.892363	1.104962	0.511416	0.421381	2.897478
2000	22	0.590909	1.079603	1.041766	0.35823	0.519947	2.087286
2001	23	0.608696	1.019339	1.14822	0.332354	0.600999	2.193697
2002	15	0.6	0.695736	0.621883	0.490858	0.245553	1.574967
2003	10	0.6	0.505672	0.534831	0.563972	0.186965	1.529929
2004	20	0.55	0.827463	0.709113	0.445885	0.302582	1.661835
2005	11	0.818182	0.599006	0.448251	0.456095	0.187899	1.069343
2006	22	0.727273	0.919859	1.12404	0.281386	0.647164	1.952314
2007	19	0.421053	0.31991	0.32046	0.593469	0.10682	0.961381
2008	19	0.684211	0.941102	0.999616	0.321933	0.533421	1.873249
2009	10	0.8	1.149255	1.32702	0.349491	0.673001	2.616611

Table 3. (a) Proportion positive binomial model and (b) positive catch rate model development for dusky shark.

a)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	392	473.3	1.2075		-236.7		
MONTH	389	437.6	1.1249	6.84	-218.8	35.77	0
YEAR	368	410.2	1.1148	7.68	-205.1	63.1	0.00002
STATION	388	417.7	1.0766	10.84	-208.9	55.61	0

The explanatory factors in the base model are: STATION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	388	417.7	1.0766		-208.9		
MONTH	385	377.4	0.9803	8.95	-188.7	40.33	0
YEAR	364	347.3	0.954	11.39	-173.6	70.48	0

The explanatory factors in the base model are: STATION YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	364	347.3	0.954		-173.6		
MONTH	361	308	0.8532	10.56	-154	39.23	0

Mixed Model	**AIC**	**BIC**	**-LL**
Base Month Station Year	434.7	438.6	432.7
Year*station	430.5	435.9	426.5

Final
Month+Year+Station Year*Station

b)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	30	10.6	0.3542		-28.6		
YEAR	15	4.4	0.2927	17.34	-25.5	6.23	0.97555
MONTH	28	10	0.3577	-1.01	-28.3	0.61	0.73764
STATION	27	8.3	0.3072	13.27	-27.4	2.33	0.50655

Mixed Model	**AIC**	**BIC**	**-LL**
Base Year	271.7	274.1	269.7
Year*station	273.3	278.8	269.3

Final
Year

Table 4. Results for standardized index for dusky sharks. (CV=coefficient of variation, LCI and UCI=Lower and upper 95% confidence intervals)

YEAR	N	Proportion positive	Observed index	Standardized index	CV	LCI	UCI
1975	8	0.75	4.137282	4.39814	0.5158334	1.6648447	11.618883
1977	7	0.285714	0.680933	0.205953	1.4149058	0.0252982	1.6766695
1978	3	0.333333	2.952893	1.21345	1.7073531	0.1172965	12.553327
1980	16	0.5	1.963674	2.3112505	0.5354967	0.8466635	6.3093297
1981	20	0.5	1.570939	1.8743562	0.4977972	0.731423	4.8032547
1987	3	0.666667	0.56269	0.6597661	0.6834145	0.1912784	2.275695
1989	4	0.25	0.224677	0.1158157	1.5206558	0.0129778	1.0335594
1990	24	0.083333	0.076463	0.0630144	1.3267178	0.0083991	0.4727662
1991	20	0.1	0.165362	0.0784142	1.3370029	0.01035	0.5940841
1992	18	0.055556	0.045934	0.0216576	2.0030635	0.0017094	0.2743921
1993	14	0.214286	0.295289	0.3370735	1.0157601	0.0625752	1.8157118
1995	21	0.095238	0.19686	0.1644734	1.2767362	0.0230121	1.1755334
1996	26	0.346154	0.669775	0.5057179	0.7698182	0.1292312	1.9790161
1998	21	0.142857	0.19686	0.174824	1.061063	0.0307816	0.9929135
1999	17	0.294118	0.875446	0.8406402	0.8745532	0.1861897	3.7954618
2000	22	0.409091	1.033512	1.2762972	0.6566945	0.3853466	4.2271929
2001	23	0.173913	0.467327	0.298937	1.0226263	0.0550459	1.6234335
2002	15	0.333333	1.166237	0.9580419	0.89004	0.2079385	4.414017
2003	10	0.1	0.537426	0.1764296	1.4799768	0.0204655	1.5209702
2004	20	0.45	1.260885	1.0054627	0.6734926	0.2959026	3.4165138
2005	11	0.636364	1.65362	2.2077087	0.6781028	0.645202	7.5541887
2006	22	0.5	1.78563	2.8680265	0.4880427	1.1379001	7.2287325
2007	19	0.263158	0.456921	0.2822455	0.8834027	0.0617924	1.2891967
2008	19	0.105263	0.535107	0.1266159	1.3170765	0.0170329	0.9412111
2009	10	0.4	1.488258	2.8356883	0.740493	0.7557064	10.640544

Figure 1. Locations of all sets for the VIMS Longline Survey 1974-2007.

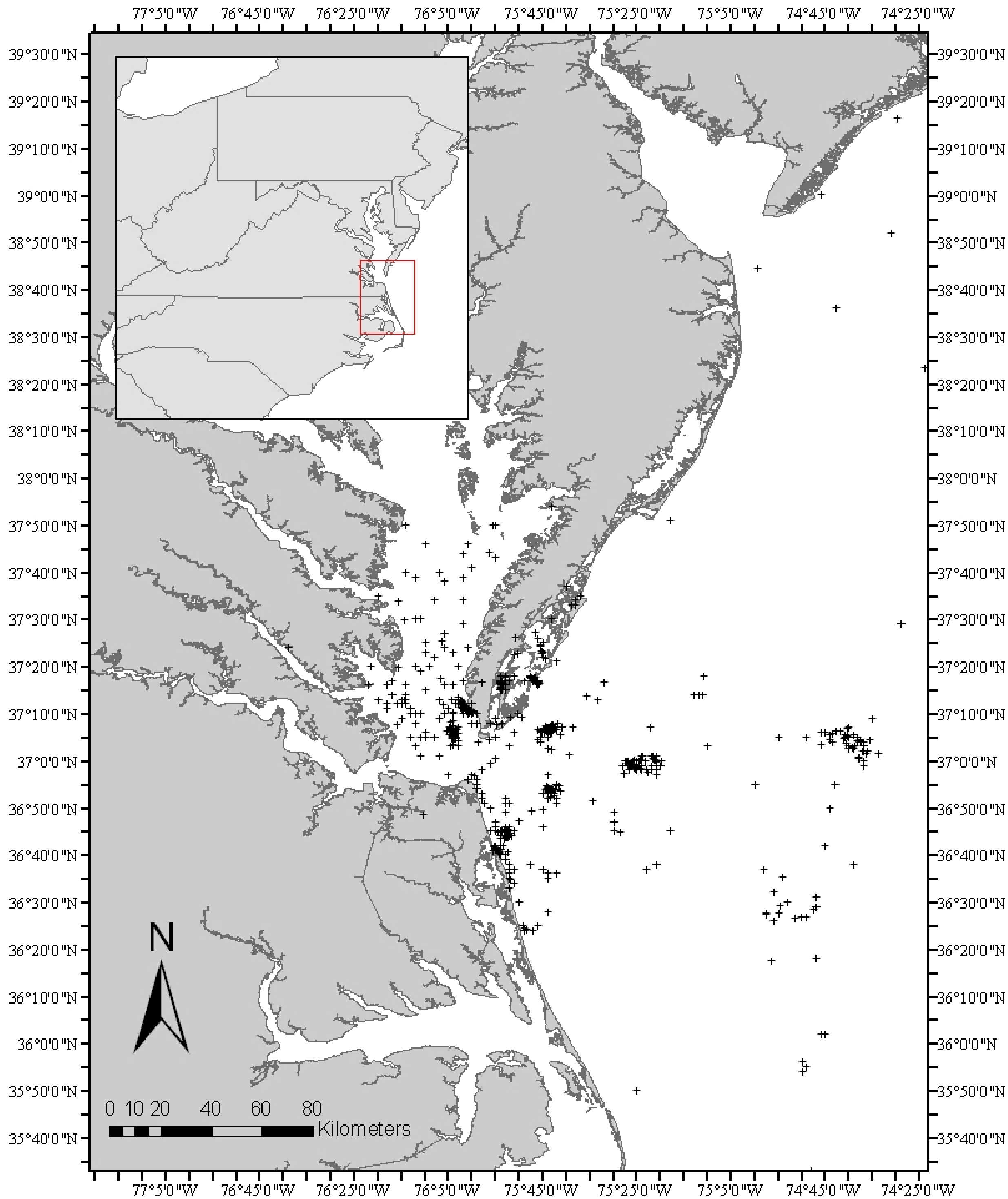


Figure 2. Locations of monthly standard stations for the VIMS Longline Survey

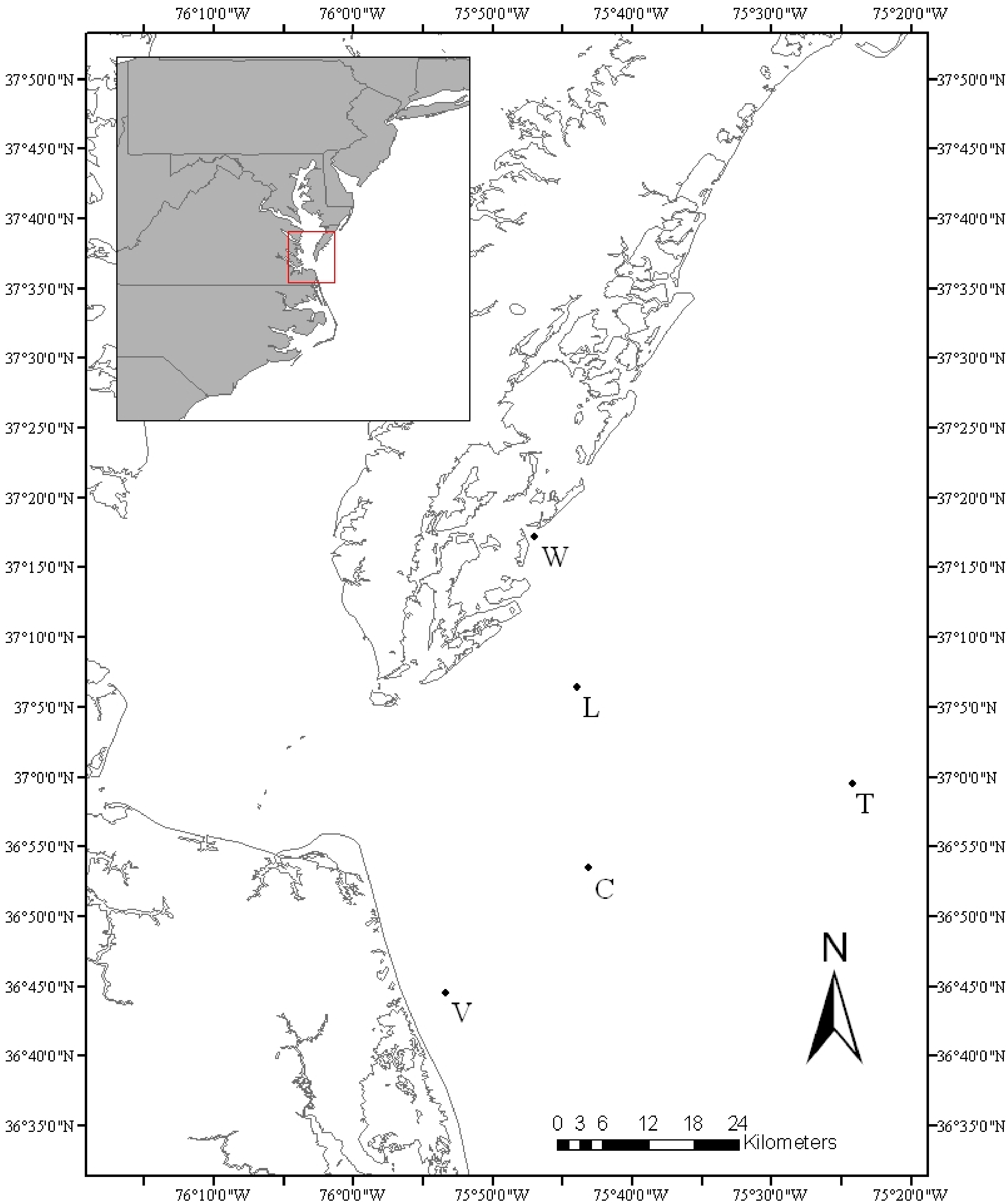
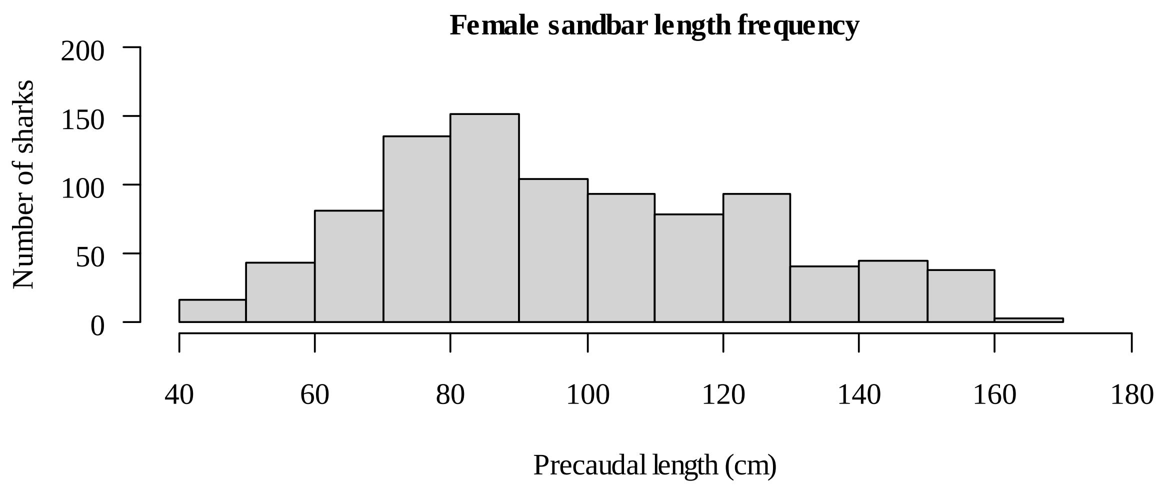


Figure 3. Length frequencies for female (n=923) and male (n=484) sandbar sharks caught at standard stations on standard gear.



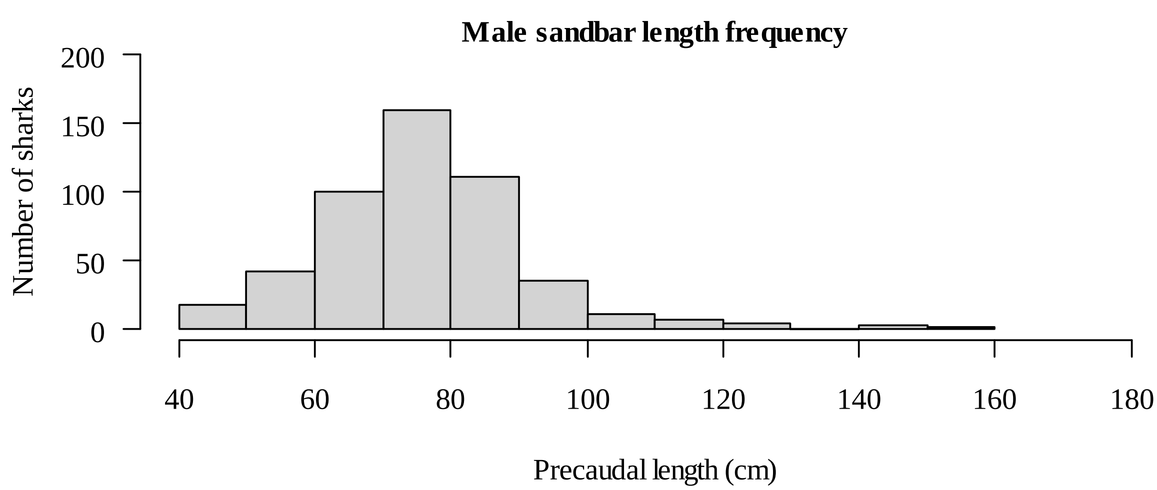
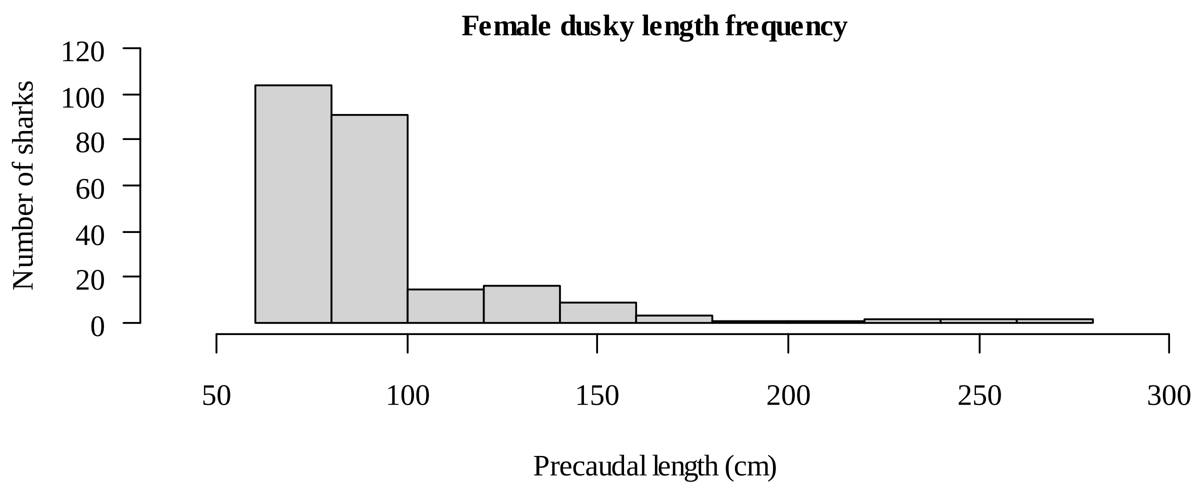


Figure 4. Length frequencies for female (n=246) and male (n=192) dusky sharks caught at standard stations on standard gear.



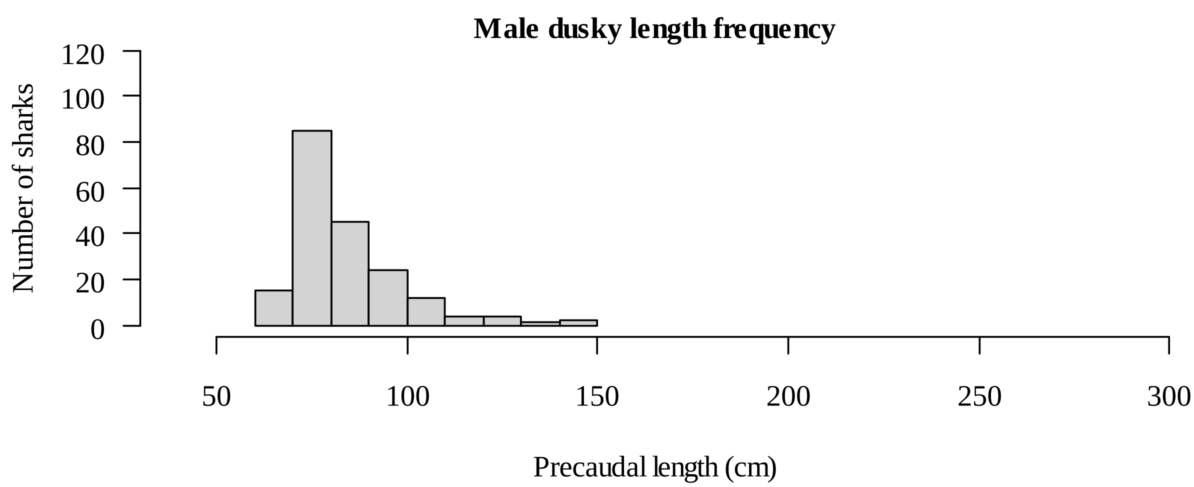


Figure 5. Mean monthly catches of sandbar sharks.

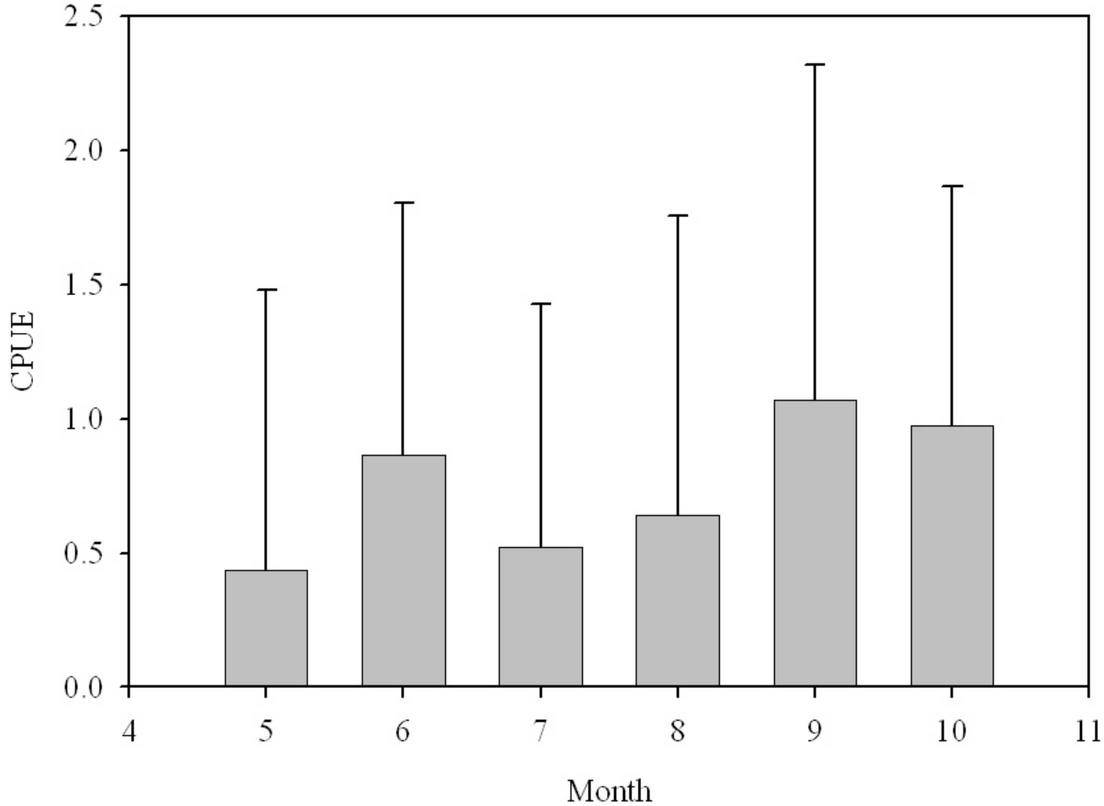
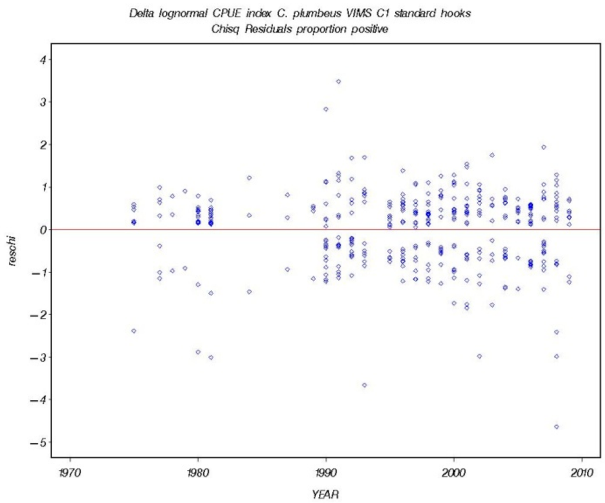


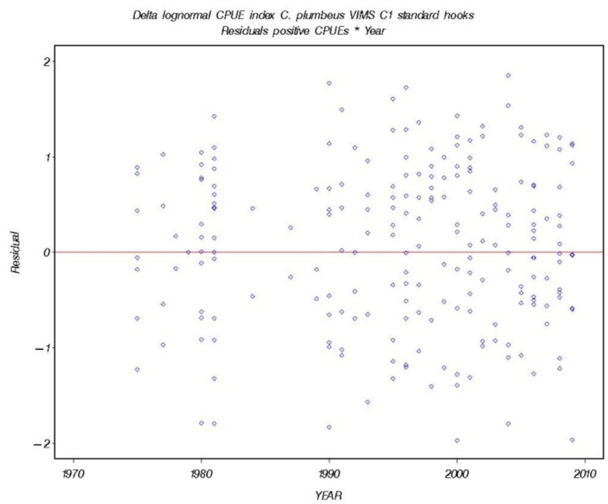
Figure 6. Annual proportion of positive sets for sandbar sharks.

Figure 7. Diagnostic plots for model fits of (a) proportion positve submodel (b) positive catch rate model and (c) positive cpue rates.

a)



b)



c)

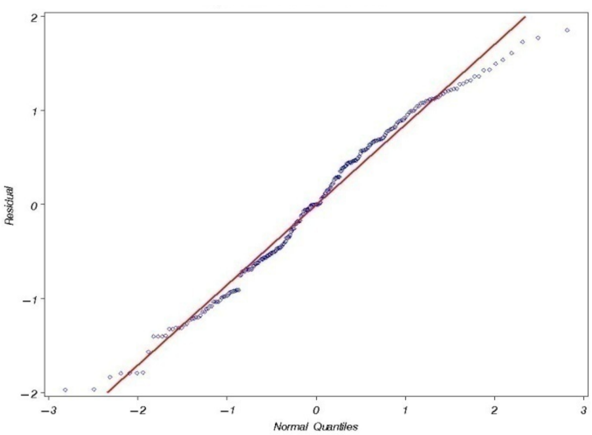


Figure 8. Nominal and standardized abundance indices for sandbar sharks, indices were divided by their respective mean.

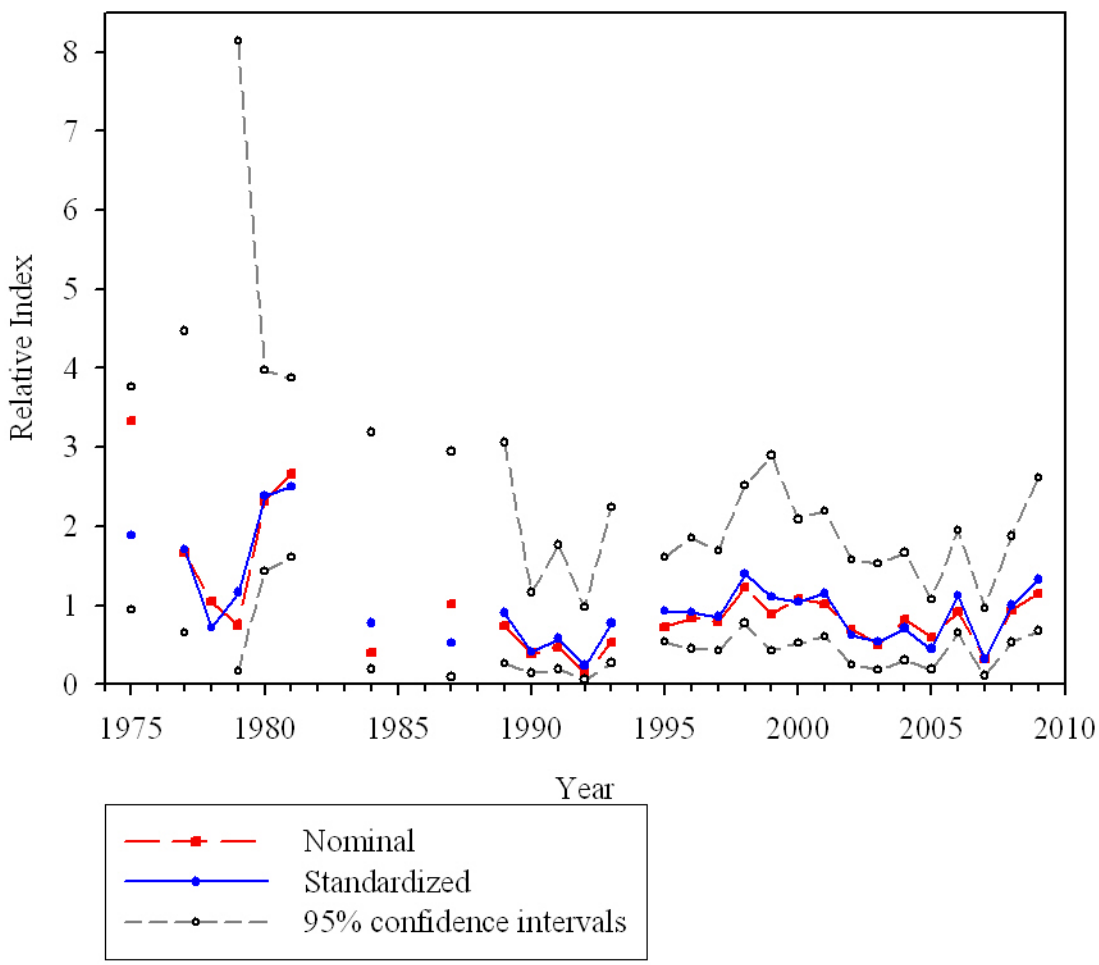


Figure 9. Monthly mean CPUE for dusky sharks.

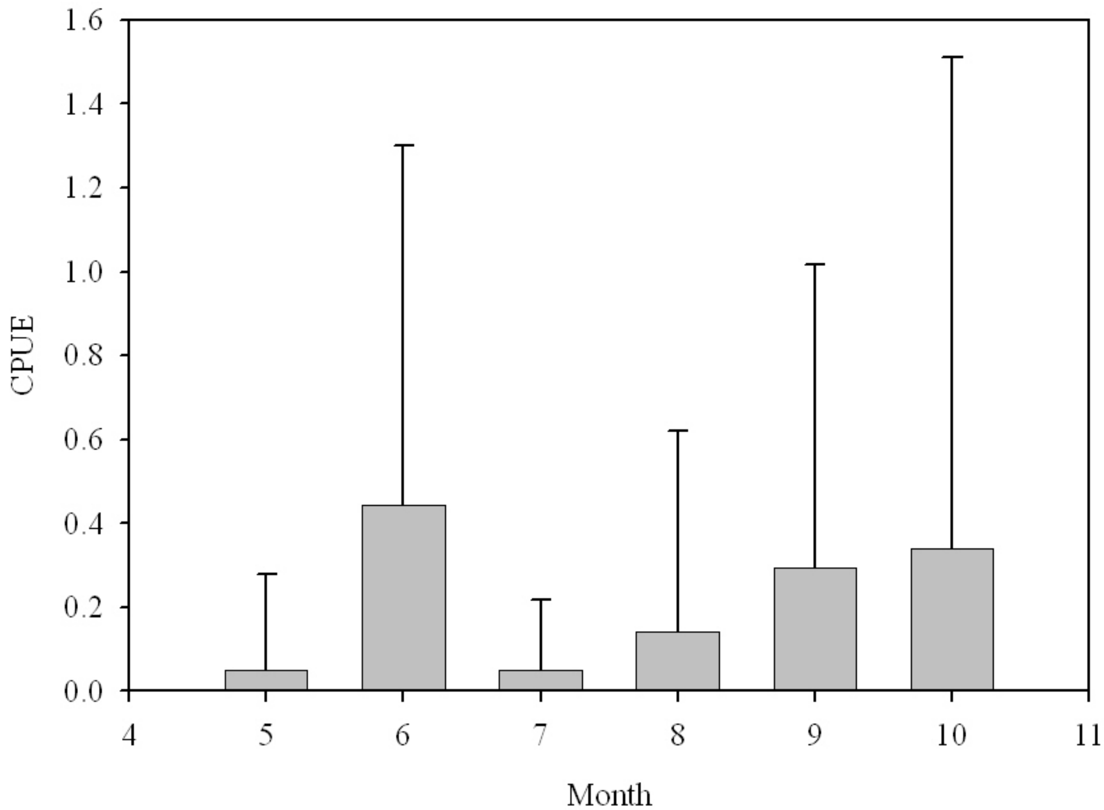


Figure 10. Annual proportion of positive sets for dusky sharks.

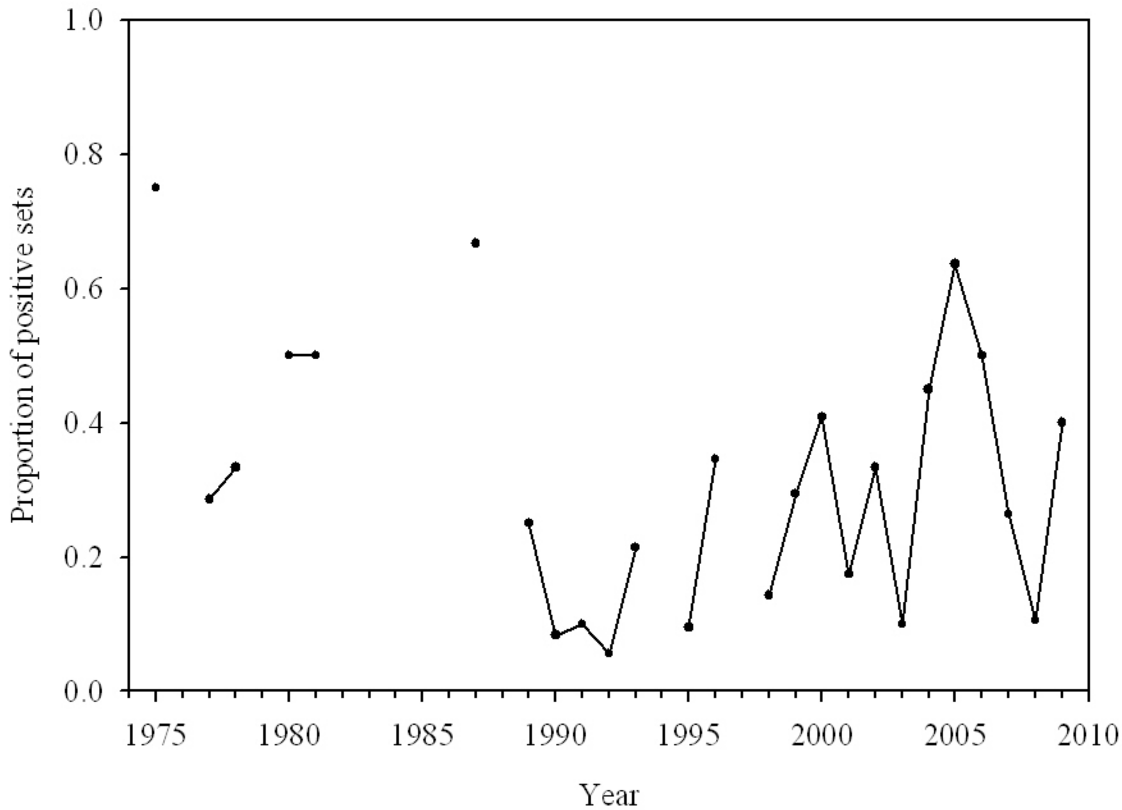
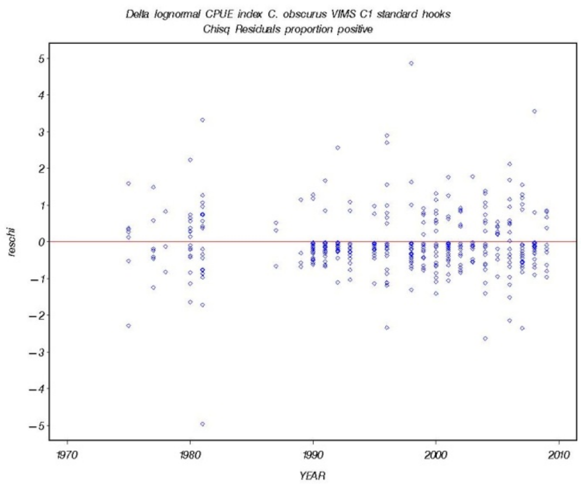
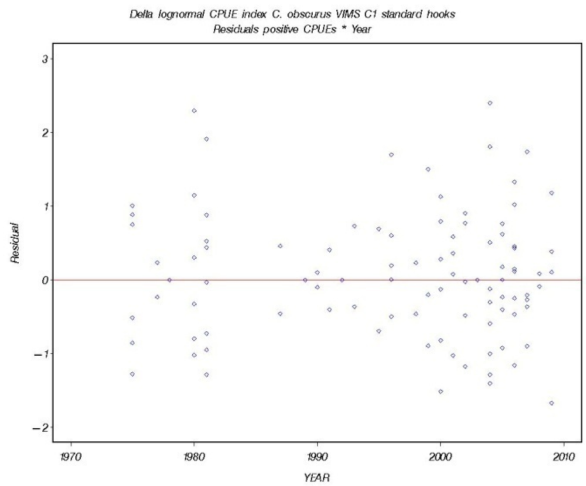


Figure 11. Diagnostic plots for model fits of (a) proportion positve submodel (b) positive catch rate submodel and (c) positive cpue rates for dusky sharks.

a)



b)



c)

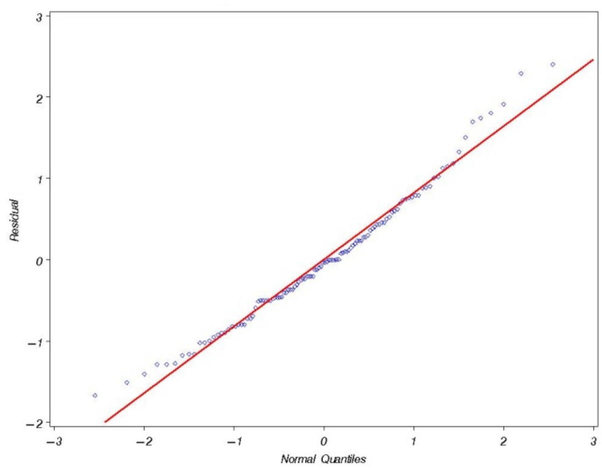
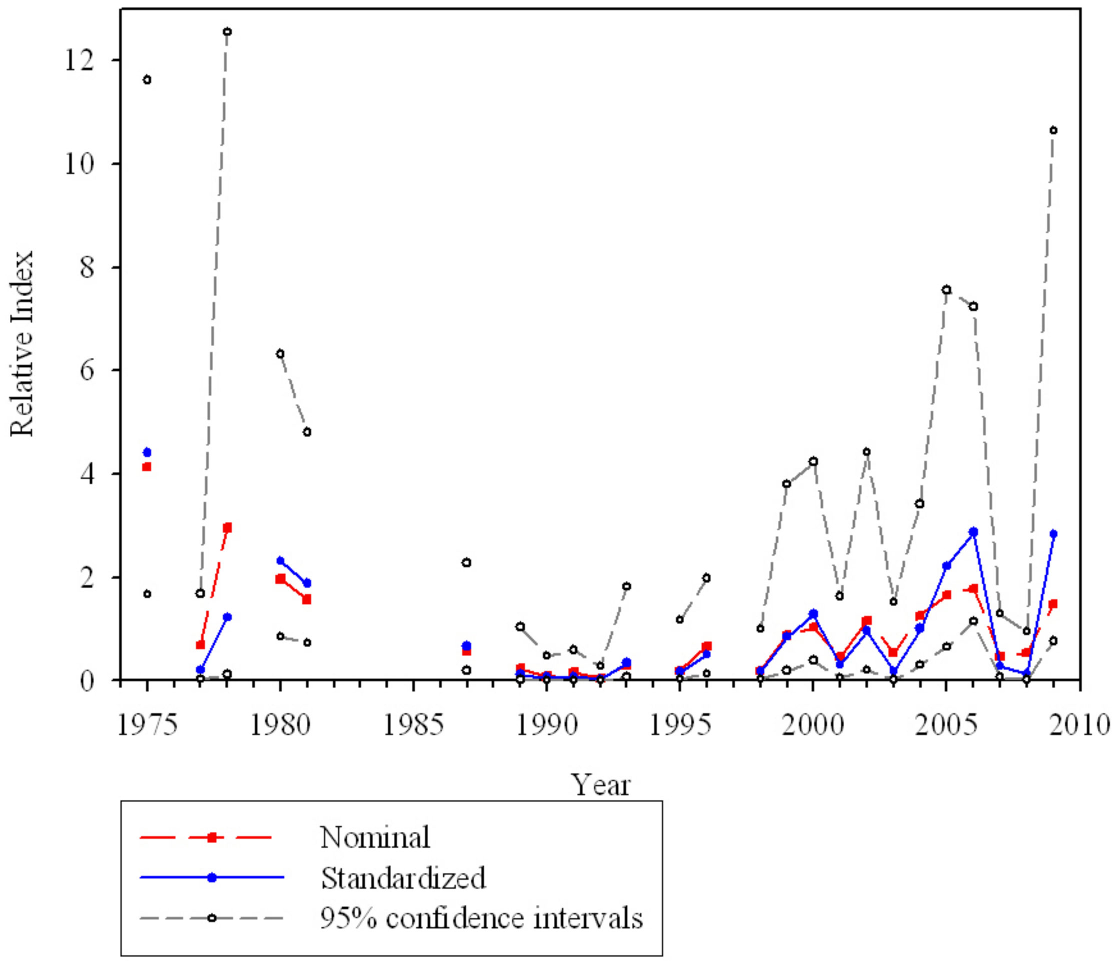


Figure 12. Nominal and standardized abundance indices for dusky sharks, indices were divided by their respective mean.



ADDENDUM TO SEDAR21-DW-18

(Standardized catch rates of sandbar sharks and dusky sharks in the
VIMS Longline Survey: 1975-2009)

Introduction

Based on SEDAR 21 Data workshop discussions, the Indices working group recommended removal of all years where less than five standard stations were sampled. Thus these years were removed and analyses were conducted on the new data sets for sandbar and dusky sharks. The years 1978, 1979, 1984, 1987, and 1989 were removed from the sandbar analysis and 1978, 1987, and 1989 were removed from the dusky analysis. Removal of these years did not change explanatory factors in the models. This addendum to document **SEDAR21-DW-18** revises the proportion positive binomial and positive catch rate models and provides new abundance indices and diagnostic plots for sandbar and dusky sharks. Analyses were conducted following standardization procedures previously detailed in **SEDAR21-DW-18**.

Table 1. (a) Proportion positive binomial model and (b) positive catch rate model development for sandbar shark.

a)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	405	547	1.3505		-273.5		
YEAR	382	498.4	1.3048	3.383931877	-249.2	48.55	0.0014
STATION	401	511.5	1.2756	5.546094039	-255.8	35.46	<0.0001
MONTH	402	503.4	1.2523	7.27138097	-251.7	43.54	<0.0001

The explanatory factors in the base model are: MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	402	503.432	1.25232		-251.716		
YEAR	379	456.795	1.20526	3.75749	-228.397	46.64	0.0025
STATION	398	461.847	1.16042	7.33833	-230.923	41.59	<0.0001

The explanatory factors in the base model are: MONTH STATION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
Base	398	461.847	1.16042		-230.923		
Year	375	407.669	1.08712	6.31673	-203.835	54.18	0.0003

Mixed Model		**AIC**	**BIC**	**-LL**
Base	Month Station Year	462	466	460
Year*station		460	465	456

Final
Month+Year+Station Year*Station

b)

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
NULL	112	42.9398	0.38339		-106.062		
YEAR	90	33.8584	0.3762	1.875374945	-101.521	9.08	0.9929
MONTH	109	41.9005	0.38441	-0.266047628	-105.542	1.04	0.7917
STATION	108	42.4719	0.39326	-2.574402045	-105.828	0.47	0.9766

Final Log(CPUE)=Year

Table 2. Results for standardized index for sandbar sharks. (CV = coefficient of variation, LCI and UCI = lower and upper 95% confidence intervals).

Year	N	Proportion positive	Observed Index	Standardized Index	CV	LCI	UCL
1975	8	0.875	1.57719	1.82563	0.36038	0.90761	3.67221
1977	7	0.57143	1.41327	1.63589	0.52158	0.61331	4.36346
1980	16	0.875	1.98118	2.29327	0.26406	1.36441	3.85445
1981	20	0.9	2.07085	2.39706	0.22655	1.53234	3.74977
1990	24	0.45833	0.34232	0.39624	0.5971	0.13132	1.19564
1991	20	0.4	0.48165	0.55753	0.62842	0.17586	1.76752
1992	18	0.27778	0.20008	0.23159	0.89807	0.04975	1.0782
1993	14	0.42857	0.64675	0.74863	0.59382	0.2494	2.24715
1995	21	0.66667	0.76418	0.88456	0.29405	0.49728	1.57346
1996	26	0.57692	0.76184	0.88185	0.37181	0.42938	1.81112
1997	21	0.61905	0.70699	0.81836	0.36713	0.40186	1.6665
1998	21	0.66667	1.15327	1.33493	0.30967	0.72881	2.44514
1999	17	0.41176	0.91072	1.05418	0.52878	0.3905	2.84582
2000	22	0.59091	0.86423	1.00036	0.36877	0.48978	2.0432
2001	23	0.6087	0.95309	1.10322	0.34085	0.56846	2.14104
2002	15	0.6	0.51495	0.59607	0.51848	0.22463	1.58168
2003	10	0.6	0.43919	0.50838	0.61135	0.16471	1.56906
2004	20	0.55	0.58881	0.68156	0.46398	0.28182	1.6483
2005	11	0.81818	0.37559	0.43475	0.49066	0.17172	1.10066
2006	22	0.72727	0.93243	1.07931	0.29031	0.61104	1.90643
2007	19	0.42105	0.26871	0.31104	0.64545	0.09555	1.01251
2008	19	0.68421	0.82735	0.95768	0.33476	0.49904	1.83782
2009	10	0.8	1.09537	1.26791	0.36219	0.62826	2.55881

Table 3. (a) Proportion positive binomial model and (b) positive catch rate model development for dusky shark.

a)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
Base	382	459.318	1.2024		-229.659		
MONTH	379	423.335	1.11698	7.1044	-211.668	35.98	<.0001
YEAR	361	398.106	1.10279	8.2846	-199.053	61.21	<.0001
STATION	378	403.757	1.06814	11.1662	-201.878	55.56	<.0001

The explanatory factors in the base model are: station

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
STATION	378	403.757	1.06814		-201.878	55.56	
MONTH	375	363.706	0.96988	9.1988	-181.853	40.05	<.0001
YEAR	357	337.612	0.94569	11.4637	-168.806	66.14	<.0001

The explanatory factors in the base model are: Station year

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
Base	357	337.612	0.94569		-168.806		
MONTH	354	297.861	0.84142	11.0264	-148.93	39.75	<.0001

Mixed Model		**AIC**	**BIC**	**-LL**
Base	Station year month	417.9	421.8	415.9
Year*station		414	419.3	410

Final
Month+Year+Station Year*Station

b)

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
Base	29	10.1036	0.3484		-27.366		
MONTH	27	9.5332	0.35308	-1.3444	-27.0808	0.57	0.7519
STATION	26	8.2268	0.31642	9.1799	-26.4276	1.88	0.5984
YEAR	15	4.3911	0.29274	15.9751	-24.5098	5.71	0.9732

Mixed Model		**AIC**	**BIC**	**-LL**
Base	Year	268.8	271.3	266.8
Year*station		270.4	275.7	266.4

Final
Year

Table 4. Results for standardized index for dusky sharks. (CV = coefficient of variation, LCI and UCI = lower and upper 95% confidence intervals).

Year	N	Proportion positive	Observed Index	Standardized Index	CV	LCI	UCI
1975	8	0.75000	4.28134	4.15208	0.51740	1.56759	10.99766
1977	7	0.28571	0.70464	0.19411	1.90271	0.01635	2.30465
1980	16	0.50000	2.03205	2.20772	0.54130	0.80101	6.08485
1981	20	0.50000	1.62564	1.75966	0.51794	0.66374	4.66505
1990	24	0.08333	0.07913	0.06121	2.50187	0.00366	1.02266
1991	20	0.10000	0.17112	0.08210	2.26040	0.00557	1.21021
1992	18	0.05556	0.04753	0.02125	5.09093	0.00056	0.80069
1993	14	0.21429	0.30557	0.33935	1.23253	0.04963	2.32029
1995	21	0.09524	0.20371	0.16406	1.81546	0.01467	1.83513
1996	26	0.34615	0.69310	0.49995	0.85683	0.11336	2.20493
1998	21	0.14286	0.20371	0.16860	1.50926	0.01907	1.49022
1999	17	0.29412	0.90593	0.81669	0.94187	0.16591	4.02013
2000	22	0.40909	1.06950	1.23480	0.68051	0.35956	4.24055
2001	23	0.17391	0.48360	0.29274	1.26732	0.04134	2.07287
2002	15	0.33333	1.20685	0.94000	0.94582	0.19002	4.64996
2003	10	0.10000	0.55614	0.17099	2.13854	0.01243	2.35209
2004	20	0.45000	1.30479	0.97120	0.71011	0.27058	3.48592
2005	11	0.63636	1.71120	2.08714	0.68861	0.60040	7.25544
2006	22	0.50000	1.84781	2.68798	0.49766	1.04917	6.88666
2007	19	0.26316	0.47283	0.27572	1.10909	0.04598	1.65327
2008	19	0.10526	0.55374	0.12422	2.01205	0.00975	1.58271
2009	10	0.40000	1.54008	2.74844	0.74596	0.72670	10.39491

Figure 1. Annual proportion of positive sets for sandbar sharks.

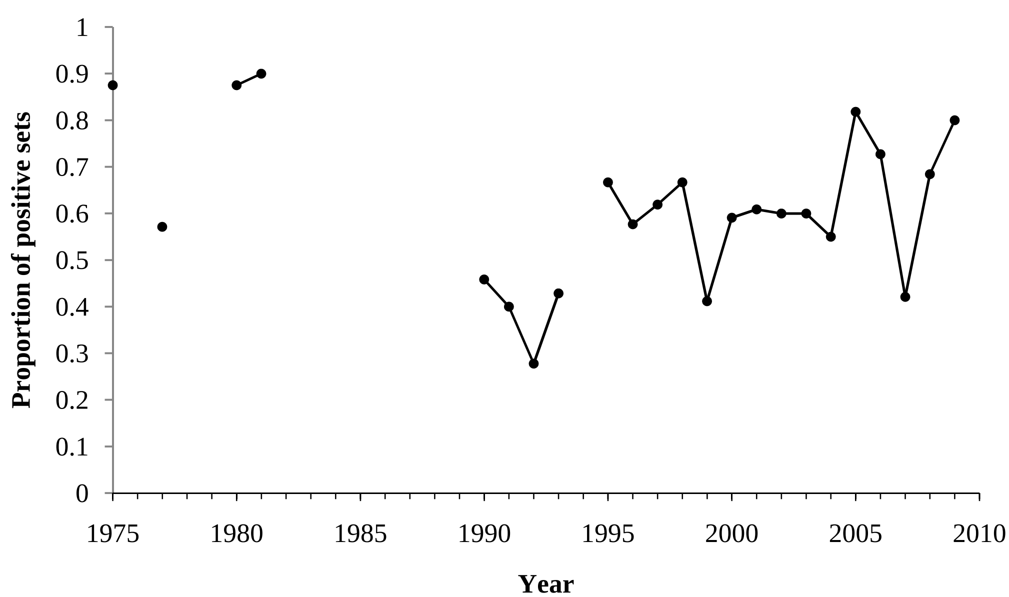
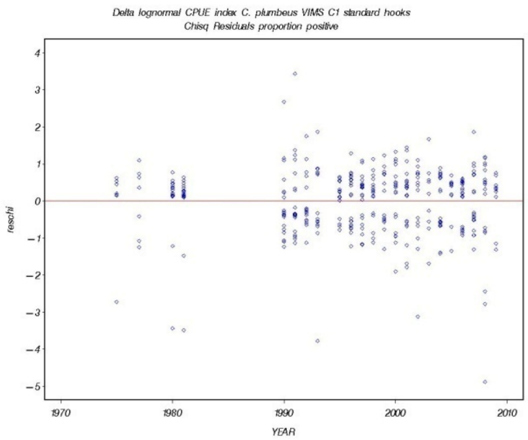
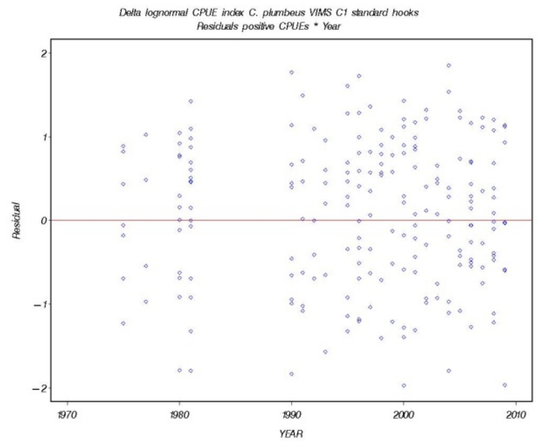


Figure 2. Diagnostic plots for sandbar model fits of (a) proportion positve submodel (b) positive catch rate model and (c) positive CPUE rates.

a)



b)



c)

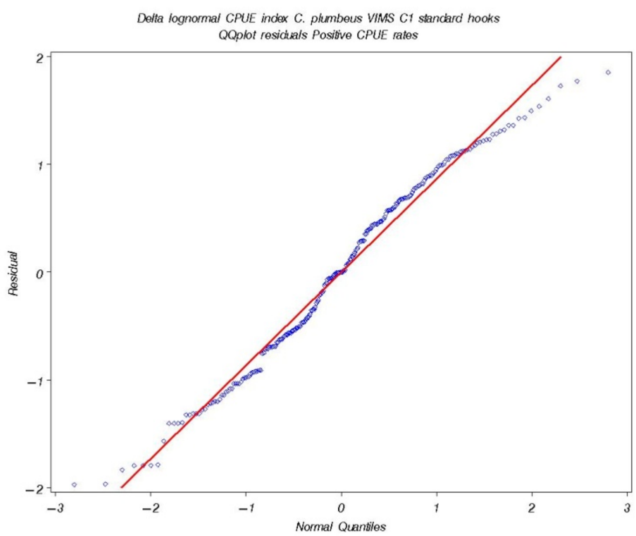


Figure 3. Nominal and standardized abundance indices for sandbar sharks, indices were divided by their respective mean.

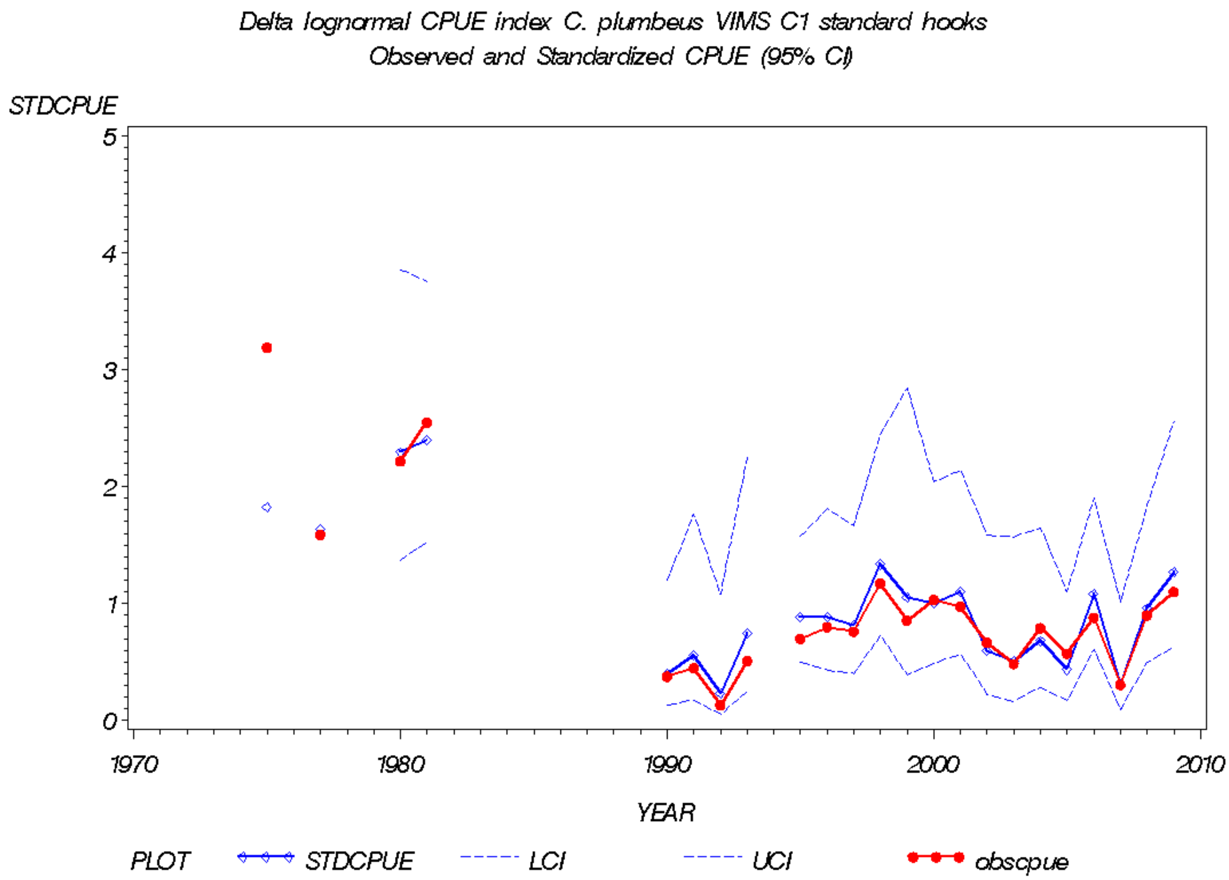


Figure 4. Annual proportion of positive sets for dusky sharks.

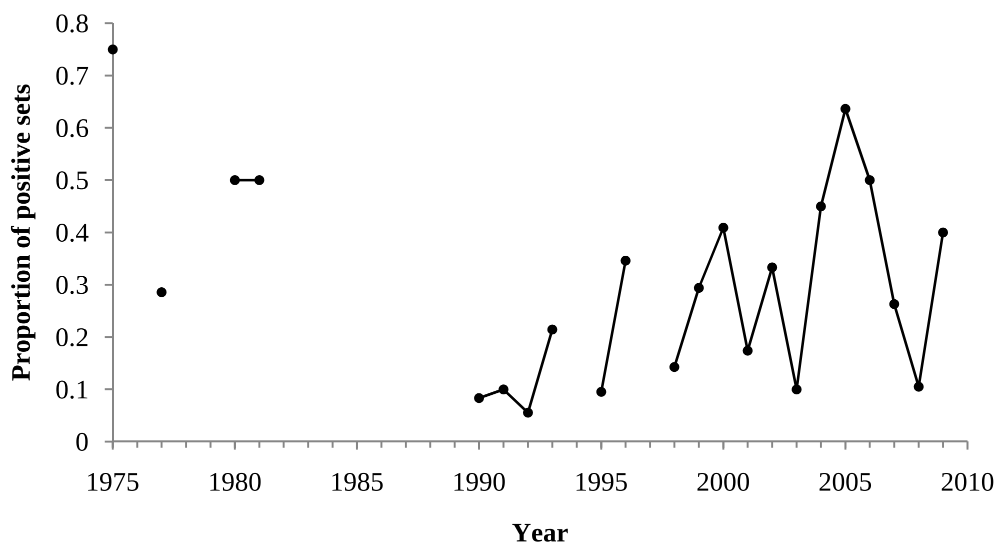
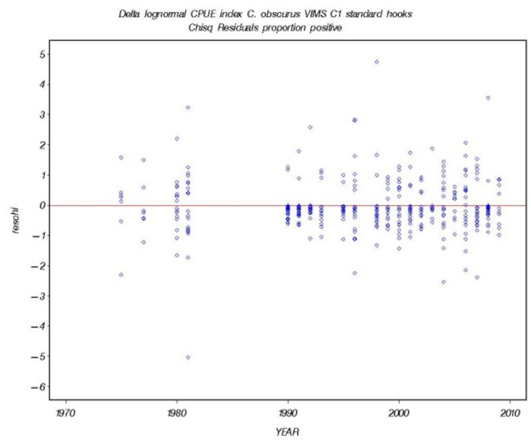
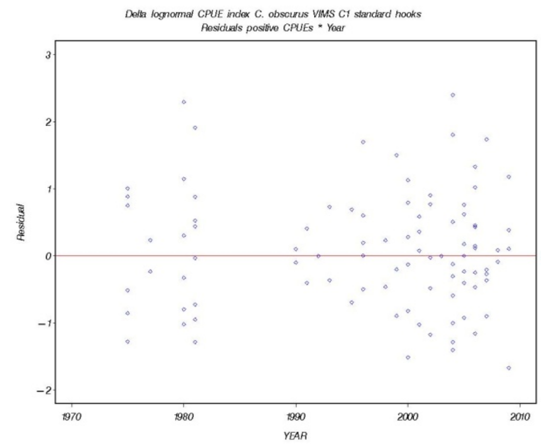


Figure 5. Diagnostic plots for dusky model fits of (a) proportion positve submodel (b) positive catch rate model and (c) positive CPUE rates.

a)



b)



c)

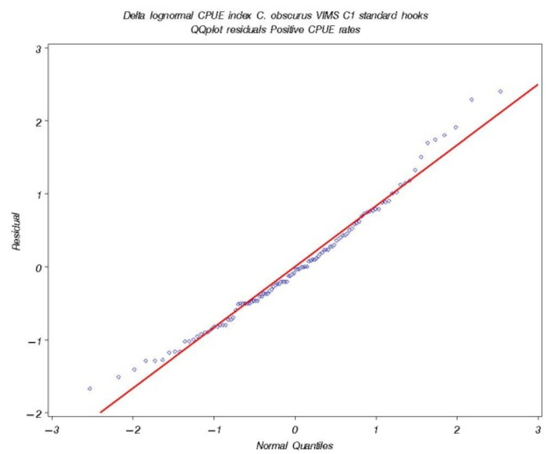


Figure 6. Nominal and standardized abundance indices for dusky sharks, indices were divided by their respective mean.