SEDAR 21 DATA WORKSHOP DOCUMENT

Standardized catch rates for sandbar and dusky sharks from exploratory longline surveys conducted by the Sandy Hook, NJ and Narragansett, RI labs: 1961-1996

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Summary

This document details shark catch from the exploratory longline surveys conducted by the National Marine Fisheries Service, Sandy Hook, NJ and Narragansett, RI labs from 1961-1996. Data from these surveys were used to look at the trends in relative abundance of sandbar and dusky sharks in the waters off the east coast of the United States. Catch per unit effort (CPUE) by set in number of sharks/hooks was used to examine trends in relative abundance. The CPUE was standardized using a two-step delta-lognormal approach originally proposed by Lo et al (1992) that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The resulting time series for sandbar sharks shows an initial decline in relative abundance in the early 1960s, followed by a sharp increase in 1964. Sandbar shark relative abundance then dropped down again to lower levels and held steady until the mid 1980s when a slight increase in relative abundance can be seen. For dusky sharks, the time series also begins with a decreasing trend, but it continues throughout the 1960s followed by a more stable trend throughout the remainder of the time series with a few small peaks in the early 1970s, mid 1980s and early 1990s.

Introduction

The United States National Marine Fisheries Service (NMFS), and its predecessor agencies; the Bureau of Commercial Fisheries (BCF) and the Bureau of Sport Fish and Wildlife (BSFW), have conducted periodic longline surveys for swordfish, tuna, and sharks off the east coast of the United States since the early 1950s. While the BCF surveys focused on the development of a tuna fishery, the initiation of shark surveys in1961 at the Sandy Hook Marine Lab (SHML) responded to concerns about shark attacks off the coast of New Jersey and resort owner demands for legislation that would require sport and commercial fishermen to fish further offshore. While surveys predominantly relied on longline gear, early sampling also used chain bottom gear, gillnets, and sport fishing gear. In subsequent years, monitoring of sport fishing tournaments during summer months complimented dedicated surveys on research vessels and opportunistic trips aboard commercial and sport fishing vessels. Early experimentation with different tag types, ultimately lead to the establishment of the ongoing Cooperative Shark Tagging Program. After the initial coastal surveys were conducted between 1961 and 1965, there was a gradual transition from coastal work to offshore effort along the edge of the continental shelf and associated Gulf Stream waters. The shark research program moved from the Sandy Hook to the Narragansett Lab in the early 1970s.

Methods

Data Sources

Data from research cruises and opportunistic deployments were coded as consistently as possible with the data design for the more recent pelagic observer program. Not all of the gear and operational variables currently recorded by observers were recorded aboard early surveys or on opportunistic trips aboard commercial vessels. Some of these variables reflect new gear innovations. Set specific gear, deployment, retrieval, and species composition data were coded from original cruise reports, field fishing logs maintained by scientific personnel, final grant reports, or published papers. Species counts were initially entered as catch per set totals. For the shark survey data, catch per set totals were subsequently matched against separate morphometric and tagging databases to verify total set counts. While catch per set discrepancies were rare, when they could not be resolved by referring to the original field notes the higher value was accepted for a specific species catch per set estimate.

Species

Scientific observers attempt to identify all animals that are caught or entangled by the gear. Invariably there are animals that are coded as unidentified or unknown, and others that can only be identified to species family groups such as tunas, billfish, sharks, or species groups such as hammerhead, mako, or thresher sharks. This is particularly prevalent in recent observer data, where between 80 and 90 unique codes are recorded for species, species families, species groups, and unclassified records. In the recent observer time series, 30 to 35 rare codes account for 10 or fewer individuals. To simplify analyses and presentation of species catch per set data, the original 80 to 90 codes are combined into @ 34 categories that include the dominant target and incidentally caught (bycatch) species and species groupings. The original species codes are maintained in associated animal files. The shark survey records are geographically and operationally less diverse than observer time series, so the number of unique species identified is reduced.

Operational variables

Operating practices generally reflect targeting strategies that can influence catch rates for target and incidental species. Observers record gear characteristics and operating practices along with location and environmental variables. These include the date, location (latitude and longitude), time, and sea surface temperature at the start and end of setting and hauling operations for each set. For some of the earliest survey data, only one location was recoverable, although for most records the begin set and end haul locations were available. Survey gear information includes number of hooks set, gangion and dropper line lengths, mainline material, number of hooks between floats, hook sizes, types, and bait information. Additional information on the rare use of line throwers, lightsticks, weights, and sets where the gear is tended during the soak period is being recovered.

In comparison to recent observer records, the gear characteristics of the shark survey records; especially those north of Cape Hatteras, are less variable in terms of component dimensions and rigging patterns (hooks between floats, distances between hooks, etc.). The major change over time relates to the annual proportions of sets deployed in coastal shallow depths versus offshore effort along the edge of the continental shelf and in Gulf Stream waters. The vast majority of shark survey records described in this report deployed pelagic (free floating) gear similar to Japanese style “basket gear” used by the BCF in tuna surveys and “Yankee Style” swordfish gear. The primary characteristic of these gears is that the major components consist of a multi-filament nylon 3/8” mainline with ¼” nylon gangions that end with 3/32” stainless steel leaders. When deployed with between 5 and 10 hooks between floats and in depths less than 40 or 50 meters, field notes on bait loss, species composition of the catch and reported hangs, clearly indicate that the gear is fishing on or near-bottom.

Prior to 1966 almost all of the sets occurred in the northern Mid-Atlantic bight in the approaches to New York harbor. Most occurred east and southeast of Sandy Hook with a smaller number of sets off the southern coast of Long Island to Montauk in depths less than 40 meters. A small number of sets occurred in Delaware Bay and three sets occurred in Baltimore and Hudson canyons. A multi-filament nylon mainline was generally suspended with 5 meter dropper lines, 8 hooks between floats and gangions that were 5 to 6 meters in total length. The major transitional changes that occurred in the shark surveys occurred after 1966. Most of these cruises occurred between Cape Hatteras and the northeast peak of Georges Bank, where they overlapped BCF and Woods Hole Oceanographic (WHOI) tuna cruises and Canadian DFO swordfish surveys. Effort was primarily concentrated along the edge of the continental shelf and in Gulf Stream waters. Occasional cruises, including cruises with other institutions, extend south of 34° N both along the US continental shelf and in deeper offshore waters north and north east of the Bahamas. While the mainline material remained constant, and hooks between floats rarely exceeded 10, gangion lengths increased slightly to 8 to 12 meters in length. Greater variability occurred in dropper lengths. While dropper lengths exceeding 30 meters were rare, these deep rigs were attempted in offshore waters with depths > 1,000 m especially south of 34 N. During the final three large scale pelagic surveys (Wieczno 86, Del II 89 and Del II 91), a small proportion of monofilament gangions were fished on 55 deep water sets.

Data Analysis

Catch per unit effort (CPUE) for each set is defined as the number of sharks/hooks. The CPUE was standardized using the Lo et al. (2002) method, which models the proportion of positive sets separately from the positive catch. Factors considered as potential influences on CPUE were: year (1961-1996), area (<34.5 ^{o} latitude, 34.5 to 37.0 ^{o} latitude, 37.1 to 39.0 ^{o} latitude, and > 39.0 ^{o} latitude), season (February and March; April, May and June; July, August and September; October, November and December), depth (< 50 m, 50 to 99 m, 100 to 2499 m and > 2499 m), temperature (<15, 15-19, 20-24, 25+ deg C), target (coastal shark, pelagic shark, inshore pelagic shark, swordfish, tuna), and leader type (wire, monofilament, or a combination of both). The proportion of sets with positive catch values was modeled assuming a binomial distribution with a logit link function and the positive catch sets were modeled assuming a lognormal distribution.

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. The factor “year” was kept in all final models, regardless of its significance, to allow for calculation of indices. Single factors were incorporated first, followed by fixed first-level interactions. All models in the stepwise approach were fitted using the SAS GENMOD procedure (SAS Institute, Inc.). The final models were then run through the SAS GLIMMIX macro to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Institute, Inc), in which all interactions including the “year” factor were treated as a random effect. The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and lognormal components.

Results

Sandbar shark

A total of 1992 sandbar sharks were caught during 896 longline sets from 1961 to 1996. The proportion of sets with positive catch (at least one sandbar shark caught) was 27%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 1. Model diagnostic plots reveal that the model fit is acceptable (Figures 2a and 2b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 2 and are plotted by year in Figure 3.

Dusky shark

A total of 283 dusky sharks were caught during 896 longline sets from 1961 to 1996. The proportion of sets with positive catch (at least one sandbar shark caught) was 9%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 3. Model diagnostic plots reveal that the model fit is acceptable (Figures 5a and 5b).

The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 4 and are plotted by year in Figure 6.

References Cited

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González-Ania, L.V., C.A. Brown, and E. Cortés. 2001. Standardized catch rates for yellowfin tuna (Thunnus albacares) in the 1992-1999 Gulf of Mexico longline fishery based upon observer programs from Mexico and the United States. Col. Vol. Sci. Pap. ICCAT 52:222-237.

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 catch rate model for sandbar sharks caught during the NEFSC exploratory longline surveys. %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.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	860	1003.4355	1.1668				
DEPTH	857	897.6346	1.0474	10.2331	10.2331	105.80	<.0001
TARGET	854	923.0299	1.0808	7.3706		80.41	<.0001
TEMP	857	972.8394	1.1352	2.7083		30.60	<.0001
AREA	857	987.7637	1.1526	1.2170		15.67	0.0013
LEAD	858	993.2646	1.1577	0.7799		10.17	0.0062
SEASON	857	996.2691	1.1625	0.3685		7.17	0.0668
YEAR	828	890.9296	1.0760	7.7820		Negative of Hessian not positive definite	
DEPTH +							
AREA	854	860.3815	1.0075	13.6527	3.4196	127.38	<.0001
TEMP	854	872.1986	1.0213	12.4700		25.44	<.0001
TARGET	851	875.7781	1.0291	11.8015		Negative of Hessian not positive definite	
YEAR	825	829.1694	1.0051	13.8584		Negative of Hessian not positive definite	
DEPTH + AREA +							
TEMP	851	841.7694	0.9892	15.2211	1.5684	18.61	0.0003
YEAR	822	800.1864	0.9735	16.5667		Negative of Hessian not positive definite	
DEPTH + AREA + TEMP +							
YEAR	819	783.7267	0.9569	17.9894	2.7683	Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res LL
DEPTH + AREA +TEMP + YEAR	1776.2	1780.1	1774.2

Type 3 Test of Fixed Effects for Final Model = DEPTH + AREA + TEMP + YEAR

Significance (Pr>Chi) of Type 3	DEPTH	AREA	TEMP	YEAR
test of fixed effects for each factor	<.0001	0.0011	0.0275	0.3591
DF	2	3	3	26
CHI SQUARE	34.85	15.99	9.14	27.99

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	231	395.8415	1.7136				
YEAR	205	280.9629	1.3706	20.0163	20.0163	79.53	<.0001
DEPTH	229	326.6262	1.4263	16.7659		44.59	<.0001
TARGET	228	343.3551	1.5059	12.1207		33.00	<.0001
AREA	225	343.1043	1.5249	11.0119		32.26	<.0001
SEASON	228	380.1398	1.6673	2.7019		9.39	0.0245
TEMP	228	388.6939	1.7048	0.5135		4.23	0.2379
LEAD	230	392.8527	1.7081	0.3210		1.76	0.1848
YEAR +							
DEPTH	203	252.8983	1.2458	27.2993	7.2829	24.41	<.0001
AREA	202	266.8350	1.3210	22.9108		11.97	0.0075
TARGET	201	266.2844	1.3248	22.6891		12.45	0.0143
SEASON	202	278.1485	1.3770	19.6429		2.34	0.5057
YEAR + DEPTH +							
TARGET	199	241.7920	1.2150	29.0966	1.7974	10.42	0.0339
AREA	200	250.9412	1.2547	26.7799		1.8	0.6144
YEAR + DEPTH + TARGET							
YEAR*DEPTH	174	200.6394	1.1531	32.7089	3.6123	43.28	0.0130
YEAR*TARGET	185	217.7923	1.1773	31.2993	2.2026	24.25	0.0527
DEPTH*TARGET	197	236.1240	1.1986	30.0537	0.9571	9.27	0.0097

MIXED MODELS	AIC	BIC	(-2) Res LL
YEAR + DEPTH + TARGET	664.0	667.3	662.0
YEAR + DEPTH + TARGET + YEAR*DEPTH	*583.9*	*587.1*	*581.9*

Type 3 Test of Fixed Effects for Final Model = YEAR + DEPTH + TARGET + YEAR*DEPTH

Significance (Pr>Chi) of Type 3	YEAR	DEPTH	TARGET	YR*DEPTH
test of fixed effects for each factor	0.0284	0.0587	0.0887	0.0765
DF	25	2	4	25
CHI SQUARE	40.11	5.67	8.08	35.69

Table 2. Sandbar shark analysis number of sets per year (obs n), number of positive sets per year (obs pos), proportion of positive sets per year (obs ppos), nominal cpue as sharks per hook (obs cpue), resulting estimated cpue from the model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

year	**n obs**	**obs pos**	**obs ppos**	**obs cpue**	**est cpue**	**LCI**	**UCI**	**CV**
1961	29	17	0.5862	0.0274	0.0817	0.0155	0.4300	0.9963
1962	18	6	0.3333	0.0297	0.0458	0.0073	0.2867	1.1492
1963	25	7	0.2800	0.0085	0.0283	0.0048	0.1670	1.0954
1964	18	10	0.5556	0.1201	0.1462	0.0258	0.8285	1.0591
1965	30	18	0.6000	0.0965	0.1176	0.0226	0.6133	0.9887
1966	15	0	0.0000	0.0000				
1967	24	3	0.1250	0.0016	0.0008	0.0002	0.0045	1.0248
1968	22	1	0.0455	0.0004	0.0003	0.0000	0.0028	1.5820
1969	30	2	0.0667	0.0014	0.0046	0.0007	0.0327	1.2614
1970	7	1	0.1429	0.0004	0.0034	0.0005	0.0258	1.3269
1971	12	0	0.0000	0.0000				
1972	14	0	0.0000	0.0000				
1973	3	0	0.0000	0.0000				
1974								
1975	8	1	0.1250	0.0008	0.0016	0.0002	0.0128	1.3675
1976	17	2	0.1176	0.0011	0.0016	0.0002	0.0101	1.1712
1977	55	9	0.1636	0.0027	0.0012	0.0003	0.0058	0.9259
1978	64	18	0.2813	0.0088	0.0061	0.0022	0.0171	0.5517
1979	74	22	0.2973	0.0076	0.0099	0.0032	0.0306	0.6094
1980	73	18	0.2466	0.0144	0.0079	0.0027	0.0227	0.5685
1981	52	10	0.1923	0.0108	0.0027	0.0006	0.0133	0.9281
1982	35	12	0.3429	0.0060	0.0074	0.0024	0.0236	0.6272
1983	34	8	0.2353	0.0122	0.0044	0.0012	0.0160	0.7213
1984	16	10	0.6250	0.0457	0.0300	0.0085	0.1054	0.6956
1985	37	16	0.4324	0.0281	0.0126	0.0043	0.0370	0.5801
1986	43	13	0.3023	0.0756	0.0175	0.0055	0.0556	0.6285
1987	9	5	0.5556	0.0582	0.0196	0.0047	0.0820	0.8184
1988	14	2	0.1429	0.0062	0.0027	0.0004	0.0181	1.2193
1989	48	17	0.3542	0.0793	0.0108	0.0033	0.0349	0.6404
1990	9	1	0.1111	0.0012	0.0015	0.0002	0.0137	1.5466
1991	40	9	0.2250	0.0276	0.0172	0.0051	0.0580	0.6685
1992	4	0	0.0000	0.0000				
1993	9	2	0.2222	0.0046	0.0017	0.0003	0.0114	1.2131
1994	6	0	0.0000	0.0000				
1995								
1996	2	0	0.0000	0.0000				

Table 3. Results of the stepwise procedure for development of the catch rate model for dusky sharks caught during the NEFSC exploratory longline surveys. %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.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	860	523.3264	0.6085				
TARGET	854	441.7967	0.5173	14.9860	14.9860	81.53	<.0001
TEMP	857	488.3031	0.5698	6.3658		35.02	<.0001
DEPTH	857	495.9717	0.5787	4.8953		27.35	<.0001
SEASON	857	496.0411	0.5788	4.8820		27.29	<.0001
LEADER	858	519.4789	0.6055	0.5038		3.85	0.1461
AREA	857	519.4853	0.6062	0.3865		3.84	0.2792
YEAR	828	397.6109	0.4802	21.0861		Negative of Hessian not positive definite	
TARGET +							
DEPTH	851	433.3594	0.5092	16.3156	1.3296	8.44	0.0378
SEASON	851	435.8805	0.5122	15.8288		5.92	0.1158
TEMP	851	411.3829	0.4834	20.5594		Negative of Hessian not positive definite	
YEAR	823	384.0517	0.4666	23.3141		Negative of Hessian not positive definite	
TARGET + DEPTH +							
YEAR	822	800.1864	0.9735	-59.9786		Negative of Hessian not positive definite	

FINAL MODEL	**AIC**	**BIC**	**(-2) Res LL**
TARGET + DEPTH + YEAR	1828.4	1832.2	1826.4

Type 3 Test of Fixed Effects for Final Model = TARGET + DEPTH + YEAR

Significance (Pr>Chi) of Type 3	TARGET	DEPTH	YEAR
test of fixed effects for each factor	0.0119	0.0737	0.0098
DF	3	3	21
CHI SQUARE	10.97	6.94	40.20

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	77	95.0529	1.2345				
YEAR	55	43.1677	0.7849	36.4198	36.4198	61.57	<.0001
DEPTH	74	60.6423	0.8195	33.6151		35.06	<.0001
TARGET	73	62.8419	0.8608	30.2648		32.28	<.0001
SEASON	74	80.0878	1.0823	12.3282		13.36	0.0039
LEADER	76	88.6309	1.1662	5.5293		5.46	0.0195
TEMP	75	92.2815	1.2304	0.3267		2.31	0.3154
AREA	74	92.1775	1.2456	-0.9064		2.40	0.4944
YEAR +							
DEPTH	52	38.0264	0.7313	40.7611	4.3412	9.89	0.0195
SEASON	52	40.4811	0.7785	36.9370		5.01	0.1709
LEADER	55	43.1677	0.7849	36.4198		0.00	.
TARGET	52	43.0021	0.8270	33.0097		0.30	0.9601
YEAR + DEPTH +							
YEAR*DEPTH	199	241.7920	1.2150	1.5759	-39.1852	10.42	0.0339

FINAL MODELS	**AIC**	**BIC**	**(-2) Res LL**
YEAR + DEPTH	156.5	158.5	154.5

Type 3 Test of Fixed Effects for Final Model = YEAR + DEPTH

Significance (Pr>Chi) of Type 3	YEAR	DEPTH
test of fixed effects for each factor	0.0976	0.0709
DF	22	3
CHI SQUARE	30.93	7.03

Table 4. Dusky shark analysis number of sets per year (obs n), number of positive sets per year (obs pos), proportion of positive sets per year (obs ppos), nominal cpue as sharks per hook (obs cpue), resulting estimated cpue from the model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

year	n obs	n pos	obs ppos	obs cpue	est cpue	LCI	UCI	CV
1961	29	17	0.5862	0.0167	0.0177	0.0079	0.0393	0.4169
1962	18	7	0.3889	0.0140	0.0163	0.0054	0.0488	0.5925
1963	25	6	0.2400	0.0124	0.0110	0.0026	0.0462	0.8216
1964	18	2	0.1111	0.0055	0.0091	0.0015	0.0562	1.1333
1965	30	2	0.0667	0.0025	0.0063	0.0013	0.0300	0.9132
1966	15	3	0.2000	0.0017				
1967	24	0	0.0000	0.0000				
1968	22	3	0.1364	0.0012	0.0027	0.0006	0.0124	0.8769
1969	30	5	0.1667	0.0007	0.0008	0.0001	0.0038	0.9660
1970	7	2	0.2857	0.0068	0.0021	0.0003	0.0160	1.3470
1971	12	0	0.0000	0.0000				
1972	14	4	0.2857	0.0009	0.0003	0.0000	0.0022	1.2528
1973	3	0	0.0000	0.0000				
1974								
1975	8	1	0.1250	0.0012	0.0019	0.0003	0.0145	1.3297
1976	17	1	0.0588	0.0002	0.0003	0.0000	0.0020	1.3847
1977	55	1	0.0182	0.0001	0.0002	0.0000	0.0015	1.4943
1978	64	3	0.0469	0.0004	0.0007	0.0001	0.0031	0.9038
1979	74	1	0.0135	0.0001	0.0003	0.0000	0.0025	1.4118
1980	73	2	0.0274	0.0002	0.0004	0.0001	0.0024	1.0676
1981	52	1	0.0192	0.0000	0.0000	0.0000	0.0002	1.4607
1982	35	3	0.0857	0.0027	0.0033	0.0007	0.0153	0.8905
1983	34	0	0.0000	0.0000				
1984	16	0	0.0000	0.0000				
1985	37	5	0.1351	0.0047	0.0036	0.0009	0.0142	0.7781
1986	43	6	0.1395	0.0085	0.0051	0.0014	0.0187	0.7214
1987	9	0	0.0000	0.0000				
1988	14	0	0.0000	0.0000				
1989	48	2	0.0417	0.0027	0.0012	0.0002	0.0068	1.0830
1990	9	0	0.0000	0.0000				
1991	40	2	0.0500	0.0015	0.0010	0.0002	0.0058	1.0773
1992	4	1	0.2500	0.0147	0.0223	0.0032	0.1543	1.2420
1993	9	0	0.0000	0.0000				
1994	6	1	0.1667	0.0017	0.0013	0.0002	0.0074	1.0545
1995								
1996	2	0	0.0000	0.0000				

Figure 1. Stations sampled during the NEFSC exploratory longline surveys conducted from 1961-1996

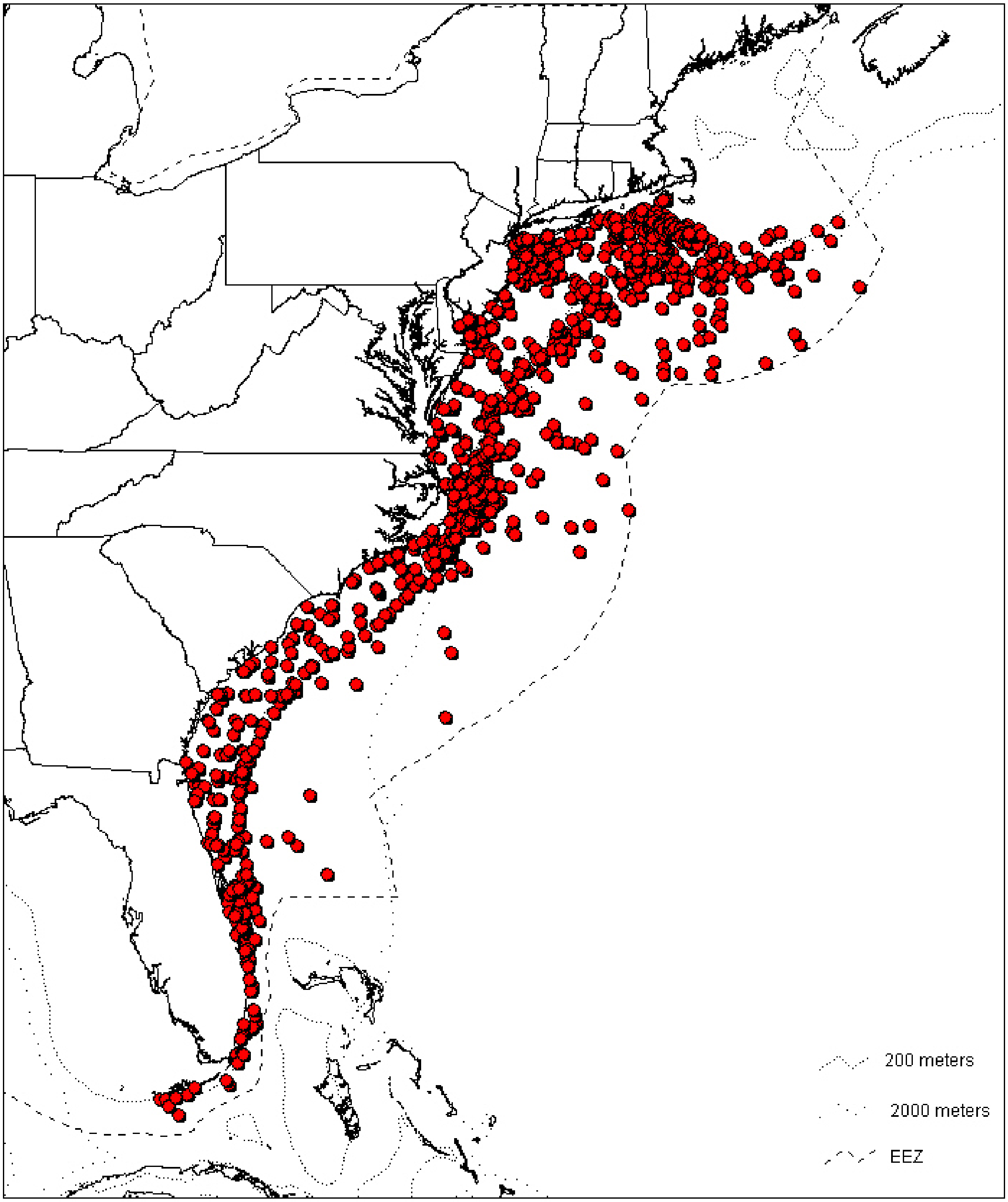
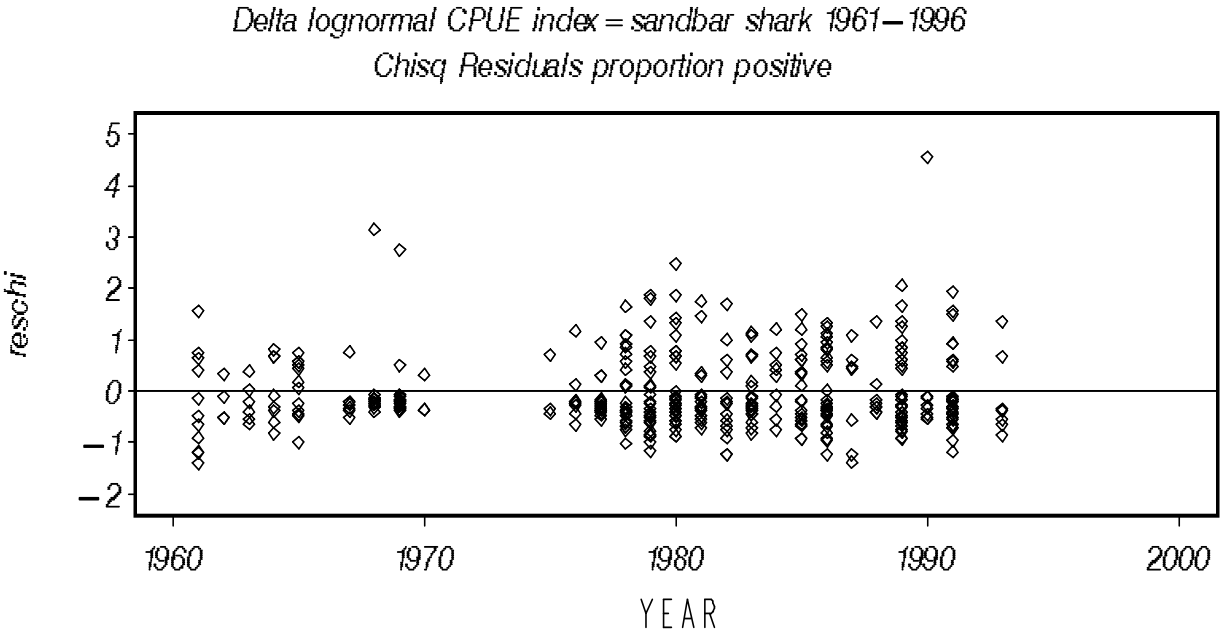


Figure 2a. Sandbar shark model diagnostic plots for the binomial component.


Delta lognormal CPUE index = sandbar shark 1961–1996
Chisq Residuals proportion positive

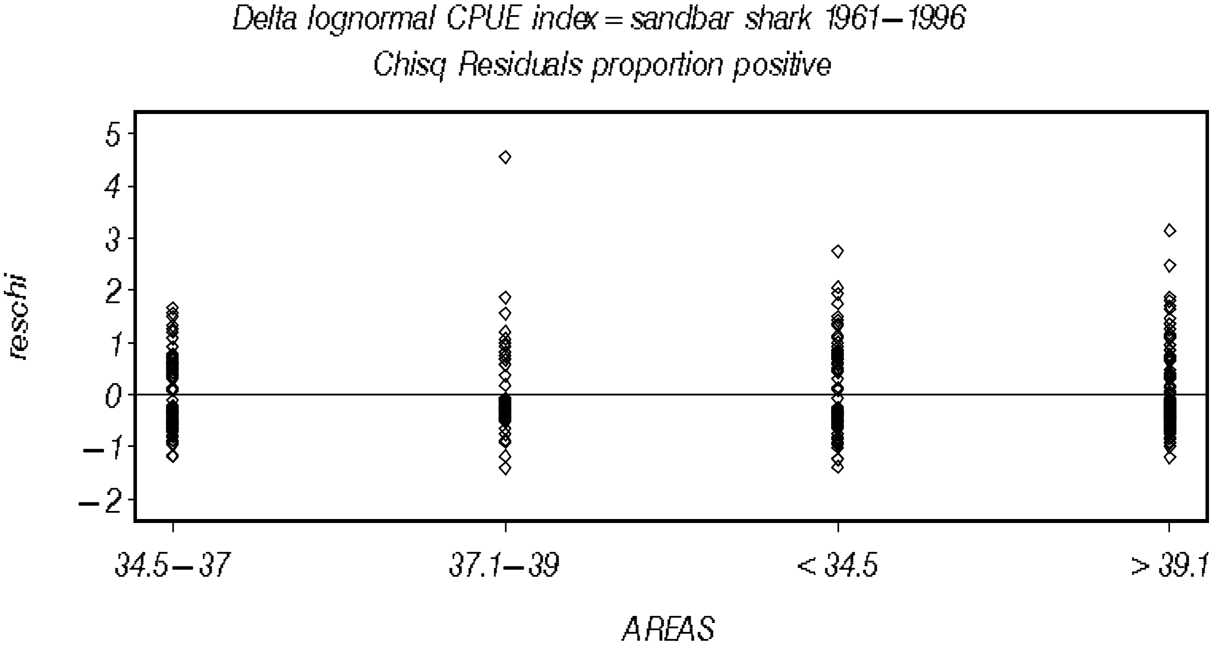

Delta lognormal CPUE index = sandbar shark 1961–1996
Chisq Residuals proportion positive

Figure 2a continued. Sandbar shark model diagnostic plots for the binomial component.

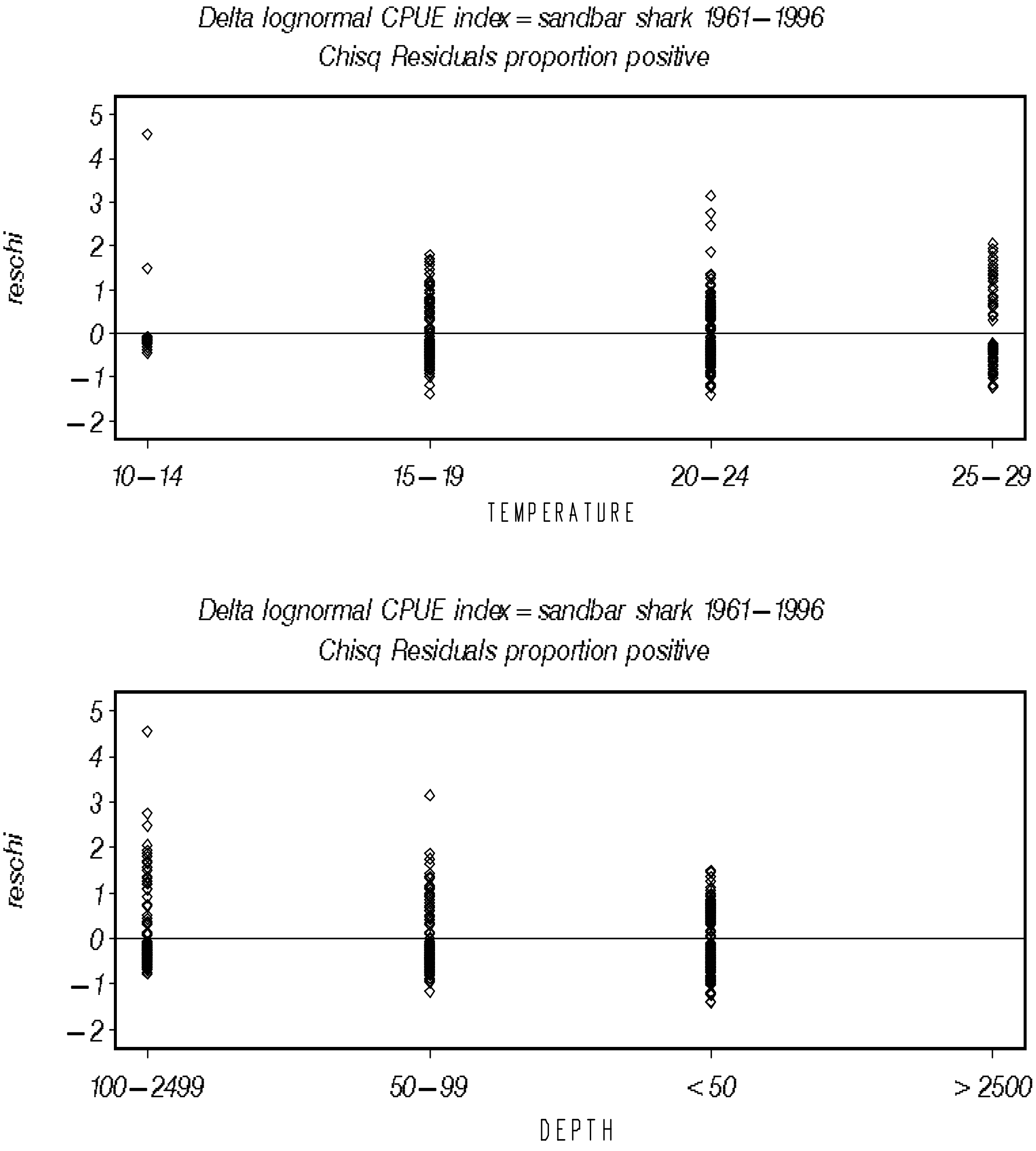


Figure 2a continued. Sandbar shark model diagnostic plots for the binomial component.

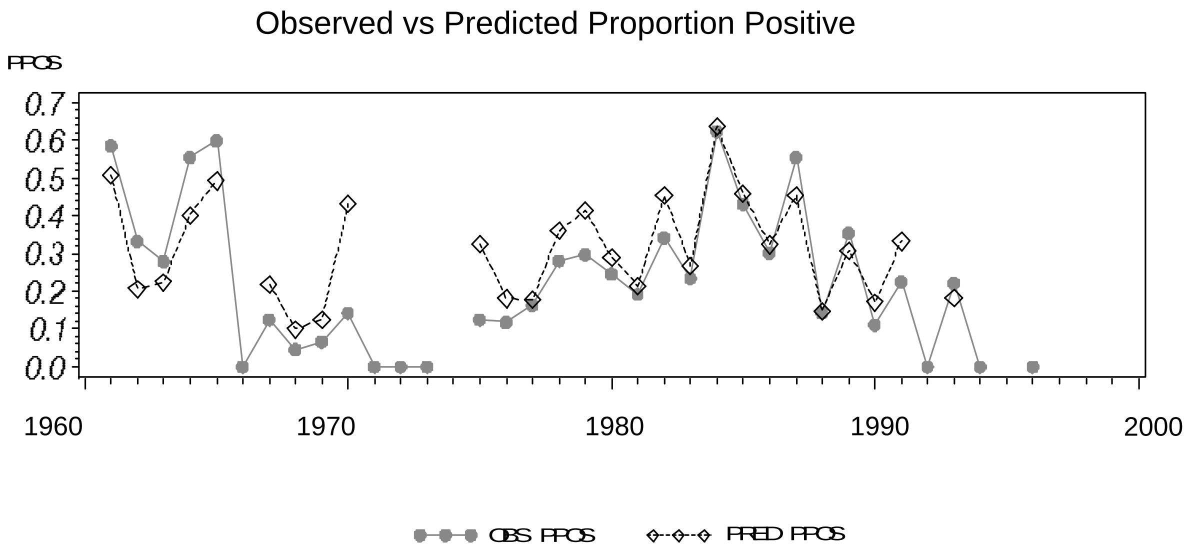


Figure 2b. Sandbar shark model diagnostic plots for the lognormal component.

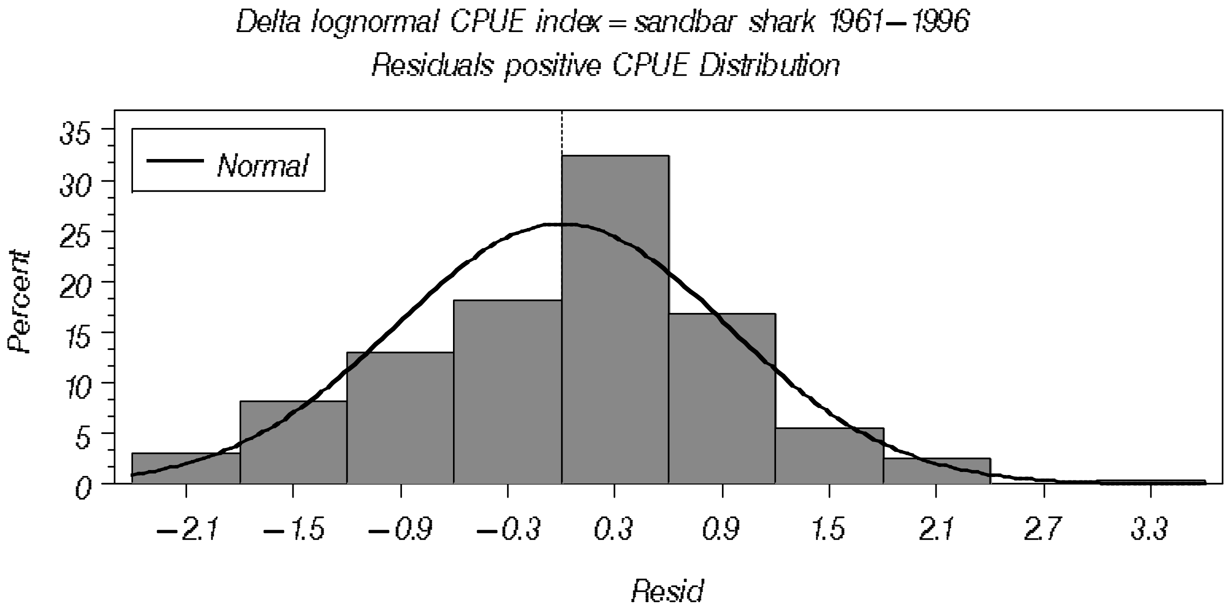
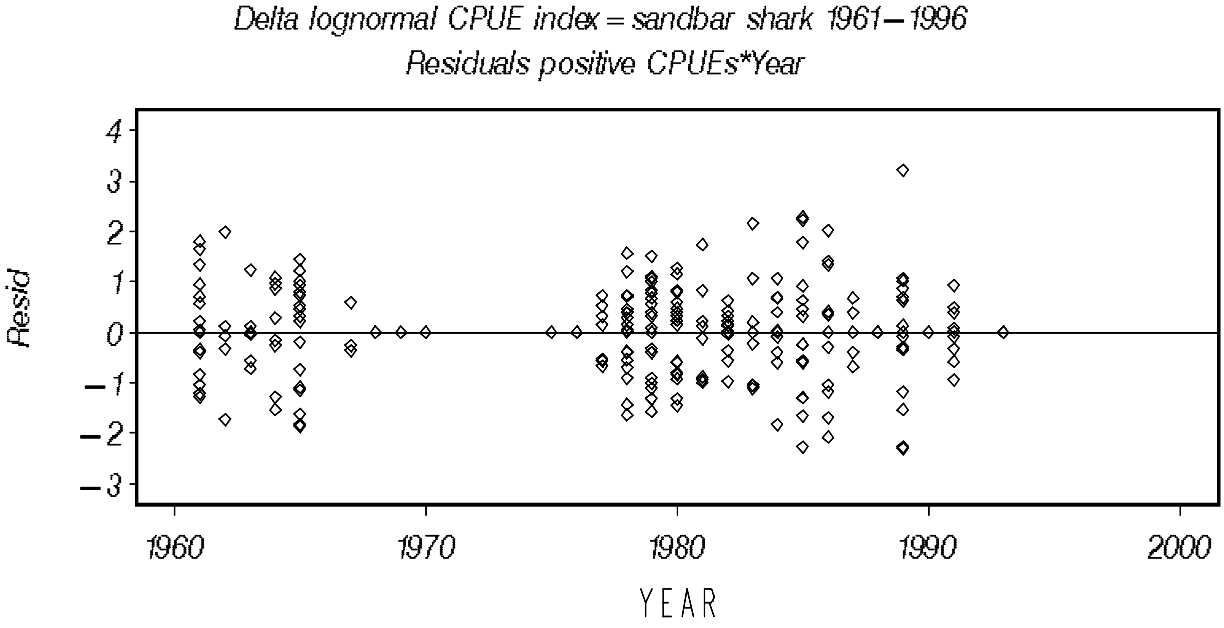


Figure 2b continued. Sandbar shark model diagnostic plots for the lognormal component.



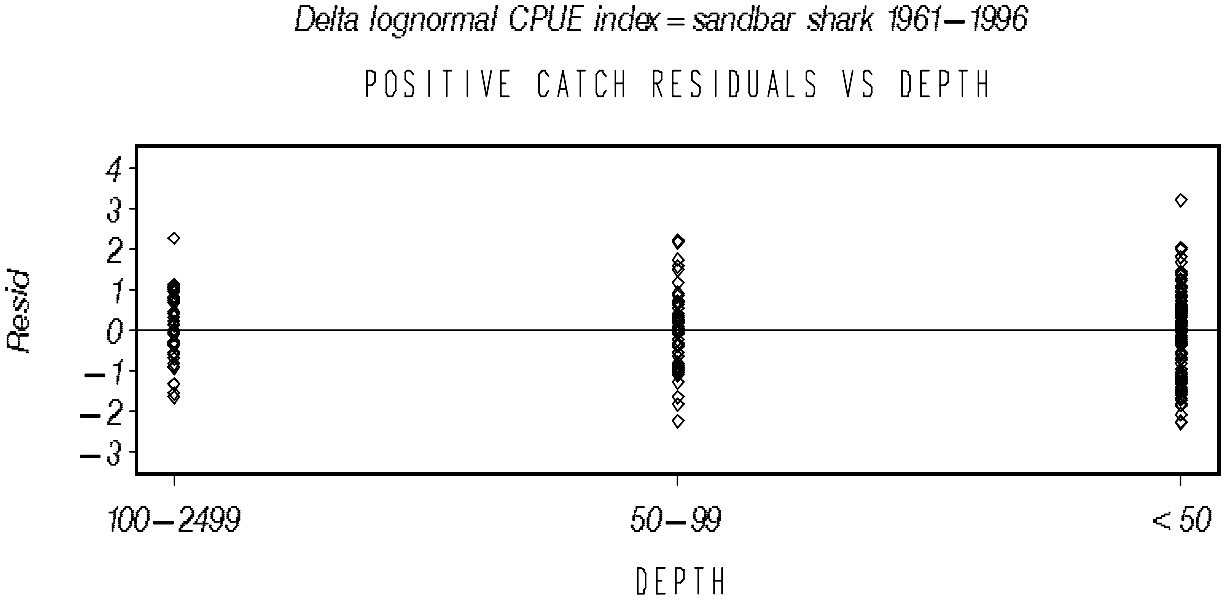


Figure 2b continued. Sandbar shark model diagnostic plots for the lognormal component.

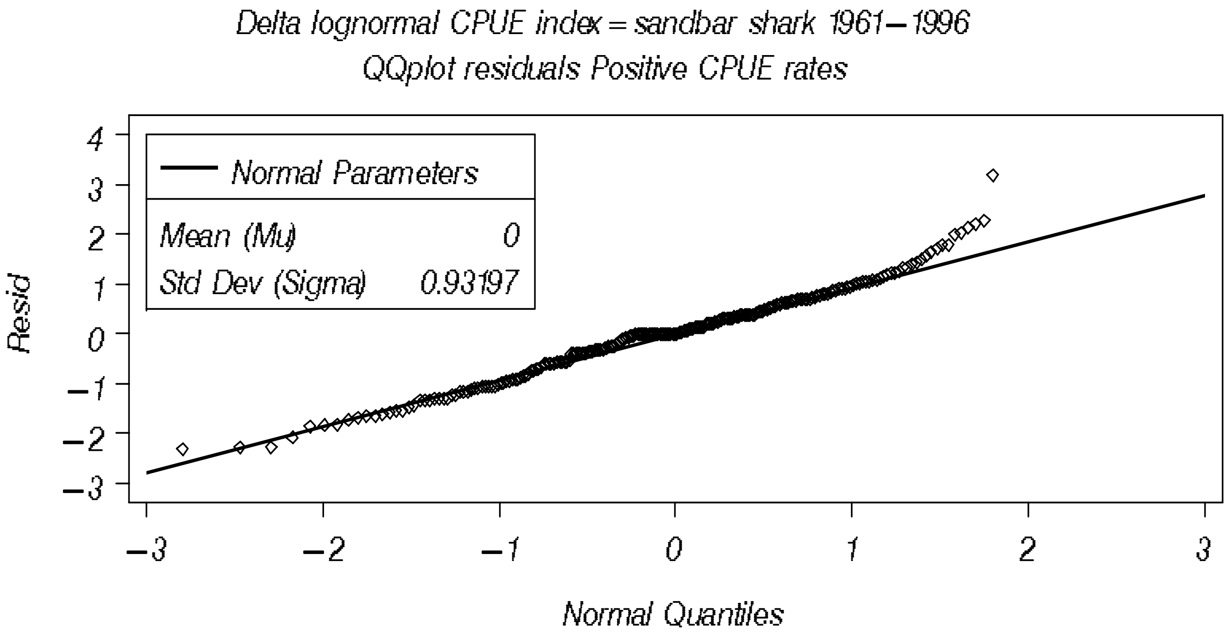


Figure 3. Sandbar shark nominal (OBS CPUE) and estimated (EST CPUE) indices divided by the maximum values with 95% confidence limits (LCL, UCL).

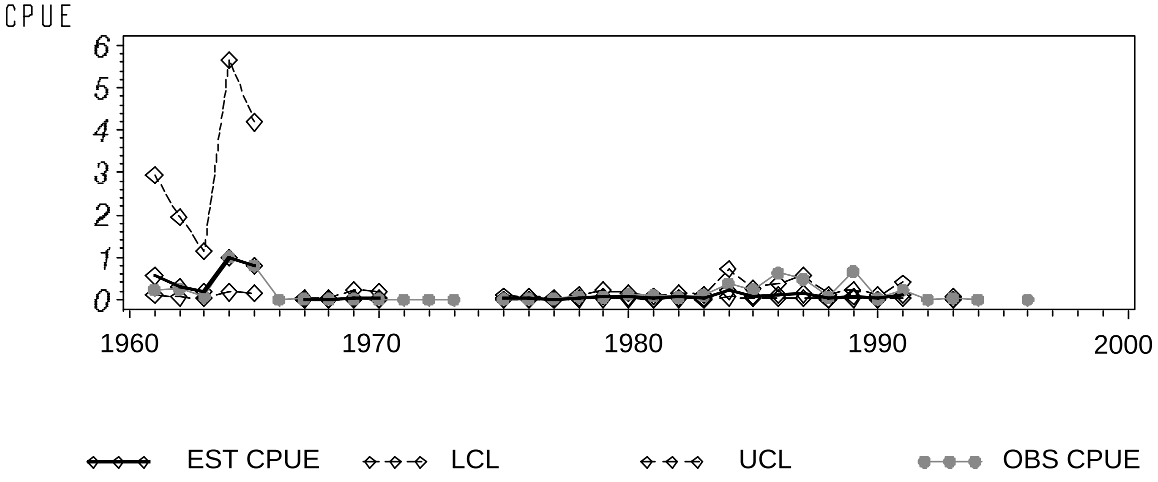
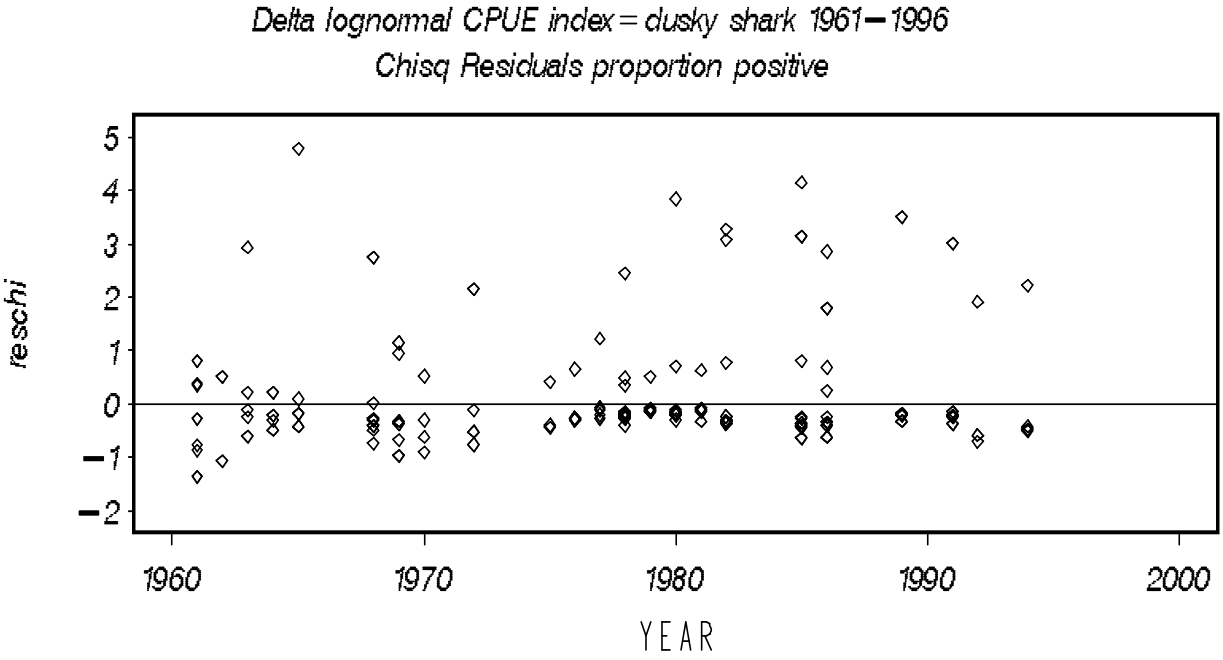


Figure 4a. Dusky shark model diagnostic plots for the binomial component.



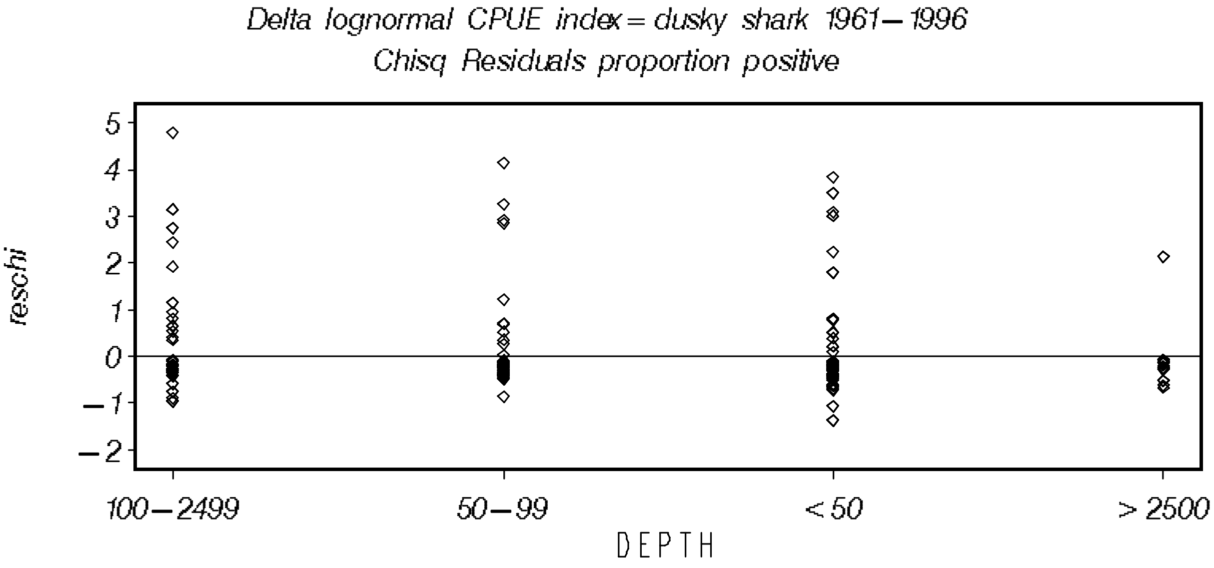


Figure 4a continued. Dusky shark model diagnostic plots for the binomial component.

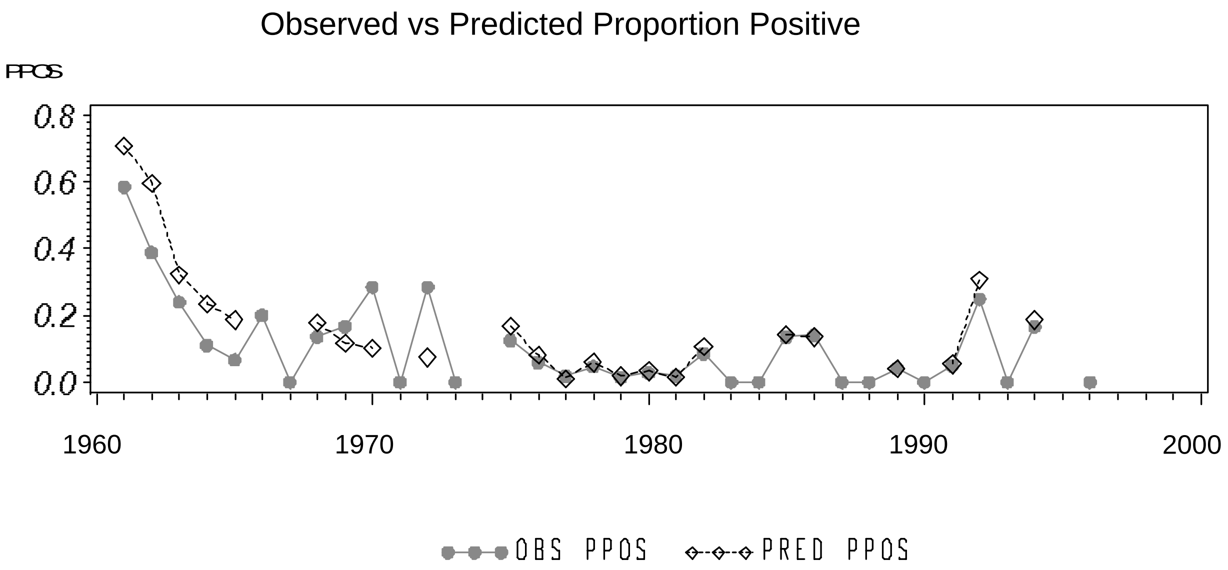


Figure 4b. Dusky shark model diagnostic plots for the lognormal component.

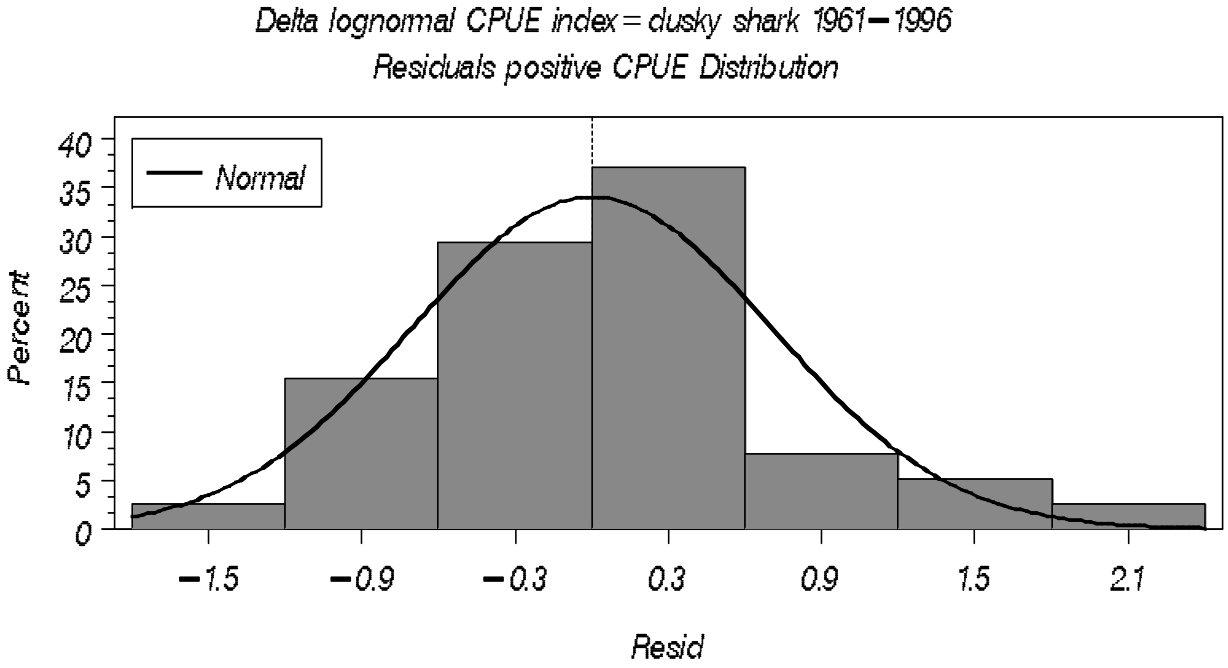
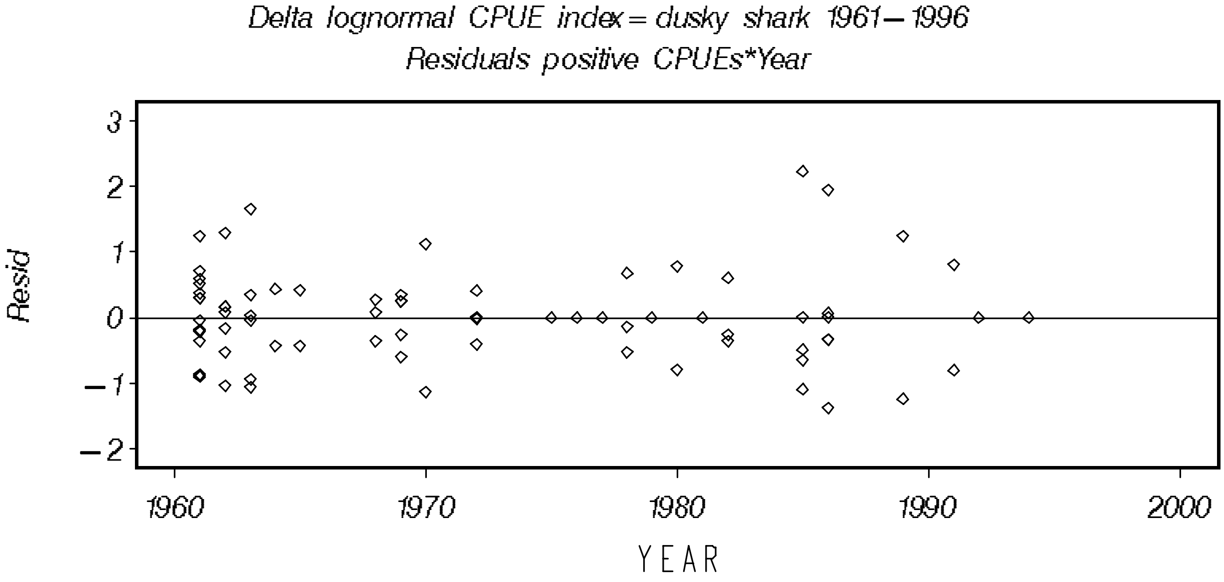


Figure 4b continued. Dusky shark model diagnostic plots for the lognormal component.



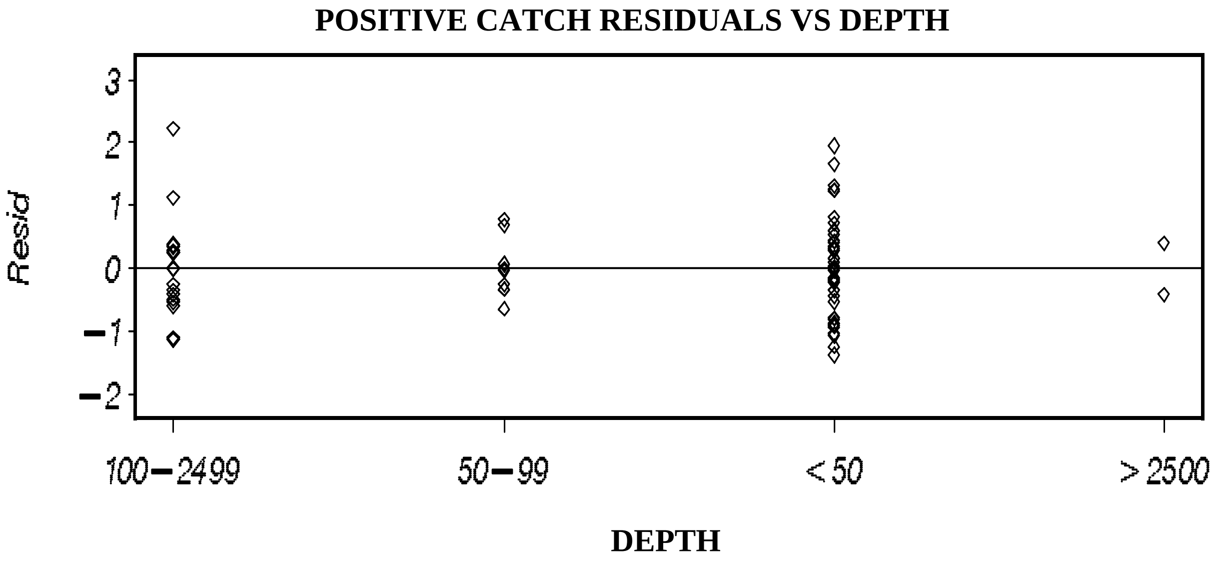


Figure 4b continued. Dusky shark model diagnostic plots for the lognormal component.

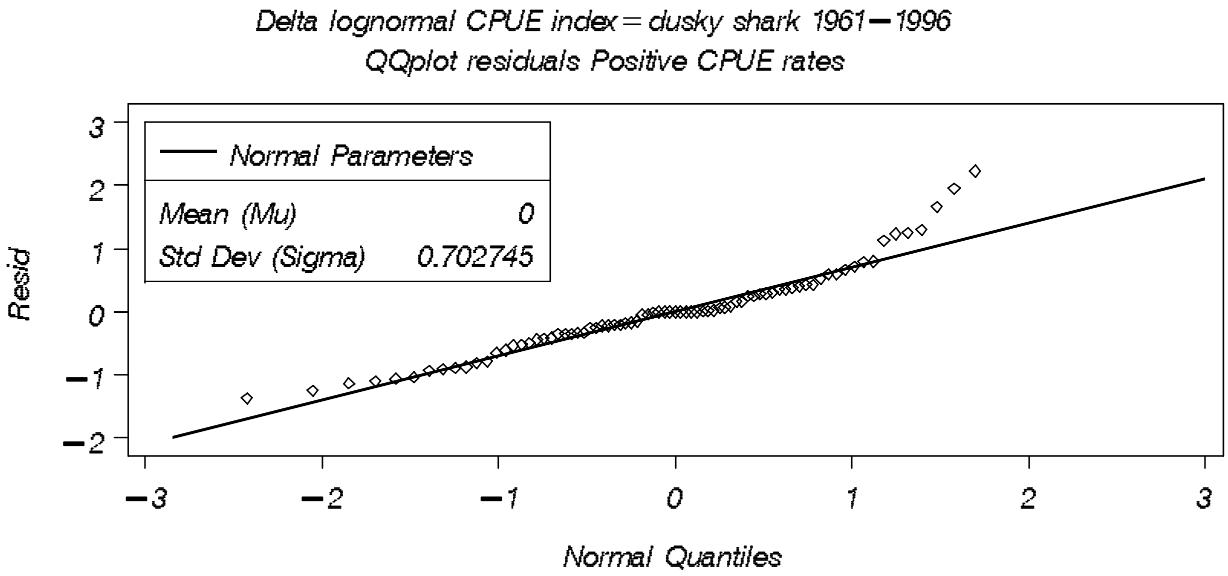


Figure 5. Sandbar shark nominal (OBS CPUE) and estimated (EST CPUE) indices divided by the maximum values with 95% confidence limits (LCL, UCL).