INDICES OF ABUNDANCE FROM THE MARINE RECREATIONAL FISHERIES STATISTICS SURVEY

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Abstract

The Marine Recreational Fisheries Statistics Survey (MRFSS) data set was used to derive standardized indices of abundance for sandbar and dusky sharks. Both indices were highly variable due to the low number of sharks observed in the intercept surveys. The number of blacknose sharks in the survey was too low to allow an abundance trend to be calculated. The fraction of the catch of carcharhinid sharks identified to species in the MRFSS data has declined over the last 20 years, as more sharks have been released alive rather than landed. Thus, these indices are likely to be biased.

Introduction

The Marine Recreational Fisheries Statistics Survey (MRFSS, MRFSS 2010) conducts dockside interviews (called the intercept survey) with returning recreational anglers, stratified by year (1981-2009), sub regions (North Atlantic, Mid Atlantic, South Atlantic and Gulf of Mexico, etc.), fishing mode (shore based, charter/party boat and private boat) and wave (2 month intervals). Additional data are collected on the area of fishing (inland waters, state waters, or federal waters (>10 miles in Florida, >3 miles in other states)), disposition of the catch (A: landed, B1: dead but not present during the interview, B2:released alive) as well as catch and effort data. The catch and effort data from the intercepts are then extrapolated using effort data from telephone surveys to yield estimates of total catch and effort. The objective of this analysis is to extract unbiased indices of abundance for sandbar (*Carcharhinus plumbeus*) and dusky (*C. obscurus*) sharks from the MRFSS intercept survey data. It was not possible to extract an index for blacknose sharks (*C. acronotus*) because only 322 blacknose sharks have been recorded in the intercept surveys, and 4 of the 29 years reported no catches of blacknose sharks.

Methods

The MRFSS intercept survey has sampled 2.5 million trips since 1981, of which only 0.26% report catches of any sharks in the large coastal, pelagic, small coastal or prohibited categories (Table 1). Therefore, for each species, we extracted trips from only those strata (wave, mode, area, region) that caught substantial numbers of either sandbar or dusky sharks. Trips that used any gear other than hook and line and those for which area and fishing mode data were missing were also excluded. In some cases strata were combined to increase sample size.

A delta-lognormal generalized linear (GLM) model was used to standardize the indices, in which the proportion of trips with a positive catch was modeled with a logit link GLM appropriate for binomial data, and the CPUE (in numbers per 1000 angler hours) of positive trips was lognormal. Potential explanatory variables were year, sub-region, fishing mode, area and target species guild (carcharhinid, reef, non-reef, pelagic, inshore, unclassified, and unknown (i.e. no target species reported), based on Ortiz (2005)). All second order interactions were also considered.

Explanatory variables were included if the addition of the factor to the model was significant ($p<0.05$) and the factor explained at least 5% of the deviance explained by the full model (Ortiz 2005). If interaction terms were included, a generalized linear mixed model (GLMM) was used (glmer in R, Bates 2010), to fit the interactions as random effects. The random effects included in the final model was

selected based on the Akaike Information Criterion (AIC). The year effects from the binomial and lognormal methods were combined using the method of Lo et al. (1992) to produce the yearly standardized CPUE. Analyses were conducted in Splus 8.0 (Venables and Ripley 2002) and R10.1 (R Core Development Team 2010).

Results and Discussion

The MRFSS estimate data set (MRFSS 2010) includes estimates of the total catch of each species, expanded from the intercept surveys using the effort estimates from the telephone surveys. According to the estimate data set, the number of sharks caught increased throughout the 1980s and 1990s (Figure 1); however, the number of carcharhinid sharks that were only identified to the family or genus level increased dramatically during this period. This might be partly explained by the fact that the fraction of sharks that are returned to the dock (type A catch), rather than released alive or discarded dead has been declining (Figure 2). Thus, fewer sharks are observed and identified by the MRFSS samplers. The decreasing percentage of sharks that are identified to species is likely to bias any abundance trend derived from the MRFSS data, as there is no way to tell whether a carcharhinid species is less common in the data because it is less abundant, or because more are released without being identified (Ortiz 2005).

A total of 8362 sandbar sharks were reported in MRFSS intercept surveys, of which the majority were caught with private fishing boats, in waves 3, 4 and 5 (Table 2); therefore, only private boats from modes 3, 4 and 5 were included in this analysis. Most were caught in the Mid Atlantic sub-region, although there were also some reported in the South Atlantic and Gulf of Mexico; only trips from these three regions were included, and the South Atlantic and Gulf of Mexico were combined. This subset of the data included 27% of the total number of trips, but 72% of the total catch of sandbar sharks. Sandbar sharks were caught in all target species guilds, and many were caught in trips for which no target species data were recorded. Using all 7 levels of the target species guild variable caused sample sizes to be very low, with zero trips in many combinations of target species and the other factors. Therefore we combined the target species guilds into three categories: carcharhinid, other and unknown.

All the year interactions were significant in both the binomial GLM and the lognormal GLM (Table 3). The year:area, year:gear and year:region interaction random effects were all included in the best fit model according to the AIC for both the binomial and lognormal models (Table 4). The final CPUE index (Table 5, Figure 3) shows a trend fairly similar to the nominal values, generally declining, but increasing since 2005.

A total of 1434 dusky sharks were reported in MRFSS intercept surveys, of which the majority were caught with private fishing boats or charter/party boats, in waves 3, 4 and 5 (Table 2), Mid Atlantic, South Atlantic and Gulf of Mexico (Table 6). This subset of the data included 38% of the total number of trips, but 81% of the total catch dusky sharks. Target species guild was collapsed into 3 categories as for sandbar sharks.

A number of year interactions were significant for dusky sharks (Table 7, Table 8). The best model according to the AIC included the random effects of year:area and year:region for the binomial model, and area:region, mode:region, year:mode, year:region and year:guild for the lognormal GLMM. The final CPUE index (Table 9, Figure 4) shows a trend fairly similar to the nominal values, which are highly variable.

References

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Table 1. Number of trips sampled in the MRFSS intercept survey from 1981 to 2009, classified by target species and whether or not they reported any catch of large coastal, small coastal, pelagic or prohibited shark species.

Target species	No sharks	Sharks
carcharhinid	3570	326
inshore	200803	452
nonreef	274946	475
pelagic	349059	820
reef	97123	527
unclassified	509356	840
unknown	1012145	3007
Total	2447002	6447

Table 2. Number of sandbar sharks caught by stratification categories of the MRFSS survey

(a) fishing mode

charter/ party	private boat	shore-based	unknown
1022	6401	626	313

(b) sub-region

Gulf of Mexico	Mid Atlantic	North Atlantic	South Atlantic	Unknown/other
499	5748	170	1942	3

(c) wave

1:Jan-Feb	2:Mar-Apr	3:May-Jun	4:Jul-Aug	5:Sep-Oct	6:Nov-Dec
30	177	2238	4325	1380	212

(d) area

coastal	inland waters	offshore
1794	4208	2360

(e) primary species in catch

carcharhinid	inshore	nonreef	pelagic	reef	unclassified
4328	312	1583	275	521	1343

(f) target species guild

carcharhinid	inshore	nonreef	pelagic	reef	unclassified	unknown
497	292	2250	725	154	2592	1852

Table 3. For sandbar sharks in the MRFS intercept data, analysis of deviance.
(a) binomial GLM of presence/absence.

Model	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)	percent deviance	include?
NULL			464	5000			1
year	28	1027.8	436	3972.2	0	23.6	1
year+area	2	313.3	434	3658.9	0	7.2	1
year+area+region	1	1743.3	433	1915.7	0	40	1
year+area+region+guild	2	161.2	431	1754.5	0	3.7	0
year+area+region+guild +area:region	2	53.4	429	1701.1	0	1.2	0
year+area+region+guild +area:guild	4	158.5	427	1596	0	3.6	0
year+area+region+guild +region:guild	2	62.9	429	1691.6	0	1.4	0
year+area+region+guild +year:area	56	579.3	375	1175.2	0	13.3	1
year+area+region+guild +year:guild	50	232.8	381	1521.7	0	5.3	1
year+area+region+guild +year:region	28	278	403	1476.5	0	6.4	1

(b) lognormal GLM of CPUE in positive trips

Model	Df	Deviance	Resid Df	Resid. Dev	Pr(F)	percent deviance	include
NULL			2374	2055.7			1
year	28	80	2346	1975.7	0.00	26.1	1
year+area	2	2.6	2344	1973.1	0.21	0.9	0
year+area+region	1	0.4	2343	1972.8	0.52	0.1	0
year+area+region+guild	2	4.9	2341	1967.9	0.05	1.6	0
year+area+region+guild +area:guild	4	11.5	2337	1956.4	0.01	3.8	0
year+area+region+guild +area:region	2	9.3	2339	1958.6	0.00	3	0
year+area+region+guild +region:guild	2	11.5	2339	1956.3	0.00	3.8	0
year+area+region+guild +year:area	56	100.3	2285	1867.6	0.00	32.7	1
year+area+region+guild +year:guild	47	69.8	2294	1898.1	0.00	22.8	1
year+area+region+guild +year:region	28	68.2	2313	1899.6	0.00	22.3	1

Table 4. Sandbar shark delta lognormal GLMM models, with the AIC best model in bold.
(a) presence or absence

model	AIC	BIC
year+area+region+guild+year:area	1417.6	1347.6
year+area+region+guild+year:region	1643.1	1573.1
year+area+region+guild+year:guild	1696.7	1626.7
year+area+region+guild+year:area+year:region	1312.6	1240.6
year+area+region+guild+year:area+year:guild	1352.2	1280.2
year+area+region+guild+year:guild+year:region	1546.9	1474.9
year+area+region+guild+year:area+year:region+year:guild	1237.2	1163.2

(b) positive trip log cpue

model	AIC	BIC
year+area+region+guild+year:area	6427.8	6237.8
year+area+region+guild+year:region	6426.4	6244.1
year+area+region+guild+year:guild	6448.9	6256.4
year+area+region+guild+year:area+year:region	6409.8	6243
year+area+region+guild+year:area+year:guild	6423.3	6254.2
year+area+region+guild+year:guild+year:region	6417.6	6261.2
year+area+region+guild+year:area+year:region+year:guild	6403.9	6254.2

Table 5. Sandbar shark delta lognormal standardized index, from the AIC best model defined in Table 4.

year	nominal	index	index.se
1981	0.87	1.03	0.30
1982	0.98	1.07	0.42
1983	2.82	2.16	0.84
1984	2.51	1.99	0.79
1985	2.36	1.37	0.54
1986	2.70	1.71	0.66
1987	1.48	1.07	0.42
1988	1.53	1.31	0.51
1989	0.40	0.75	0.30
1990	1.63	1.22	0.50
1991	0.51	0.58	0.23
1992	0.71	0.89	0.35
1993	1.27	0.83	0.33
1994	0.44	0.59	0.25
1995	0.97	0.81	0.33
1996	0.80	1.10	0.44
1997	1.07	1.14	0.47
1998	0.85	1.55	0.63
1999	0.73	1.33	0.52
2000	0.28	0.68	0.27
2001	0.61	0.85	0.34
2002	1.22	1.57	0.62

2003	0.55	0.48	0.20
2004	0.13	0.24	0.10
2005	0.25	0.49	0.20
2006	0.08	0.25	0.11
2007	0.31	0.49	0.20
2008	0.30	0.47	0.19
2009	0.66	0.97	0.39

Table 6. Number of dusky sharks caught in each level of the explanatory variables.

(a) mode

charter party	private boat	shore based	unknown
466	845	116	7

(b) region

Gulf of Mexico	Mid Atlantic	North Atlantic	South Atlantic	Unknown/other
244	789	7	391	3

(c) wave

1:Jan-Feb	2:Mar-Apr	3:May-Jun	4:Jul-Aug	5:Sep-Oct	6:Nov-Dec
12	128	262	733	228	71

(d) area

coastal	inland	offshore
325	503	606

(e) guild of primary species in the catch

carcharhinid	inshore	nonreef	pelagic	reef	unclassified
788	43	147	176	164	116

(f) guild of target species

carcharhinid	inshore	nonreef	pelagic	reef	unclassified	unknown
161	34	148	228	64	435	364

Table 7. Dusky shark deviance analysis.

(a) presence/absence

Model	DF	Deviance	Resid DF	Resid Dev	Pr(Chi)	Percent Deviance	Include?
NULL			1245	2242.			
year	28	224.4	1217	2017.6	0.0000	17.1	1
year+area	2	177.3	1215	1840.3	0.0000	13.5	1
year+area+mode	1	0.0	1214	1840.3	0.8751	0	0
year+area+mode+region	2	210.6	1212	1629.6	0.0000	16.1	1
year+area+mode+region +guild	2	239.3	1210	1390.3	0.0000	18.3	1
year+area+mode+region +guild+area:mode	2	4.6	1208	1385.8	0.1018	0.3	0

year+area+mode+region +guild+area:region	4	11.8	1206	1378.5	0.0187	0.9	0
year+area+mode+region +guild+area:guild	4	16.5	1206	1373.9	0.0024	1.3	0
year+area+mode+region +guild+mode:guild	2	1.0	1208	1389.4	0.6084	0.1	0
year+area+mode+region +guild+mode:region	2	48.2	1208	1342.2	0.0000	3.7	0
year+area+mode+region +guild+guild:region	4	10.1	1206	1380.3	0.0392	0.8	0
year+area+mode+region +guild+year:mode	28	49.3	1182	1341.1	0.0078	3.8	0
year+area+mode+region +guild+year:area	56	147.2	1154	1243.2	0.0000	11.2	1
year+area+mode+region +guild+year:guild	50	69.8	1160	1320.5	0.0333	5.3	1
year+area+mode+region +guild+year:region	56	217.5	1154	1172.8	0.0000	16.6	1

(b) log cpue in positive trips

Model	DF	Deviance	Resid DF	Resid Dev	Pr(F)	Percent Deviance	Include?
NULL			607	639.9			
year	28	37.2	579	602.6	0.0555	11.1	0
year+area	2	50.5	577	552.1	0.0000	15	1
year+area+mode	1	22.4	576	529.7	0.0000	6.7	1
year+area+mode+region	2	8.1	574	521.6	0.0114	2.4	0
year+area+mode+region +guild	2	6.9	572	514.7	0.0225	2	0
year+area+mode+region +guild+area:mode	2	12.2	570	502.6	0.0011	3.6	0
year+area+mode+region +guild+area:guild	4	1.6	568	513.2	0.7876	0.5	0
year+area+mode+region +guild+area:region	4	24.6	568	490.2	0.0000	7.3	1
year+area+mode+region +guild+mode:guild	2	0.9	570	513.9	0.6208	0.3	0
year+area+mode+region +guild+mode:region	2	21.3	570	493.4	0.0000	6.3	1
year+area+mode+region +guild+guild:region	4	2.9	568	511.9	0.5276	0.9	0
year+area+mode+region +guild+year:mode	27	39.6	545	475.1	0.0178	11.8	1
year+area+mode+region +guild+year:area	52	51.8	520	462.9	0.2704	15.4	0
year+area+mode+region +guild+year:guild	46	48.5	526	466.2	0.1887	14.4	0
year+area+mode+region +guild+year:region	44	70.8	528	443.9	0.0005	21.1	1

Table 8. Dusky shark delta lognormal GLMM, with the AIC best model in bold.
(a) presence/absence

Model	AIC	BIC
year+area+region+guild+year:area	1423.9	1351.9
year+area+region+guild+year:region	1403.4	1331.4
year+area+region+guild+year:guild	1438.9	1366.9
year+area+region+guild+year:area+year:region	1384.7	1310.7
year+area+region+guild+year:area+year:guild	1425.9	1351.9
year+area+region+guild+year:region+year:guild	1405.4	1331.4
year+area+region+guild+year:area+year:region+year:guild	1386.7	1310.7

(b) positive log cpue

Model	AIC	BIC
year+area+mode+region+area:region	1736.2	1586.7
year+area+mode+region+area:region+mode:region	1726.1	1584.1
year+area+mode+region+area:region+mode:region+year:mode	1726.4	1604
year+area+mode+region+area:region+mode:region+year:region	1716.5	1616.5
year+area+mode+region+area:region+mode:region+year:mode+year:region +year:guild	1712.8	1625.3

Table 9. Dusky shark delta lognormal index, based on the AIC best model with random interactions.

year	nominal	index	index.se	index.cv
1981	2.06	1.82	0.28	0.16
1982	1.03	0.70	0.15	0.22
1983	1.19	0.98	0.22	0.22
1984	0.96	0.78	0.18	0.24
1985	1.47	1.35	0.28	0.21
1986	2.03	1.75	0.34	0.20
1987	1.43	1.23	0.25	0.20
1988	1.15	1.49	0.30	0.20
1989	1.92	1.24	0.25	0.20
1990	1.22	1.01	0.21	0.20
1991	1.03	1.03	0.20	0.20
1992	1.57	1.70	0.33	0.19
1993	0.24	0.34	0.08	0.22
1994	1.17	0.99	0.20	0.20
1995	0.33	0.43	0.09	0.21
1996	1.07	1.06	0.21	0.20
1997	1.04	1.11	0.22	0.20
1998	1.37	1.41	0.28	0.20
1999	0.48	0.62	0.13	0.21
2000	1.22	1.37	0.28	0.20
2001	0.32	0.50	0.10	0.21
2002	0.31	0.51	0.11	0.22
2003	0.75	0.56	0.12	0.21

2004	0.28	0.33	0.08	0.24
2005	0.38	0.63	0.13	0.21
2006	0.64	0.79	0.16	0.21
2007	0.63	1.00	0.20	0.20
2008	0.87	1.36	0.28	0.21
2009	0.83	0.93	0.19	0.20

Figure 1. Total estimated catch (A, B1 and B2) of carcharhinid sharks by species from the MRFSS estimate data set.

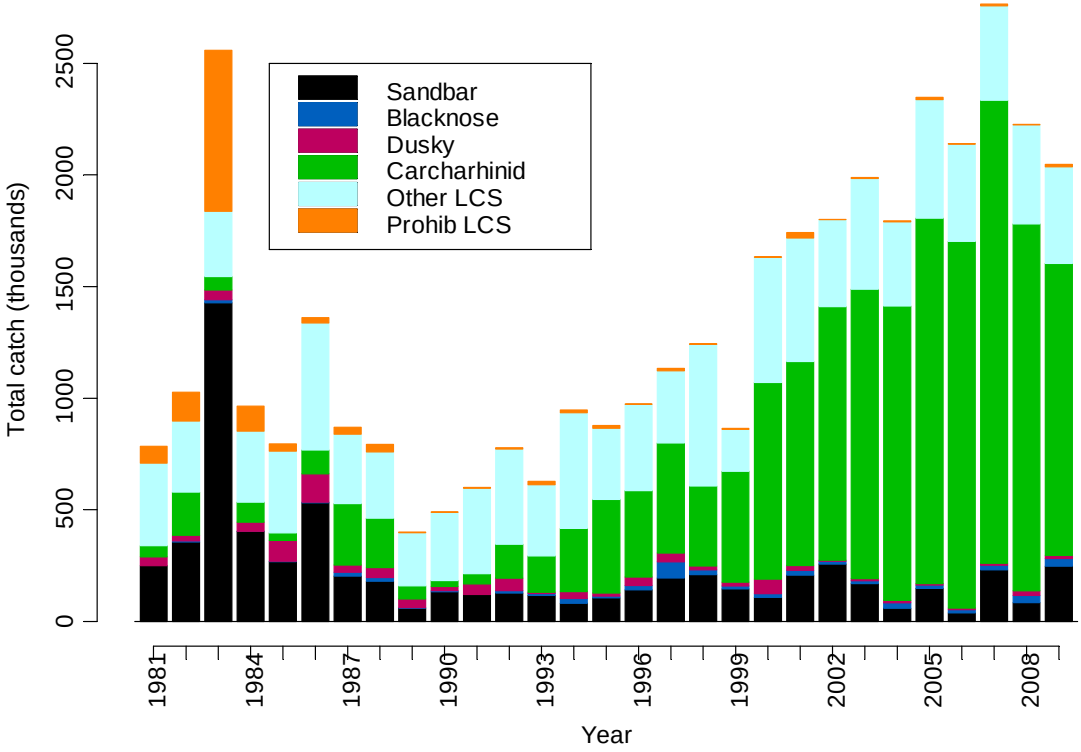

Figure 2. Percent of MRFSS estimated catches in each disposition category, for (a) sandbar, (b) blacknose, (c) dusky and (d) unspecified Carcharhinid sharks.

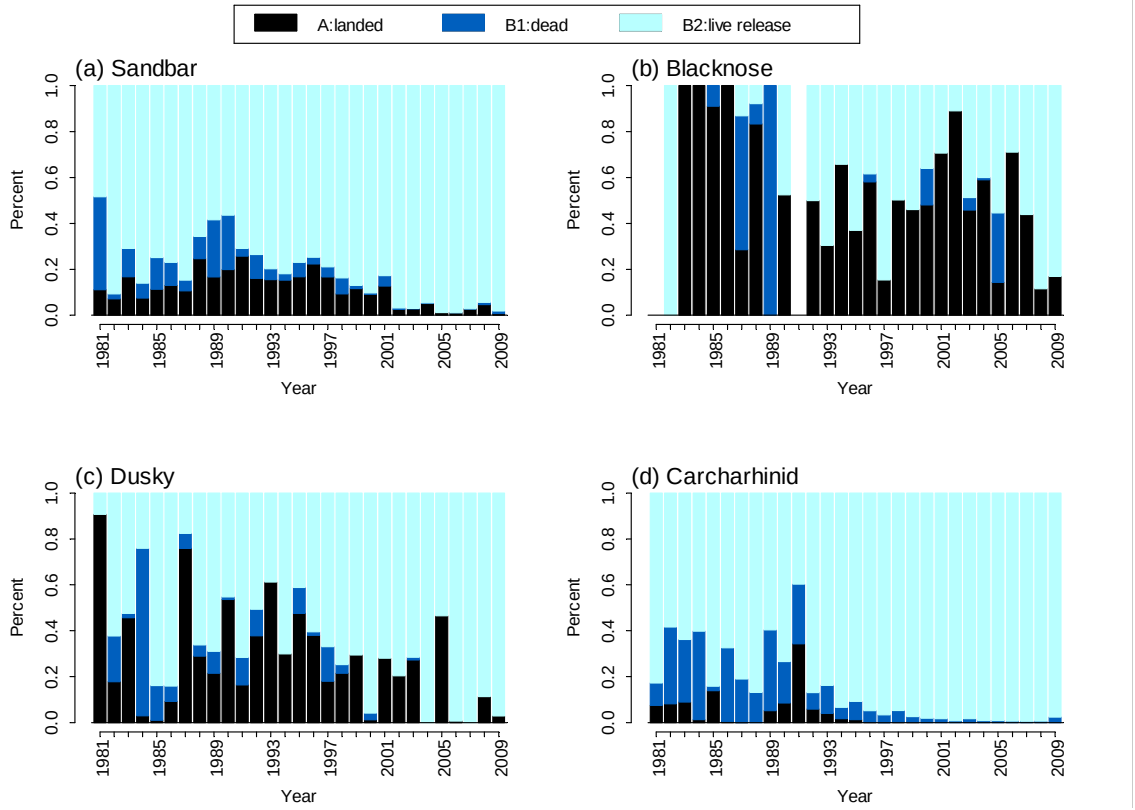

Figure 3. Sandbar CPUE index with 95% confidence intervals (lines) with nominal values (points).

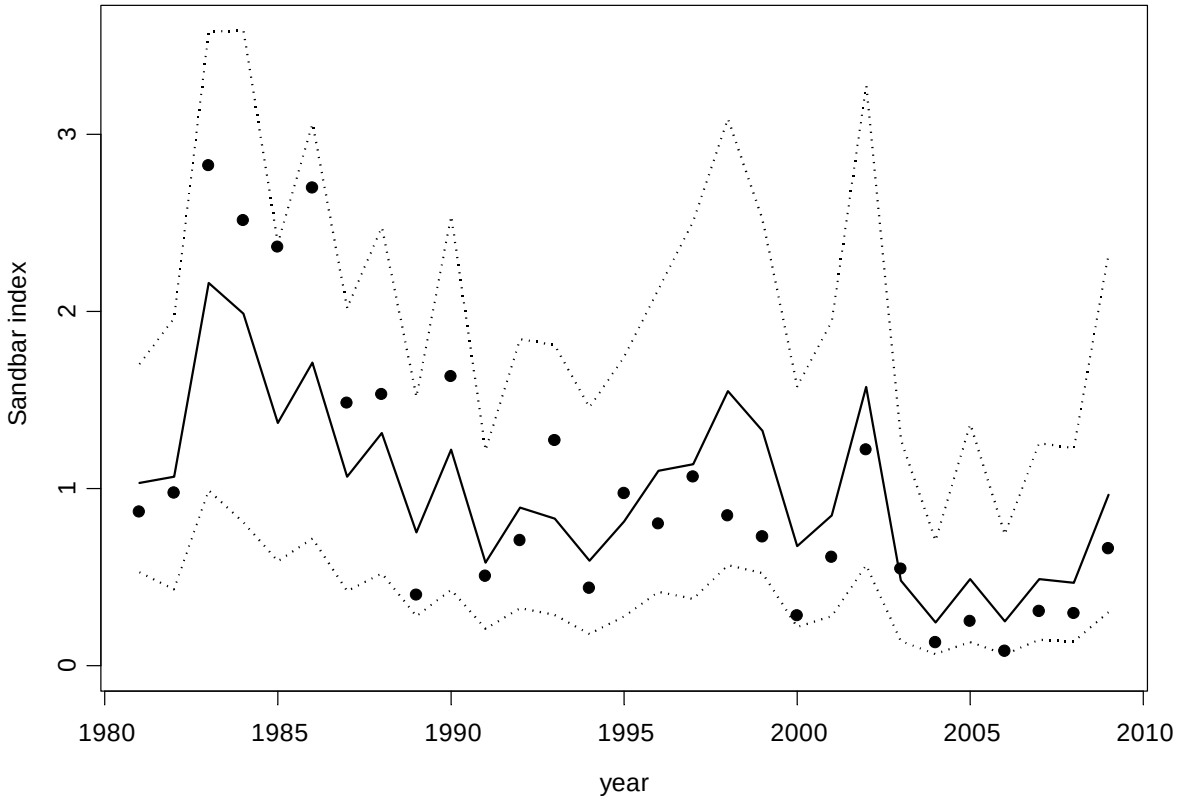

Figure 4. Dusky shark CPUE index with 95% confidence intervals (lines) with nominal values (points).