

CATCH RATES OF BLUE SHARKS (*PRIONACE GLAUCA*) IN THE U.S. ATLANTIC RECREATIONAL FISHERY

Elizabeth A. Babcock¹, Ellen K. Pikitch¹, Murdoch McAllister²

SUMMARY

Intercept survey (interviews of returning anglers) data from the National Marine Fisheries Service Marine Recreational Fishery Statistics Survey (MRFSS) were used to examine blue shark (Prionace glauca) catch rates in the recreational fishery off the U.S. Atlantic and Gulf of Mexico coasts for the years 1981 to 1996. A generalized linear model (GLM) was used to assess the effects of region, fishing mode (private versus charter boats), season and year on the proportion of fishing trips that caught any blue sharks, and the catch rate in trips that caught blue sharks.

RÉSUMÉ

Des données relevées par la National Marine Fisheries Service Marine Recreational Fishery Statistics Survey (MRFSS) dans le cadre d'enquêtes menées lors du retour au port des pêcheurs sportifs ont servi à étudier le taux de capture du requin peau bleue (Prionace glauca) dans la pêche sportive menée au large des côtes américaines atlantiques et du golfe du Mexique pendant les années 1981 à 1996. Un modèle linéaire généralisé (GLM) a été utilisé pour évaluer les effets de la région, de la modalité de pêche (bateau privé/en location), de la saison et de l'année sur la proportion de sorties qui ont pris des requins peau bleue, ainsi que le taux de capture de ces sorties.

RESUMEN

Se usaron datos procedentes del "National Marine Fisheries Service Marine Recreational Fishery Statistics Survey" (MRFSS), obtenidos en entrevistas con pescadores de caña a su regreso tras finalizar su actividad, para examinar las tasas de captura de tintorera (Prionace glauca) en la pesquería de recreo frente a las costas atlánticas de Estados Unidos y en el golfo de México, referentes a los años 1981-1996. Se aplicó un modelo lineal generalizados (GLM) para evaluar los efectos de región, tipo de pesca (barcos privados comparados con barcos fletados), temporada y año, sobre la proporción de salidas en las que se pescó alguna tintorera y la tasa de captura en salidas en las que se capturaron tintoreras.

¹ Wildlife Conservation Society, Marine Conservation Program, Bronx Zoo, Bronx, NY 10460 USA

² Renewable Resources Assessment Group, Centre for Environmental Technology, T. H. Huxley School of Environment, Earth Sciences and Engineering, Imperial College, London, SW7 1NA UK

INTRODUCTION

The objective of this analysis was to develop an index of blue shark abundance from the U.S. National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS). The MRFSS survey consists of two parts, an intercept survey in which returning anglers are interviewed on the docks, and a telephone survey which is used to estimate total effort (Fisheries Statistics and Economics Division 1996). Not all charter/party boats are covered by the MRFSS survey. However, the survey is a representative sample of private vessel and shore-based fishing. Although blue sharks are not a primary target species in this fishery, they are caught by both private and party boats.

METHODS

Catch information was available from the MRFSS intercept survey (dockside angler interview) data in the form of SAS datasets. These files were imported into S-plus and all subsequent analyses were done in S-plus for Windows.

Fishing effort was defined as the number of fishing trips by charter or private boats fishing greater than 3 miles (4.8 km) offshore. Pelagic sharks caught included blue, thresher (*Alopias vulpinus*) and shortfin mako (*Isurus oxyrinchus*).

Catch of blue sharks was defined as the number of sharks landed plus dead discards and live releases (Fisheries Statistics and Economics Division 1996). Some trips recorded discards or live releases of unidentified sharks that could have been blue sharks. Also, discards reported as blue sharks could have been misidentified. However, for this analysis, only sharks that were identified as blue sharks were counted. Most records in the dataset reported the catch of individual fishermen. For the few trips for which the number of fishermen contributing to the recorded catch was greater than one, the sharks caught were divided evenly among the anglers contributing to the reported catch (Fisheries Statistics and Economics Division 1996).

Catch rates were standardized in a two part generalized linear model (GLM) analysis, one to model the proportion of trips that caught any blue sharks, and one to model the catch per trip (CPUE) for the positive trips only.

The MRFSS intercept survey is stratified by state, wave (two-month periods), year and fishing mode (shore-based, private/rental boats and charter/party boats). For both GLM models, the explanatory variables considered were year, wave, fishing mode, and region. The years were 1981 through 1996. The only waves with substantial catches were May-June, July-August and September-October; all others were excluded from the analysis (Table 1a). The modes considered were private/rental boats and party/charter (the few shore-based trips were excluded, because almost none of them caught blue sharks, Table 1b). The MRFSS is stratified by state; however, for pelagic sharks the number of trips was too low to analyze individual state effects for every state, so states were combined into regions (North Atlantic: Maine through Connecticut; Mid Atlantic: New York through Virginia; South Atlantic: North Carolina through the East Coast of Florida and the Gulf of Mexico, Table 1c). Because most pelagic sharks were caught in the north and mid Atlantic, only these regions were included in the analysis. The sample size was 66 761 trips, 883 of which reported a blue shark catch. (Table 2).

The GLMs were performed as follows. For the CPUE of positive trips, the model was a log link GLM appropriate for Poisson data. The original model was:

$$\hat{U}_{i,j,k,l,m} = \mathbf{b}_0 + \mathbf{b}_{yr,i} + \mathbf{b}_{wv,j} + \mathbf{b}_{reg,k} + \mathbf{b}_{md,l} + 2 \text{ way interactions} + 3 \text{ way interactions} + \mathbf{e}_{i,j,k,l}$$

where $\hat{U}_{i,j,k,l}$ is the average CPUE in year i , wave j , region k and mode l . \mathbf{b}_0 is the average CPUE for the year 1981, wave May-June, the mid Atlantic region and the private /rental boat mode. $\mathbf{b}_{yr,i}$, $\mathbf{b}_{wv,j}$, $\mathbf{b}_{reg,k}$ and $\mathbf{b}_{md,l}$ are the parameters associated with the main effects of year i , wave j , region k and mode l , respectively, and $\mathbf{e}_{i,j,k,l}$ is an error term.

The best model was chosen by a stepwise algorithm using the Akaike information criterion (the stepAIC function, Venables and Ripley 1997). The AIC is defined (Venables and Ripley 1997) as:

$$\text{AIC} = -2 \cdot \text{maximized log likelihood} + 2 \cdot \text{number of parameters}$$

so that a lower value indicates a more parsimonious model. Because the order of the predictor variables affects their significance, the model was run with the main effects in various orders.

The proportion of offshore trips with a catch of blue sharks was modeled with a logit link GLM (family binomial) with the same predictor variables, but without three way interactions.

$$P_{i,j,k,l,m} = \mathbf{b}_0 + \mathbf{b}_{yr,i} + \mathbf{b}_{wv,j} + \mathbf{b}_{reg,k} + \mathbf{b}_{md,l} + 2 \text{ way interactions} + \mathbf{e}_{i,j,k,l}$$

where $P_{i,j,k,l}$ is the average proportion of positive trips in year i , wave j , region k and mode l . All other parameters are defined as above. The AIC was used to choose the best model.

As indices of the relative abundance of blue sharks, the GLM models were used to predict the proportion of positive trips in each year, the positive trip CPUE in each year and a total CPUE index which was the product of the two. The proportion positive (\hat{P}) and positive trip CPUE (\hat{U}) were estimated for each year i as $\mathbf{b}_0 + \mathbf{b}_{yr,i}$ from the appropriate model. The combined index was the product of \hat{P} and \hat{U} and the standard error of the combined index was estimated with the delta method as calculated by Lo et al (1992):

$$\text{Var}(\hat{d}\hat{P}) = \left[\text{Var}(\hat{d})\hat{P}^2 + \hat{d}^2\text{Var}(\hat{P}) + 2\hat{d}\hat{P}\text{Cov}(\hat{d}, \hat{P}) \right]$$

where \hat{d} is the CPUE in positive trips and \hat{P} is the proportion positive. The covariance of \hat{d} and \hat{P} is estimated by (Lo et al 1992):

$$\text{Cov}(\hat{d}, \hat{P}) \approx \text{corr}(\hat{d}, \hat{P}) \left[\text{SE}(\hat{d})\text{SE}(\hat{P}) \right]$$

where corr is the correlation between \hat{d} and \hat{P} between years, and SE is the standard error.

RESULTS

For trips with any catch of blue sharks, the CPUE varied significantly with year, region, wave, and mode, and several 2-way interactions (Table 3). Of the three way interactions, only yearXwaveXregion was significant. The AIC was lower for the model shown in Table 3 than for any other model considered (953.2 vs. 968.9 for the model with all 2 and 3 way interactions).

The proportion of offshore trips with a positive catch of blue sharks varied significantly with year, wave, region, mode and various 2-way interactions (Table 4). The model shown has the lowest AIC of all models with two-way interactions (620.9 vs. 622.1 for the model with all two-way interactions).

Table 5 and Figure 1 show various potential indices of blue shark abundance. The nominal CPUE indices appear to be increasing (Fig. 1a). However, the GLM standardized indices are more irregular. Because the standardized indices incorporate the intercept (\mathbf{b}_0) and year effect ($\mathbf{b}_{yr,i}$) only, they represent the average values at the reference levels of the explanatory variables (mid-Atlantic region, May-June wave, private mode). Because there are significant interactions between year and some of the other predictor variables, other regions, modes and waves might show different trends.

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Table 1. Number of blue sharks reported caught (retained, live release or dead discard) in the MRFSS Intercept Survey. Trips fishing less than 3 miles offshore are included in this table but excluded from the analyses.

a. By year and wave

Year	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Total
1981	0	0	9	3	0	0	12
1982	0	0	1	3	0	0	4
1983	0	0	26	6	2	0	34
1984	0	0	18	1	2	0	21
1985	0	0	7	1	1	0	9
1986	0	0	68	5	45	0	118
1987	0	0	39	7	14	0	60
1988	0	0	36	31	17	0	84
1989	2	0	37	45	51	0	135
1990	0	3	30	26	14	0	73
1991	0	0	68	27	23	0	118
1992	0	7	158	51	66	0	282
1993	0	0	37	121	104	0	262
1994	0	0	21	41	64	0	126
1995	0	1	162	88	25	0	276
1996	0	0	98	193	86	0	377
Total	2	11	815	649	514	0	1991

b. By year and fishing mode (shore-based fishing, private/rented boats, and party/charter boats).

	Shore	Private	Party	Total
1981	0	10	2	12
1982	0	1	3	4
1983	0	0	34	34
1984	1	14	6	21
1985	0	1	8	9
1986	0	54	64	118
1987	0	38	22	60
1988	0	21	63	84
1989	2	73	60	135
1990	3	15	55	73
1991	0	25	93	118
1992	0	151	131	282
1993	0	92	170	262
1994	1	76	49	126
1995	0	40	236	276
1996	0	207	170	377
Total	7	818	1166	1991

c. By year and region (North, Mid and South Atlantic and Gulf of Mexico).

	N Atl	Mid Atl	S Atl	Gulf	Total
1981	1	11	0	0	12
1982	0	4	0	0	4
1983	6	28	0	0	34
1984	15	4	2	0	21
1985	1	7	1	0	9
1986	39	77	1	1	118
1987	8	50	1	1	60
1988	37	43	2	2	84
1989	52	77	2	4	135
1990	7	63	3	0	73
1991	55	63	0	0	118
1992	65	210	7	0	282
1993	86	173	3	0	262
1994	75	50	1	0	126
1995	108	168	0	0	276
1996	158	219	0	0	377
Total	713	1247	23	8	1991

Table 2. Angler trips used in the GLM analyses, by mode (Private vs Charter boats), year, region (North and Mid Atlantic) and wave (May-June, July-August and September-October).

		Private			Charter			Total
		May-Jun	Jul-Aug	Sep-Oct	May-Jun	Jul-Aug	Sep-Oct	
North Atlantic	1981	3	212	42	125	172	118	672
	1982	90	327	178	93	127	308	1123
	1983	160	193	56	642	629	305	1985
	1984	117	188	85	387	526	204	1507
	1985	51	56	16	232	123	107	585
	1986	48	117	115	239	378	335	1232
	1987	102	307	171	262	496	282	1620
	1988	243	763	250	508	1079	621	3464
	1989	125	581	256	451	577	456	2446
	1990	215	594	303	373	290	419	2194
	1991	460	643	400	411	460	417	2791
	1992	196	582	293	361	505	469	2406
	1993	278	575	458	327	381	526	2545
	1994	221	626	335	304	410	372	2268
1995	260	793	379	587	680	541	3240	
1996	250	451	186	351	417	444	2099	
Mid Atlantic	1981	147	224	167	411	1030	712	2691
	1982	94	297	83	131	260	47	912
	1983	197	385	116	199	384	141	1422
	1984	261	247	164	241	270	150	1333
	1985	349	409	160	432	653	349	2352
	1986	386	667	290	476	454	852	3125
	1987	513	411	284	318	238	335	2099
	1988	378	1071	441	217	417	142	2666
	1989	491	948	353	878	892	767	4329
	1990	458	585	540	456	511	377	2927
	1991	408	598	378	385	574	288	2631
	1992	385	464	270	341	464	312	2236
	1993	162	308	171	251	300	181	1373
	1994	168	328	231	309	295	229	1560
1995	222	217	93	171	339	165	1207	
1996	179	353	236	253	293	407	1721	
Total		7617	14520	7500	11122	14624	11378	66761

Table 3. Analysis of Deviance table for the CPUE of blue sharks in angler trips with positive CPUE, in waves, modes and regions defined in Table 1d, with a log link (Poisson data).

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
NULL			882	1207.10		
Year	15	69.17	867	1137.92	3.33	0.000
Wave	2	70.27	865	1067.65	25.39	0.000
Region	1	16.60	864	1051.05	11.99	0.001
Mode	1	5.35	863	1045.70	3.87	0.050
year:wave	25	109.77	838	935.93	3.17	0.000
year:region	12	79.26	826	856.67	4.77	0.000
Wave:region	2	11.88	824	844.80	4.29	0.014
year:wave:region	17	43.62	807	801.18	1.85	0.019

Table 4. Analysis of deviance for logit link (binomial) GLM of the proportion of trips that caught at least one blue shark for all angler trips greater than 3 miles offshore, in the waves, modes and region defined in Table 1d.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(Chi)
NULL			191	1738.74	
year	15	636.43	176	1102.31	0.000
wave	2	9.76	174	1092.55	0.008
mode	1	18.21	173	1074.34	0.000
region	1	236.72	172	837.62	0.000
Year:wave	30	141.90	142	695.71	0.000
Year:mode	15	135.02	127	560.69	0.000
Year:region	15	47.61	112	513.08	0.000
Wave:mode	2	23.53	110	489.55	0.000
Wave:region	2	36.64	108	452.91	0.000

Table 5. Number of trips greater than 3 miles offshore per year, proportion of pelagic shark trips with a positive catch of blue sharks, CPUE of blue sharks in trips with a positive catch and total CPUE, as well as the GLM standardized values and their standard errors.

Year	Trips	Nominal			GLM Standardized					
		Proportion Positive	Positive CPUE	Total CPUE	Proportion Positive	SE	Positive CPUE	SE	Total CPUE	SE
1981	3363	0.00	1.00	0.00	0.00	0.00	1.42	1.03	0.00	0.00
1982	2035	0.00	1.00	0.00	0.01	0.01	1.00	1.00	0.01	0.01
1983	3407	0.01	1.79	0.01	0.04	0.01	2.36	0.46	0.09	0.04
1984	2840	0.00	2.11	0.01	0.01	0.00	1.38	0.69	0.01	0.01
1985	2937	0.00	1.14	0.00	0.01	0.01	1.17	0.44	0.02	0.01
1986	4357	0.01	2.74	0.03	0.04	0.01	1.58	0.30	0.06	0.02
1987	3719	0.01	1.67	0.01	0.02	0.00	2.28	0.42	0.03	0.01
1988	6130	0.01	1.97	0.01	0.04	0.01	1.63	0.30	0.07	0.02
1989	6775	0.01	1.74	0.02	0.01	0.00	4.25	1.03	0.04	0.02
1990	5121	0.01	1.59	0.01	0.03	0.01	2.39	0.47	0.06	0.02
1991	5422	0.01	2.04	0.02	0.03	0.01	2.05	0.36	0.07	0.02
1992	4642	0.02	2.40	0.06	0.04	0.01	5.16	0.48	0.21	0.05
1993	3918	0.04	1.74	0.06	0.12	0.02	1.18	0.24	0.14	0.04
1994	3828	0.02	2.03	0.03	0.02	0.01	2.13	0.52	0.03	0.02
1995	4447	0.02	2.85	0.06	0.12	0.02	4.19	0.38	0.50	0.10
1996	3820	0.04	1.91	0.08	0.10	0.02	2.18	0.22	0.23	0.05

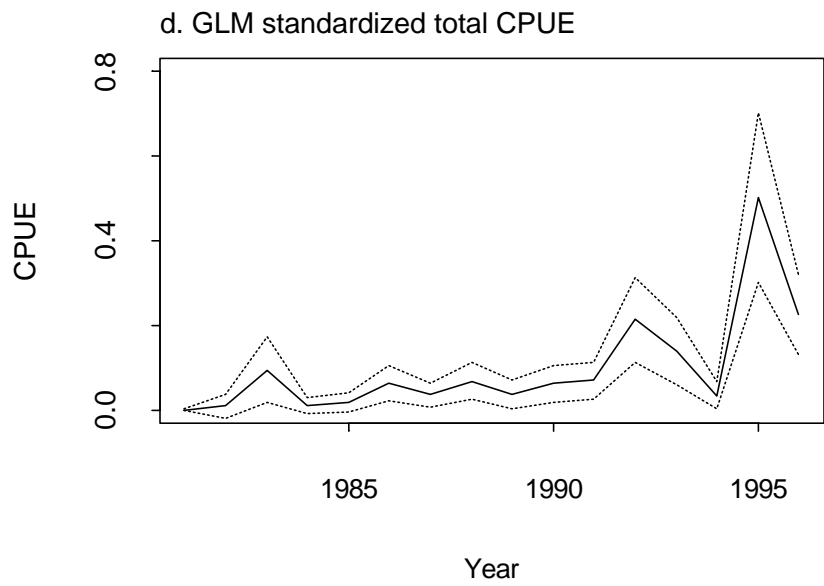
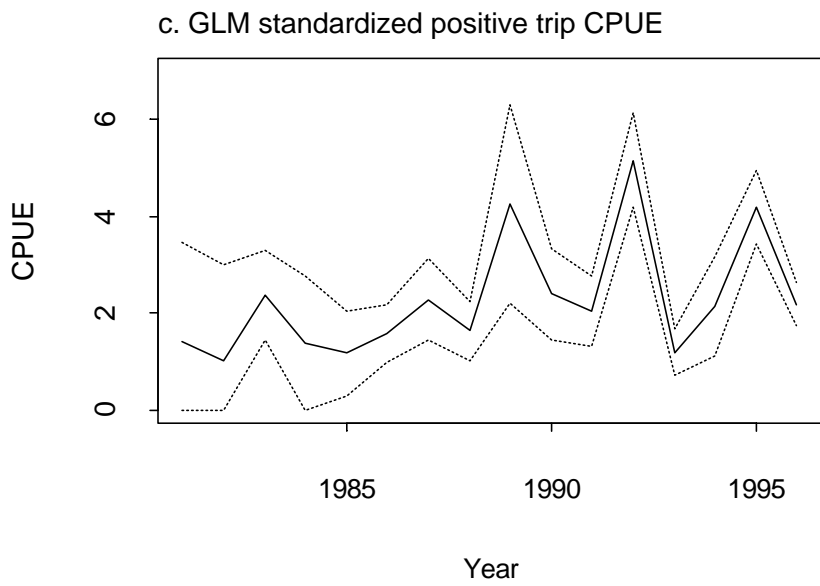
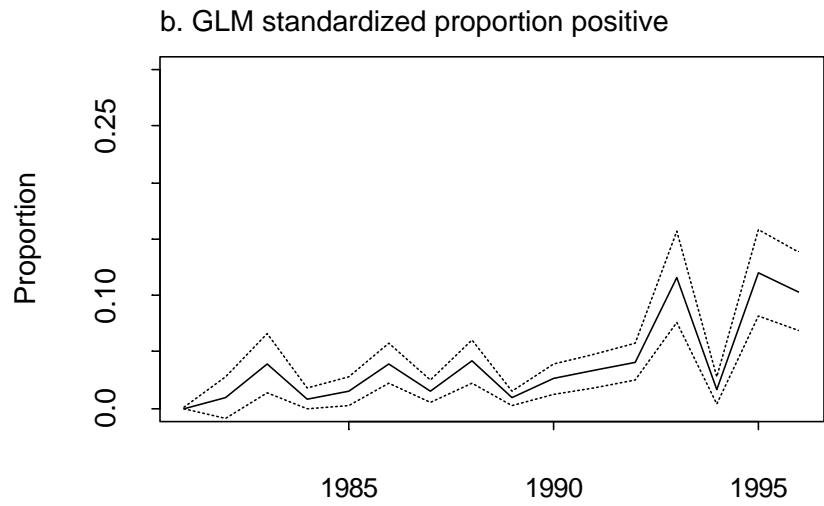
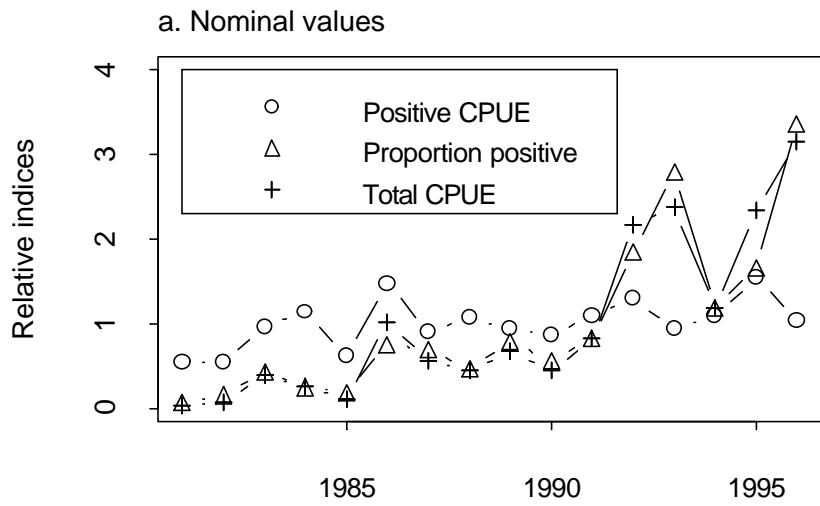


Figure 1. Nominal and GLM standardized indices of total abundance, as shown in Table 4. Dotted lines are 80% confidence bounds.