A standardized CPUE index of abundance for Gulf of Mexico blacktip sharks from the Marine Recreational Statistics Survey (MRFSS)

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Abstract

The Marine Recreational Fisheries Statistical Survey (MRFSS) data include estimates of recreational catch and effort from 1981 through 2010. The CPUE index for Gulf of Mexico blacktip sharks is derived by applying a delta-lognormal Generalized Linear Mixed Model (GLMM) to the MRFSS intercept data on the number of blacktip sharks caught (whether kept or released), with potential explanatory variables of year, area, season, region, fishing mode and target species guild. This analysis updates the series developed by Ortiz (2005). The series is quite variable with no clear trend.

Introduction

The Marine Recreational Fisheries Statistical Survey (MRFSS) includes recreational catch and effort data collected from dockside interviews with anglers (intercepts) for the years 1981 through 2010 (MRFSS 2012). The intercept surveys are 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). The catch and effort data sampled by the intercept survey are then expanded to total catch and total effort, using estimates of total fishing effort from phone interviews. From 2003 to 2010, total catch and total effort were estimated using the revised protocol with improved statistical qualities, referred to as the Marine Recreational Information Program (MRIP). The objective of this analysis is to extract unbiased indices of abundance for blacktip sharks (*Carcharhinus limbatus*) from the MRFSS intercept survey data. This is an update of the series presented in Ortiz (2005).

Methods

The CPUE index was standardized using a delta-lognormal generalized linear model (GLM), 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 modeled separately with a lognormal error structure. CPUE was calculated as catch (A, B1 and B2) per angler hour, by angler-trip. Potential explanatory variables were year (1981-2010), sub-region (Florida versus the central Gulf of Mexico, the MRFSS does not cover Texas), fishing mode (private/rental, party/charter and shore), area (inland, coastal and offshore), trimester

(January to March, etc.) and target species guild (carcharhinid, reef or pelagic, or other/unknown 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 were selected based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). 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, using the R function predSE.mer (Mazerolle 2012) to extract the standard errors from each model. Analyses were conducted in R 2.14 (R Core Development Team 2012).

Results and Discussion

The MRFSS intercept survey includes records from 6000-40000 angler-trips per year in the Gulf of Mexico, of which less than half of a percent report catching a blacktip shark (Table 1). The number of blacktip sharks observed ranges from 19 to 277 per year. Between 1981 and 2010, the number of dead-discarded blacktip sharks (type B1) has declined (Figure 1). Landings (type A) have also declined since the 1990s, and the reported live releases have increased (type B2). There has also in the number of live releases of other species of sharks (Figure 2b), and of unidentified carcharhinid sharks (Figure 2a). Because sharks that are released alive are less likely to be identified to species, it is possible that many of the unidentified sharks in the live release category are blacktip sharks. Thus, the increase in catch-and-release fishing over the time series may have introduced a bias into the CPUE index of abundance from the MRFSS data.

The GLM and GLMM models applied to the blacktip sharks were similar to the results found by Ortiz et al. (2005). For the presence/absence model, the significant interactions were area x region, mode x region, year x trimester, and year x mode (Table 2a). These four interactions were also included in the best mixed model according to both the AIC and the BIC (Table 2b). For the lognormal model of CPUE when present, there were significant interactions between year and all of the other factors (Table 3). The standardized CPUE index calculated from combining the results of the logit and lognormal models with these interactions was quite variable, and had a wide confidence interval (Figure 4, Table 1). The trend of the index between 1981 and 2004 was quite similar to the results of Ortiz (2005), shown for comparison in Figure 4. However, the CVs were higher in this analysis than in the 2005 analysis.

Considering that the number of blacktip sharks observed by the MRFSS survey is very low, and the fact that the increase in live-releases may introduce bias into the abundance index, this index probably should not be used in the base case stock assessment for blacktip sharks. However, it may be useful for a sensitivity analysis.

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Table 1. Number of trips in the MRFSS intercept survey, number of trips that caught a blacktip shark, and total number of blacktip sharks observed, along with the nominal and standardized CPUE index, its CV and 95% confidence interval.

Year	Total trips	Positive trips	Blacktip (#)	Nominal CPUE	Standardized CPUE	CV	lower 95% CI	Upper 95% CI
1981	5965	22	94	1.53	1.71	0.99	0.00	3.63
1982	10443	29	66	0.60	0.41	0.98	0.00	0.85
1983	8148	24	69	0.85	1.16	0.99	0.00	2.46
1984	9396	19	43	0.51	0.41	1.02	0.00	0.88
1985	9907	36	89	1.08	0.88	0.94	0.00	1.82
1986	14306	143	317	1.98	1.53	0.86	0.05	3.01
1987	13695	69	189	1.31	0.54	0.88	0.00	1.08
1988	15066	105	253	1.74	1.41	0.85	0.06	2.75
1989	10874	55	216	2.06	1.04	0.88	0.00	2.07
1990	9271	73	126	1.36	1.11	0.87	0.02	2.21
1991	11077	67	165	1.40	1.26	0.86	0.04	2.48
1992	23928	129	330	1.31	0.74	0.84	0.04	1.43
1993	20909	72	194	0.99	0.72	0.86	0.02	1.42
1994	24178	85	157	0.70	0.65	0.85	0.02	1.27
1995	21452	76	119	0.60	0.92	0.85	0.04	1.81
1996	22304	113	226	1.01	1.05	0.85	0.05	2.06
1997	23460	124	232	0.96	1.16	0.86	0.04	2.28
1998	29365	208	491	1.53	1.39	0.82	0.10	2.69
1999	40415	150	243	0.56	0.74	0.83	0.04	1.44
2000	37790	277	506	1.18	1.54	0.82	0.11	2.98
2001	37595	133	219	0.53	0.78	0.84	0.04	1.51
2002	39099	159	322	0.75	0.73	0.83	0.04	1.42
2003	39629	165	343	0.81	1.09	0.83	0.07	2.11
2004	41157	152	283	0.64	0.86	0.84	0.05	1.68
2005	36599	146	260	0.68	0.99	0.84	0.05	1.94
2006	35041	191	322	0.88	1.34	0.83	0.09	2.59
2007	36362	161	270	0.74	1.00	0.86	0.03	1.96
2008	36637	118	172	0.48	0.64	0.87	0.02	1.27
2009	36465	124	178	0.50	0.90	0.84	0.05	1.75
2010	35012	132	235	0.72	1.29	0.83	0.08	2.51

Table 2. Deviance analysis and mixed model results for the presence/absence model for blacktip sharks in the Gulf of Mexico. Bold text indicates that the addition of the last factor to the model was significant and explained more than 5% of the deviance explained by the full model.

(a) Deviance analysis

Model	Df	Deviance	Resid. Df	Resid. Dev	P(>Chi)	% Dev.
NULL			3950	8665.6		
year	29	305.9	3921	8359.7	0	5.9
year+area	2	416.7	3919	7943	0	8.1
year+area+trimest	3	1077.7	3916	6865.2	0	20.8
year+area+trimest+mode	2	541.3	3914	6323.9	0	10.5
year+area+trimest+mode+region	1	0.5	3913	6323.4	0.4879	0
year+area+trimest+mode+region+guild	2	740	3911	5583.5	0	14.3
year+area+trimest+mode+region+guild+area:trimest	6	94.8	3905	5488.7	0	1.8
year+area+trimest+mode+region+guild+area:mode	3	84.8	3908	5498.6	0	1.6
year+area+trimest+mode+region+guild+area:region	2	550.8	3909	5032.6	0	10.6
year+area+trimest+mode+region+guild+area:guild	4	95.1	3907	5488.4	0	1.8
year+area+trimest+mode+region+guild+trimest:mode	6	80	3905	5503.5	0	1.5
year+area+trimest+mode+region+guild+trimest:region	3	49.3	3908	5534.1	0	1
year+area+trimest+mode+region+guild+trimest:guild	6	71.8	3905	5511.6	0	1.4
year+area+trimest+mode+region+guild+mode:region	2	532.8	3909	5050.6	0	10.3
year+area+trimest+mode+region+guild+mode:guild	4	55.6	3907	5527.8	0	1.1
year+area+trimest+mode+region+guild+region:guild	2	83.1	3909	5500.3	0	1.6
year+area+trimest+mode+region+guild+year:area	58	232.9	3853	5350.6	0	4.5
year+area+trimest+mode+region+guild+year:trimest	86	329.9	3825	5253.5	0	6.4
year+area+trimest+mode+region+guild+year:mode	58	307.7	3853	5275.8	0	5.9
year+area+trimest+mode+region+guild+year:guild	58	115.4	3853	5468.1	0	2.2
year+area+trimest+mode+region+guild+year:region	29	139.9	3882	5443.5	0	2.7

(b) Mixed model results

Model	Deviance	AIC	BIC
year+area+mode+region+guild	8274.412	8354.412	8605.681
year+area+mode+trimest+region+guild+area:region	4836.652	4918.652	5176.203
year+area+mode+trimest+region+guild+area:region+mode:region	4663.903	4747.903	5011.735
year+area+mode+trimest+region+guild+area:region+mode:region+year:mode	4626.452	4712.452	4982.566

Table 3. Deviance analysis and mixed model results for the lognormal model of positive trip CPUE for blacktip sharks in the Gulf of Mexico. Bold text indicates that the addition of the last factor to the model was significant and explained more than 5% of the deviance explained by the full model.

(a) Deviance analysis

Model	Df	Deviance	Resid. Df	Resid. Dev	Pr(>F)	%Dev
NULL			3341	3260.6		
year	29	49	3312	3211.5	0.0017	5.5
year+area	2	68.2	3310	3143.4	0.0000	7.6
year+area+trimest	3	0.4	3307	3143.0	0.9369	0
year+area+trimest+mode	2	221.8	3305	2921.3	0.0000	24.8
year+area+trimest+mode+region	1	38.1	3304	2883.1	0.0000	4.3
year+area+trimest+mode+region+guild	2	26.9	3302	2856.2	0.0000	3
year+area+trimest+mode+region+guild+area:trimest	6	10.5	3296	2845.8	0.0599	1.2
year+area+trimest+mode+region+guild+area:mode	3	15.2	3299	2841.0	0.0005	1.7
year+area+trimest+mode+region+guild+area:region	2	2.5	3300	2853.7	0.2378	0.3
year+area+trimest+mode+region+guild+area:guild	4	4.1	3298	2852.1	0.3161	0.5
year+area+trimest+mode+region+guild+trimest:mode	6	32.6	3296	2823.6	0.0000	3.7
year+area+trimest+mode+region+guild+trimest:region	3	4.4	3299	2851.9	0.1695	0.5
year+area+trimest+mode+region+guild+trimest:guild	6	13.3	3296	2842.9	0.0173	1.5
year+area+trimest+mode+region+guild+mode:region	2	29.3	3300	2826.9	0.0000	3.3
year+area+trimest+mode+region+guild+mode:guild	4	16.3	3298	2840.0	0.0008	1.8
year+area+trimest+mode+region+guild+region:guild	2	2.2	3300	2854.0	0.2736	0.3
year+area+trimest+mode+region+guild+year:area	56	95.1	3246	2761.1	0.0000	10.6
year+area+trimest+mode+region+guild+year:trimest	83	123.2	3219	2733.0	0.0000	13.8
year+area+trimest+mode+region+guild+year:mode	56	97.5	3246	2758.7	0.0000	10.9
year+area+trimest+mode+region+guild+year:guild	53	85.6	3249	2770.6	0.0001	9.6
year+area+trimest+mode+region+guild+year:region	29	61.1	3273	2795.1	0.0000	6.8
year+area+trimest+mode+region+guild+year:area1	56	95.1	3246	2761.1	0.0000	10.6

(b) Mixed model results

Model	Deviance	AIC	BIC
year+area+mode+region+guild	9150.828	9222.828	9442.943
year+area+mode+region+guild+year:mode	9099.675	9179.675	9424.248
year+area+mode+region+guild+year:mode+year:area	9088.772	9170.772	9421.459
year+area+mode+region+guild+year:mode+year:area+year:guild	9075.621	9159.621	9416.422
year+area+mode+region+guild+year:mode+year:area+year:guild+year:region	9069.131	9155.131	9418.047
year+area+mode+region+guild+year:mode+year:area+year:guild+year:region+year:trimest	9054.757	9142.757	9411.787

Figure 1. Estimated total number of blacktip sharks caught and either landed, discarded or released alive in the Gulf of Mexico, from the MRFSS from 1981 through 2002, and from the MRIP from 2003 to 2010.

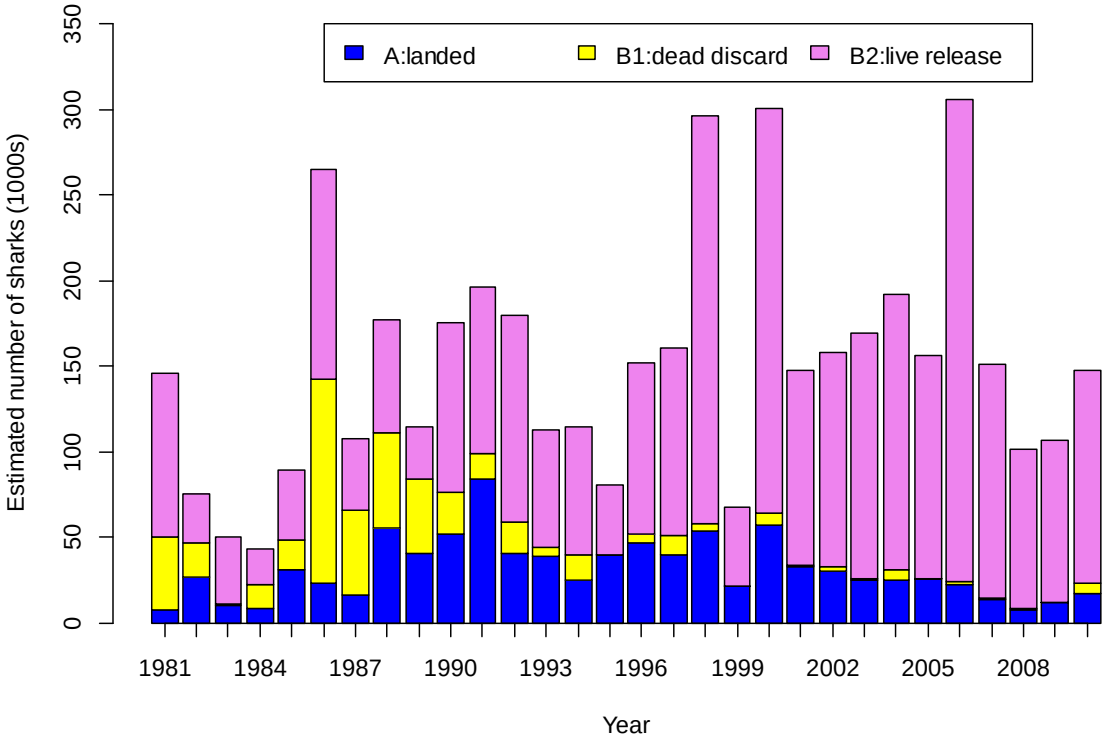

Figure 2. Estimated total catches of (a) unidentified sharks in the Carcharhinidae and (b) identified sharks other than blacktip sharks, from the MRFSS from 1981 through 2002, and from the MRIP from 2003 to 2010.

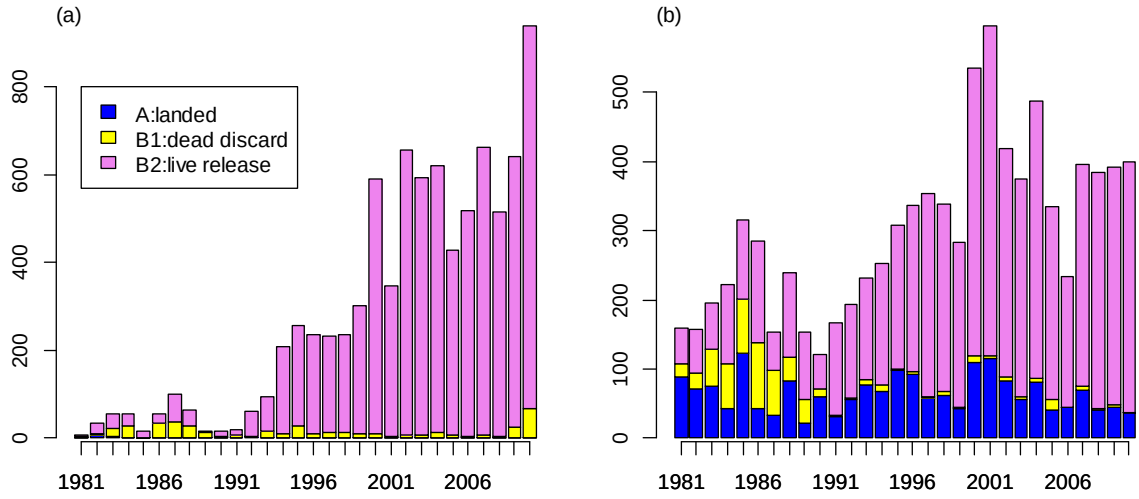

Figure 3. Nominal (points) and standardized (black solid line) CPUE index for blacktip sharks in the Gulf of Mexico based on the MRFSS data. Dashed lines are the 95% confidence interval; heavy grey line is the value of the index from Ortiz(2005). All series are divided by their mean.