Shrimp Fishery Bycatch Estimates for Smoothhound Sharks in the Gulf of Mexico, 1972-2012

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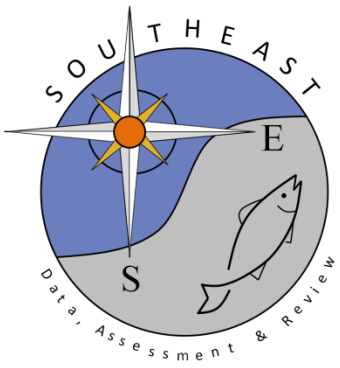

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Abstract

Shrimp bycatch estimates for Gulf of Mexico smoothhound sharks were generated using the same approach developed in the SEDAR 34 HMS Gulf of Mexico Atlantic sharpnose and bonnethead shark assessments (Zhang et al 2013a, 2013b; Cortes et al 2013). The estimated shrimp bycatch for smoothhound sharks is about 100,000 sharks during 2009-2012, but can be as high as 400,000 sharks in the earlier years when shrimp fishery effort was high.

Introduction

In 1992, in response to Congressional directives, NOAA's National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), in cooperation with the Gulf and South Atlantic Fisheries Foundation, Inc., implemented a voluntary shrimp trawl bycatch observer program to 1) characterize and estimate catch rates of trawl caught bycatch, and 2) identify,

develop, and evaluate gear options to reduce bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries (NMFS 1991, Hoar et al. 1992). To improve the statistical validity of data from the voluntary observer program, the Gulf of Mexico Fishery Management Council, through Amendment 13 to the Shrimp Fishery Management Plan mandated observer coverage of Federally permitted shrimp vessels. In 2007, the SEFSC implemented a mandatory observer program for the commercial shrimp fishery operating in the U.S. Gulf of Mexico. In June 2008, observer coverage expanded to include the South Atlantic penaeid and rock shrimp fisheries through Amendment 6 to the Shrimp Fishery Management Plan for the South Atlantic Region (Scott-Denton et al. 2012).

From 1992 through 2008 (except for characterization trips coded GC and FC), all shark species were only identified as a shark group (Scott-Denton 2004). Beginning in January 2009, species-specific identification of some shark species (as well as other teleost species) was implemented. Smoothhound sharks are on the list of species to be identified since January 2009 (Scott-Denton et al. 2012). Even though both the available shark bycatch data and commercial fleet representation through stratified selection have become much better since mandatory observer coverage of the shrimp fleet began in 2007 (Scott-Denton et al. 2012), bycatch records for Gulf of Mexico smoothhound sharks were extremely limited until January 2009. Shrimp bycatch estimates for smothhound sharks in the Gulf of Mexico were generated using the same approaches developed in the SEDAR 34 HMS Gulf of Mexico Atlantic sharpnose and bonnethead shark assessments (Zhang et al 2013a, 2013b; Cortes et al 2013).

Methods

The data used in this analysis came from shrimp observer program CPUE during 2009-2012, shrimp effort estimates during 1972-2012, and nets per vessel (NPV) estimates for the shrimp fishery during 1972-2012.

Point estimates of shrimp effort were generated by the NMFS/SEFSC Galveston Lab using their SN-pooled model (Nance 2004). In order to assign fishing activity to a geographical location, the

continental shelf of the Gulf of Mexico was divided into 21 statistical grids and effort was estimated by year, season, area (21 statistical grids were pooled into 4 areas), and depth (Table 1).

Most observer program CPUE data were expressed in fish per net-hour, while the shrimp effort data were expressed in vessel-days. Therefore, data from the NMFS/SEFSC Vessel Operating Units File (VOUF) were needed to estimate the average number of nets per vessel (NPV) for the shrimp fishery.

Estimation of the average observed smoothhound shark bycatch CPUE in the shrimp fishery was obtained from the shrimp observer program during the years 2009-2012 based on a simplified delta-lognormal model (Sprugel 1983, Lo et al. 1992), as outlined below in steps 1–3 below. Calculation of the total annual smoothhound shark bycatch in the shrimp fishery during the years 1972-2012 was based on an annual expansion of the average observed smoothhound shark bycatch CPUE obtained from the shrimp observer program during 2009-2012 multiplied by estimated shrimp effort during 1972-2012, and by the estimated number of nets per vessel (NPV) for the shrimp fishery during 1972-2012 as outlined below in steps 4–5.

Average Observed Smoothhound Shark Bycatch CPUE Estimation (2009-2012)

Step 1:

$$NZCT\_CPUE_{[yr,sea,\ ar,\ dp]} = exp\{mean[ln(NZCT\_CPUE_{[yr,\ sea,\ ar,\ dp,\ i]})] + 0.5*var[ln(NZCT\_CPUE_{[yr,\ sea,\ ar,\ dp,\ i]})]\}$$

Step 2:

$$CPUE_{[yr,sea,\ ar,\ dp]} = NZCT\_CPUE_{[yr,sea,\ ar,\ dp]} * Num\_of\_NZCT_{[yr,\ sea,\ ar,\ dp]} / Num\_of\_AT_{[yr,\ sea,\ ar,\ dp]}$$

Step 3:

$$2009\_2012\_Mean\_CPUE_{[sea,\ ar,\ dp]} = mean(CPUE_{[yr,\ sea,\ ar,\ dp]}) \qquad \text{where yr = 2009 - 2012}$$

Step 3 (L-95%CI):

$$L\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea,\ ar,\ dp]} =$$

$2009\_2011\_Mean\_CPUE_{[sea, ar, dp]} - 1.96*SE\_of\_2009\_2011\_Mean\_CPUE_{[sea, ar, dp]}$

Step 3 (U-95%CI):

$U\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]} =$

$2009\_2012\_Mean\_CPUE_{[sea, ar, dp]} + 1.96*SE\_of\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}$

Total Annual Smoothhound Shark Bycatch Calculations (1972-2012)

Step 4:

$Bycatch_{[yr, sea, ar, dp]} = 2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}*EFFORT_{[yr, sea, ar, dp]}*NPV_{[yr]}$

Step 4 (L-95%CI):

$L\_95\%CI\_Bycatch_{[yr, sea, ar, dp]} =$

$L\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]} *EFFORT_{[yr, sea, ar, dp]}*NPV_{[yr]}$

Step 4 (U-95%CI):

$U\_95\%CI\_Bycatch_{[yr, sea, ar, dp]} =$

$U\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]} *EFFORT_{[yr, sea, ar, dp]}*NPV_{[yr]}$

Step 5:

$Bycatch_{[yr]} = sum(Bycatch_{[yr,sea, ar, dp]})$

Step 5 (L-95%CI):

$L\_95\%CI\_Bycatch_{[yr]} = sum(L\_95\%CI\_Bycatch_{[yr,sea, ar, dp]})$

Step 5 (U-95%CI):

$U\_95\%CI\_Bycatch_{[yr]} = sum(U\_95\%CI\_Bycatch_{[yr,sea, ar, dp]})$

Parameter Definitions

$NZCT\_CPUE_{[yr,sea, ar, dp]}$ is the observed non-zero-catch-tow year/season/area/depth-specific CPUE,

$NZCT\_CPUE_{[yr, sea, ar, dp, i]}$ is a value of the observed non-zero-catch-tow CPUE in a year/season/area/depth combination,

$CPUE_{[yr, sea, ar, dp]}$ is the observed all-tow tow year/season/area/depth-specific CPUE,

$Num\_of\_NZCT_{[yr, sea, ar, dp]}$ is the observed number of non-zero-catch-tow in a year/season/area/depth combination,

$Num\_of\_AT_{[yr, sea, ar, dp]}$ is the observed number of all-tow in a year/season/area/depth combination,

$2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}$ is the mean of 2009-2012 season/area/depth-specific CPUE,

$L\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}$ is the lower bound of 95% confidence interval of the mean of 2009-2012 season/area/depth-specific CPUE,

$U\_95\%CI\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}$ is the upper bound of 95% confidence interval of the mean of 2009-2012 season/area/depth-specific CPUE,

$SE\_of\_2009\_2012\_Mean\_CPUE_{[sea, ar, dp]}$ is the standard error of the mean of 2009-2012 season/area/depth-specific CPUE,

$Bycatch_{[yr, sea, ar, dp]}$ is the estimated year/season/area/depth-specific bycatch,

$EFFORT_{[yr, sea, ar, dp]}$ is year/season/area/depth-specific effort,

$NPV_{[yr]\ i}$ is year-specific nets per vessel,

$L\_95\%CI\_Bycatch_{[yr, sea, ar, dp]}$ is the lower bound of 95% confidence interval of the estimated year/season/area/depth-specific bycatch,

$U\_95\%CI\_Bycatch_{[yr, sea, ar, dp]}$ is the upper bound of 95% confidence interval of the estimated year/season/area/depth-specific bycatch,

$Bycatch_{[yr]}$ is the estimated annual bycatch,

$L\_95\%CI\_Bycatch_{[yr]}$ is the lower bound of 95% confidence interval of the estimated annual bycatch,

$U\_95\%CI\_Bycatch_{[yr]}$ is the upper bound of 95% confidence interval of the observed annual bycatch,

Results

The average number of nets per vessel increased gradually from 1972 to 1996, and remained relatively constant from 1996 to 2012 at approximately three nets per vessel (Figure 1). Shrimp effort declined sharply from 2002 to 2008, and has remained at relatively low levels during the last decade (Figure 2). There are 2601-3157 tows per year during 2009-2012 (Tables 2-5). However, only 16-91 tows caught smoothhound sharks each year during 2009-2012 (Tables 2-5). Therefore, shrimp bycatch for smoothhound sharks is very data-limited and zero inflated. Estimates of the observed 2009-2012 mean season/area/depth- specific CPUE for smoothhound shark in the Gulf of Mexico are 0-0.1970 sharks per net-hour (Table 6). The estimated shrimp bycatch for smoothhound sharks is about 100,000 sharks during 2009-2012, but can be as high as 400,000 sharks in the earlier years when shrimp fishery effort was high (Figure 3, Table 7).

Following the approaches used in SEDAR 13 and SEDAR 34, Atlantic shrimp fishery bycatch can be estimated based on the estimated GOM shrimp fishery bycatch and the average shrimp fishery effort ratio between Atlantic and GOM (0.141) during 1992-2012.

Acknowledgments

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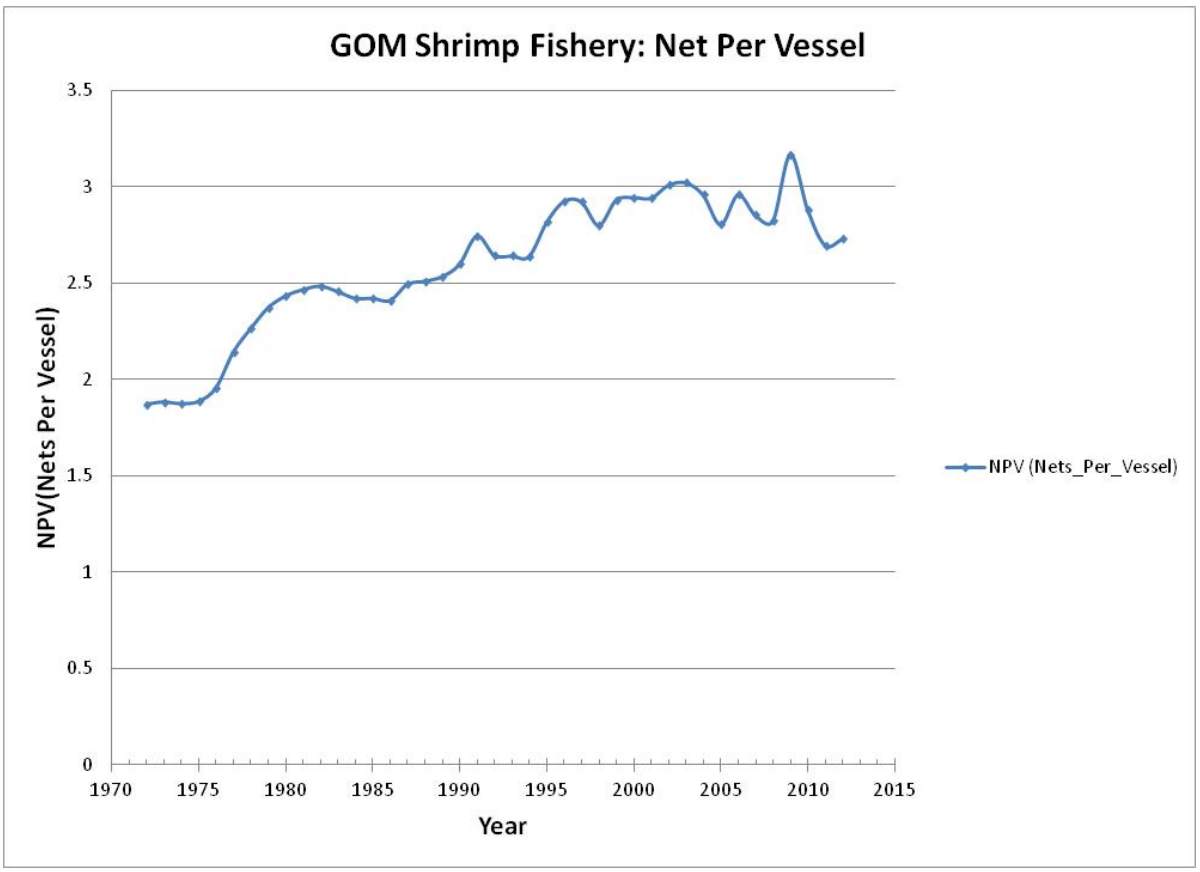

Figure 1. Gulf of Mexico shrimp fishery nets per vessel.

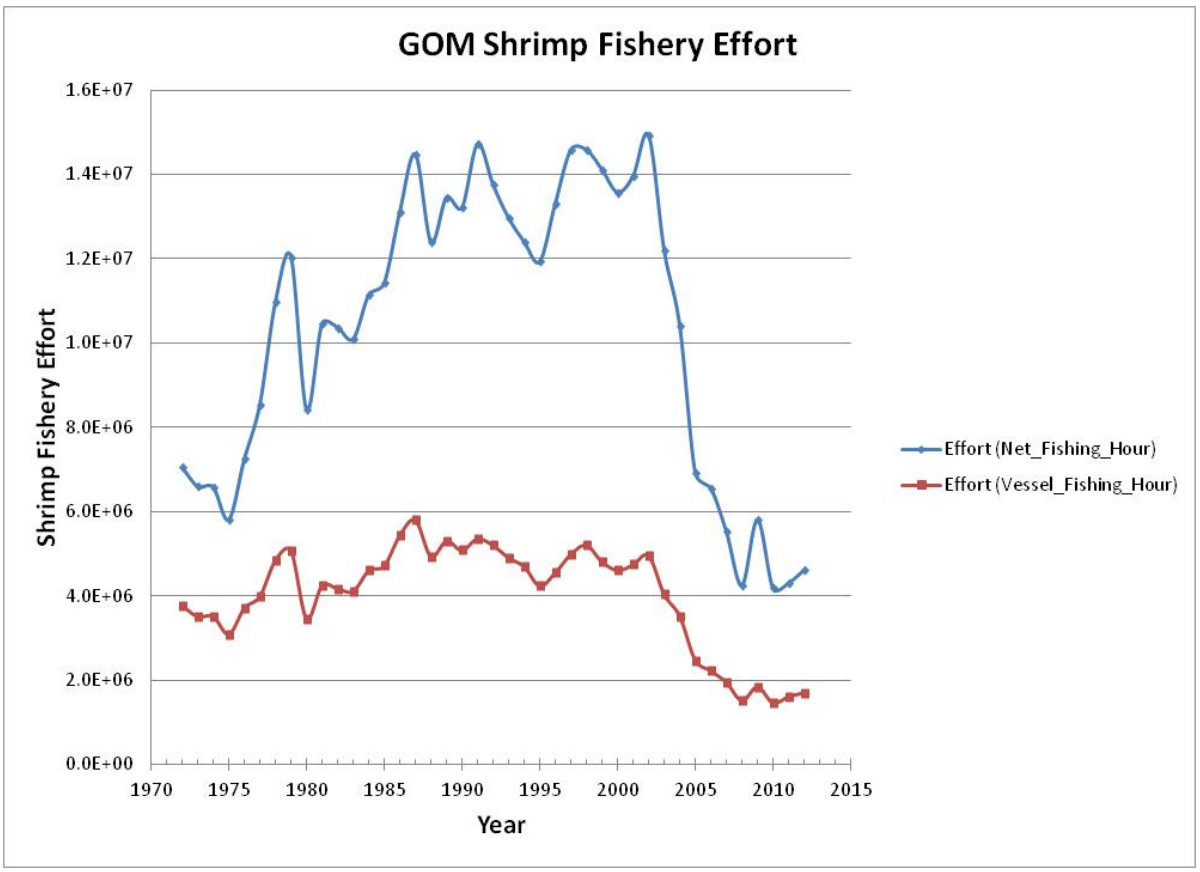

Figure 2. Gulf of Mexico shrimp fishery effort.

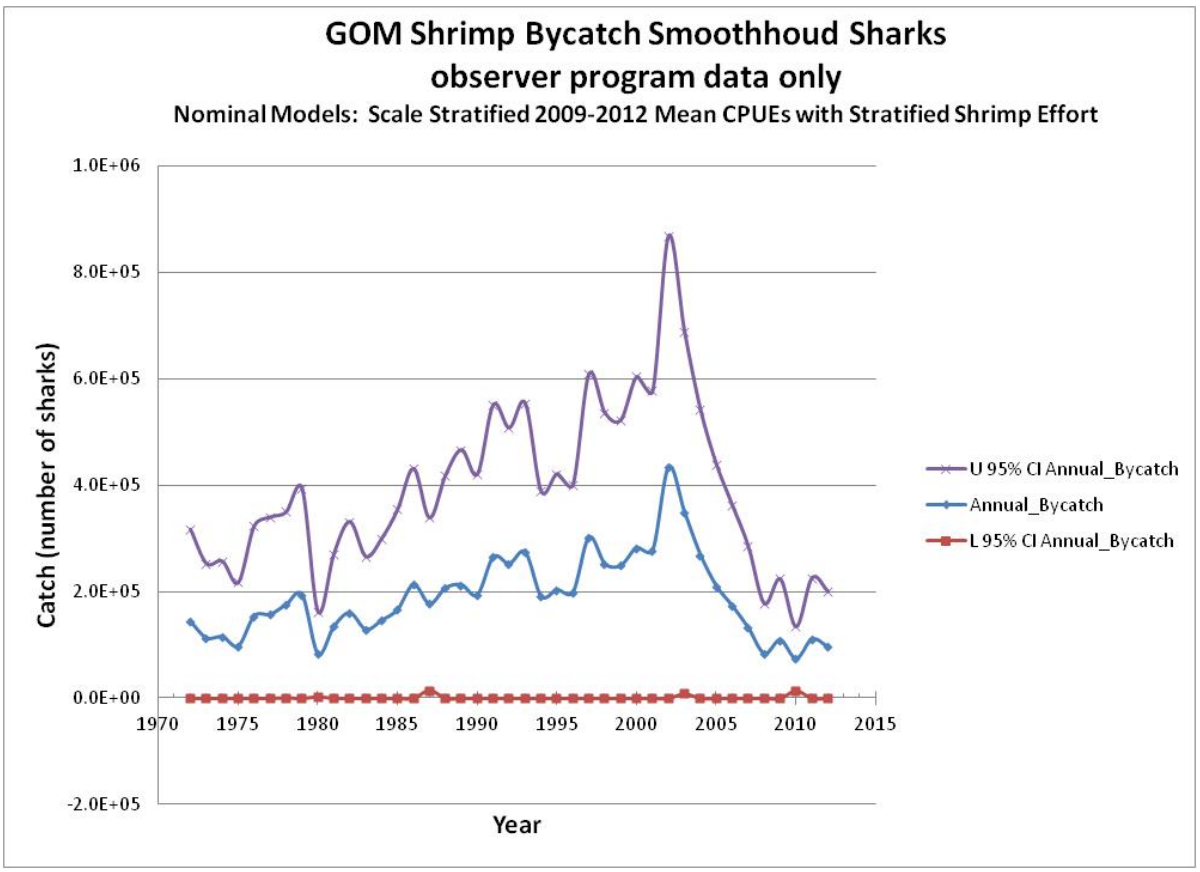

Figure 3. Estimates of the observed bycatch for smoothhound sharks in the Gulf of Mexico.

Table 1. List of factor levels used for shrimp fishery bycatch estimation.

Main Effect	Levels	Description
Year	41	1972-2012
Season	3	Jan-Apr, May-Aug, Sep-Dec
Area	4	Statistical grids 1-9, 10-12, 13-17, 18-21
Depth	2	<= 10 fathoms, > 10 fathoms

Table 2. Estimates of the observed CPUE (number of sharks per net-hour) for smoothhound sharks in the Gulf of Mexico in 2009. Num_of_NZCT is number of non-zero-catch-tow and Num_of_AT is number of all-tow.

Year	Season	Area	Depth	Num_of_NZCT	Num_of_AT	NZCT_CPUE	CPUE
2009	1	1	1	2	137	1.2776	0.0187
2009	1	1	2	0	364	0.0000	0.0000
2009	1	2	1	0	35	0.0000	0.0000
2009	1	2	2	0	26	0.0000	0.0000
2009	1	3	1	0	71	0.0000	0.0000
2009	1	3	2	5	181	0.9314	0.0257
2009	1	4	1	0	107	0.0000	0.0000
2009	1	4	2	1	317	0.3047	0.0010
2009	2	1	1				
2009	2	1	2	0	62	0.0000	0.0000
2009	2	2	1	0	100	0.0000	0.0000
2009	2	2	2	0	33	0.0000	0.0000
2009	2	3	1	0	264	0.0000	0.0000
2009	2	3	2	3	190	2.3702	0.0374
2009	2	4	1	0	60	0.0000	0.0000
2009	2	4	2	1	416	2.0375	0.0049
2009	3	1	1				
2009	3	1	2	0	33	0.0000	0.0000
2009	3	2	1	0	64	0.0000	0.0000
2009	3	2	2	0	9	0.0000	0.0000
2009	3	3	1	0	75	0.0000	0.0000
2009	3	3	2	1	59	1.2319	0.0209
2009	3	4	1	0	158	0.0000	0.0000
2009	3	4	2	3	175	1.2421	0.0213
Total				16	2936		

Table 3. Estimates of the observed CPUE (number of sharks per net-hour) for smoothhound sharks in the Gulf of Mexico in 2010. Num_of_NZCT is number of non-zero-catch-tow and Num_of_AT is number of all-tow.

Year	Season	Area	Depth	Num_of_NZCT	Num_of_AT	NZCT_CPUE	CPUE
2010	1	1	1	0	115	0.0000	0.0000
2010	1	1	2	0	218	0.0000	0.0000
2010	1	2	1	0	63	0.0000	0.0000
2010	1	2	2	7	56	0.9728	0.1216
2010	1	3	1	1	56	0.1724	0.0031
2010	1	3	2	7	140	1.2358	0.0618
2010	1	4	1	8	220	0.8496	0.0309
2010	1	4	2	2	143	0.6301	0.0088
2010	2	1	1	0	73	0.0000	0.0000
2010	2	1	2	1	138	0.1923	0.0014
2010	2	2	1				
2010	2	2	2				
2010	2	3	1	0	147	0.0000	0.0000
2010	2	3	2	24	175	1.5221	0.2087
2010	2	4	1	0	208	0.0000	0.0000
2010	2	4	2	9	238	1.0176	0.0385
2010	3	1	1	0	28	0.0000	0.0000
2010	3	1	2	0	136	0.0000	0.0000
2010	3	2	1	0	78	0.0000	0.0000
2010	3	2	2	4	32	0.3708	0.0463
2010	3	3	1	0	218	0.0000	0.0000
2010	3	3	2	4	92	1.7540	0.0763
2010	3	4	1	0	11	0.0000	0.0000
2010	3	4	2	0	16	0.0000	0.0000
Total				67	2601		

Table 4. Estimates of the observed CPUE (number of sharks per net-hour) for smoothhound sharks in the Gulf of Mexico in 2011. Num_of_NZCT is number of non-zero-catch-tow and Num_of_AT is number of all-tow.

Year	Season	Area	Depth	Num_of_NZCT	Num_of_AT	NZCT_CPUE	CPUE
2011	1	1	1	0	65	0.0000	0.0000
2011	1	1	2	0	229	0.0000	0.0000
2011	1	2	1	0	27	0.0000	0.0000
2011	1	2	2	0	8	0.0000	0.0000
2011	1	3	1	0	82	0.0000	0.0000
2011	1	3	2	10	123	0.1426	0.0116
2011	1	4	1	0	34	0.0000	0.0000
2011	1	4	2	5	28	0.1280	0.0229
2011	2	1	1	0	10	0.0000	0.0000
2011	2	1	2	0	190	0.0000	0.0000
2011	2	2	1	0	30	0.0000	0.0000
2011	2	2	2	6	27	5.0205	0.9655
2011	2	3	1	0	427	0.0000	0.0000
2011	2	3	2	16	194	0.3574	0.0295
2011	2	4	1	0	67	0.0000	0.0000
2011	2	4	2	1	224	1.0211	0.0046
2011	3	1	1				
2011	3	1	2				
2011	3	2	1	0	88	0.0000	0.0000
2011	3	2	2	0	7	0.0000	0.0000
2011	3	3	1	0	209	0.0000	0.0000
2011	3	3	2	30	343	0.4204	0.0368
2011	3	4	1	0	61	0.0000	0.0000
2011	3	4	2	23	397	0.3044	0.0176
Total				91	2870		

Table 5. Estimates of the observed CPUE (number of sharks per net-hour) for smoothhound sharks in the Gulf of Mexico in 2012. Num_of_NZCT is number of non-zero-catch-tow and Num_of_AT is number of all-tow.

Year	Season	Area	Depth	Num_of_NZCT	Num_of_AT	NZCT_CPUE	CPUE
2012	1	1	1	1	77	1.2221	0.0159
2012	1	1	2	0	118	0.0000	0.0000
2012	1	2	1	0	30	0.0000	0.0000
2012	1	2	2	2	14	3.2341	0.4620
2012	1	3	1	0	71	0.0000	0.0000
2012	1	3	2	9	182	0.8590	0.0425
2012	1	4	1	0	12	0.0000	0.0000
2012	1	4	2	2	26	0.5448	0.0419
2012	2	1	1	0	2	0.0000	0.0000
2012	2	1	2	0	112	0.0000	0.0000
2012	2	2	1	0	43	0.0000	0.0000
2012	2	2	2				
2012	2	3	1	1	308	2.2887	0.0074
2012	2	3	2	12	109	1.1645	0.1282
2012	2	4	1	0	24	0.0000	0.0000
2012	2	4	2	0	334	0.0000	0.0000
2012	3	1	1				
2012	3	1	2	0	115	0.0000	
2012	3	2	1	0	95	0.0000	0.0000
2012	3	2	2	2	94	1.8618	0.0396
2012	3	3	1	0	229	0.0000	0.0000
2012	3	3	2	13	248	1.0440	0.0547
2012	3	4	1	0	39	0.0000	0.0000
2012	3	4	2	14	875	0.8296	0.0133
Total				56	3157		

Table 6. Estimates of the observed 2009-2012 mean CPUE (number of sharks per net-hour) and 95% confidence interval (CI) for smoothhoud sharks in the Gulf of Mexico.

Year	Season	Area	Depth	CPUE	N	L 95% CI CPUE	U 95% CI CPUE
2009-2012	1	1	1	0.0086	4	-0.0012	0.0185
2009-2012	1	1	2	0.0000	4	0.0000	0.0000
2009-2012	1	2	1	0.0000	4	0.0000	0.0000
2009-2012	1	2	2	0.1459	4	-0.0681	0.3599
2009-2012	1	3	1	0.0008	4	-0.0007	0.0023
2009-2012	1	3	2	0.0354	4	0.0142	0.0566
2009-2012	1	4	1	0.0077	4	-0.0074	0.0229
2009-2012	1	4	2	0.0186	4	0.0010	0.0362
2009-2012	2	1	1	0.0000	3	0.0000	0.0000
2009-2012	2	1	2	0.0003	4	-0.0003	0.0010
2009-2012	2	2	1	0.0000	3	0.0000	0.0000
2009-2012	2	2	2	0.1970	2	-0.1891	0.5832
2009-2012	2	3	1	0.0019	4	-0.0018	0.0055
2009-2012	2	3	2	0.1010	4	0.0180	0.1839
2009-2012	2	4	1	0.0000	4	0.0000	0.0000
2009-2012	2	4	2	0.0120	4	-0.0055	0.0294
2009-2012	3	1	1	0.0000	1	0.0000	0.0000
2009-2012	3	1	2	0.0000	2	0.0000	0.0000
2009-2012	3	2	1	0.0000	4	0.0000	0.0000
2009-2012	3	2	2	0.0215	4	-0.0030	0.0460
2009-2012	3	3	1	0.0000	4	0.0000	0.0000
2009-2012	3	3	2	0.0472	4	0.0238	0.0705
2009-2012	3	4	1	0.0000	4	0.0000	0.0000
2009-2012	3	4	2	0.0131	4	0.0039	0.0222

Table 7. Estimates of the observed bycatch (number of sharks) and 95% confidence interval (CI) for smoothhound sharks in the Gulf of Mexico.

Year	Bycatch	L 95% CI Bycatch	U 95% CI Bycatch
1972	143383	0	317074
1973	112671	0	252853
1974	114896	0	257169
1975	97560	0	217009
1976	153818	0	323216
1977	156922	0	339930
1978	175177	767	349587
1979	193903	0	393892
1980	82749	2837	162661
1981	134304	0	270825
1982	159657	0	331569
1983	128662	0	266051
1984	145723	0	299905
1985	166078	0	354678
1986	212828	0	431250
1987	176622	14528	338717
1988	206474	0	418501
1989	212371	0	466419
1990	193396	0	420865
1991	264549	0	551153
1992	252004	0	507882
1993	273695	0	554155
1994	190909	0	388556
1995	203012	0	421407
1996	198321	0	400958
1997	301324	0	608436
1998	251670	0	536030
1999	248707	0	522585
2000	281993	0	603767
2001	277030	0	576888
2002	433293	0	868401
2003	348405	8008	688803
2004	268246	0	542107
2005	210109	0	439096
2006	172651	0	362316
2007	131736	0	284962
2008	83254	0	177730
2009	108711	0	223792
2010	73837	13591	134083
2011	110435	0	225892
2012	95951	0	200375