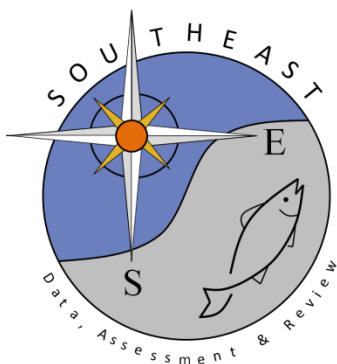


Revised Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery

Xinsheng Zhang, John Carlson, Enric Cortés, Elizabeth Babcock, Robert Latour

SEDAR77-DW38

Received: 1/31/2022



This information is distributed solely for the purpose of pre-dissemination peer review. It does not represent and should not be construed to represent any agency determination or policy.

Please cite this document as:

Zhang, Xinsheng, John Carlson, Enric Cortés, Elizabeth Babcock, Robert Latour. 2022. Revised Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery. SEDAR77-DW38. SEDAR, North Charleston, SC. 15 pp.

Revised Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal
Gillnet Fishery

Xinsheng Zhang¹, John Carlson¹, Enric Cortés¹, Elizabeth Babcock², Robert Latour³

¹NOAA Fisheries
Southeast Fisheries Science Center
3500 Delwood Beach Road
Panama City, FL

²University of Miami Rosenstiel School of Marine and Atmospheric Sciences
Department of Marine Biology and Ecology
4600 Rickenbacker Cswy
Miami, FL 33149

³Virginia Institute of Marine Science
William & Mary
Gloucester Point, VA 23062

Summary

This document details the use of the delta-lognormal method (Pennington, 1983) to calculate discard rates to produce discard estimates and associated uncertainty from US southeast commercial gillnet fishery to use in the SEDAR 77 assessment of hammerhead sharks. The ratio method was used in SEDAR77-DW-21 (Carlson et al., 2021) to calculate discard estimates and associated uncertainty. However, the estimated standard deviations (or CVs) obtained through bootstrap resampling reported in SEDAR77-DW-21 are extremely high. The panel recommended to use the delta-lognormal method as an alternative method to estimate dead discards and live discards with the same data sets. The discard estimates from the delta-lognormal are similar to those of the ratio method, but the estimated standard deviations (or CVs) from the delta-lognormal method are much smaller than the ratio method and are within a very reasonable range. Consequently, the panel recommended to use discard estimates and associated uncertainty estimates from the delta-lognormal method in the SEDAR 77 stock assessment. Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. With this recommendation, the trend of the discard estimates is solely driven by the logbook effort. The estimated discard estimates, upper 95% CI and lower 95% CI were recommended to be used in the base and high and low catch scenarios, respectively.

Introduction

The discard estimates produced using the ratio method in SEDAR77-DW-21 were not recommended for use in the SEDAR 77 assessment of hammerhead sharks. This document details the use of the delta-lognormal method (Pennington, 1983) to calculate discard rates to produce discard estimates and associated uncertainty with the same data sets. To facilitate the readers' understanding, this paper reuses the "Overview" of SEDAR77-DW-21 which provides the background information about the data sets.

The Southeast Gillnet Observer Program has adapted to the changes of the Florida- Georgia shark gillnet fishery since the program began in 1993 (e.g. Mathers et al. 2018 and references therein). The observer program initially focused efforts only on those gillnets vessels targeting shark. However, gillnet effort targeting large coastal and small coastal sharks declined as a result of Amendments 2 and 3 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan. Shark targeted gillnet effort has continued to decline in the last five years. Fishers have consequently increased effort targeting fish, including Spanish mackerel *Scomberomorus maculatus*, king mackerel *Scomberomorus cavalla*, and bluefish *Pomatomus saltatrix*, with varying types of gillnet gear. Regardless of target, hammerhead sharks are either kept or discarded as bycatch, depending on the time of the year and opening or closure of the fishery. The Southeast Gillnet Observer Program, in its continuing efforts to adapt to the fishery, currently covers anchored (sink and stab), strike, or drift gillnet fishing, regardless of target, by vessels that fish year-round from Florida to North Carolina and the Gulf of Mexico.

Methods

Following the definition of the South Atlantic from the Highly Migratory Species Office, bycatch was estimated for the "US south Atlantic", Gulf of Mexico, and areas combined.

The mean and variance of discard rates were calculated using the delta-lognormal method (Pennington, 1983). The method assumes a lognormal distribution of the positive bycatch rate observations. Effectively, the estimates are constructed as a product of the proportion of successful occurrences of an event and the average rate at which the event occurs for those successful events. The variance is a function of the variability of the positive bycatch rates as well the number of successful and unsuccessful sets. The delta estimator is more appropriate than the simple ratio estimate because catch rates are generally log-normally distributed and bycatch events (i.e., positive sets) are rare. The unit of effort in this analysis is the number of sets, consistent with the method used to estimate the dead discards of Atlantic highly migratory species by the US Atlantic pelagic longline fleet for ICCAT (Brown, 2001). Due to small number of sets in which a non-zero bycatch of the species group was observed (positive sets), observed sets are pooled by each observed year and all observed years, respectively. The annual mean discard rate is based on the pooled observed sets for each observed year. The grand mean discard rate is based on the pooled observed sets for all observed years.

When number of sets in which a non-zero bycatch was observed (positive sets) is greater than 1, the mean discard rate, C , is calculated as:

$$C = \frac{m}{n} e^L G_m \left(\frac{s^2}{2} \right) \quad (1)$$

m is number of sets in which a non-zero bycatch was observed (positive sets),

n is total number of sets observed,

L is the mean of the log-transformed number of animals taken per set for the positive sets,

s^2 is the variance of the log-transformed number of animals taken per set for the positive sets, and

$G_m \left(\frac{1}{2} s^2 \right)$ is the cumulative probability function from the Poisson distribution given as:

$$G_m \left(\frac{1}{2} s^2 \right) = 1 + \frac{m-1}{m} \left(\frac{1}{2} s^2 \right) + \sum_{j=2}^{\infty} \frac{(m-1)^{2j-1}}{m^j (m+1)(m+3)\dots(m+2j-3)} \times \frac{\left(\frac{1}{2} s^2 \right)^j}{j!} \quad (2)$$

The series was computed numerically over j terms until meeting a convergence criterion of a change in the function value of < 0.001 with additional terms (j). The variance of the delta estimator is:

$$\text{var}(C) = \frac{m}{n} (e^{2L}) \left[\frac{m}{n} G_m^2 \left(\frac{s^2}{2} \right) - \frac{m-1}{n-1} G_m \left(\frac{m-2}{m-1} s^2 \right) \right] \quad (3)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is equal to 1, the mean discard rate reduces to the simple mean rate where:

$$C = \frac{e^L}{n} \quad (4)$$

and the variance of the delta estimator is:

$$\text{var}(C) = \left(\frac{e^L}{n} \right)^2 \quad (5)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is equal to 0, the mean discard is:

$$C = 0 \quad (6)$$

and the variance of the delta estimator is:

$$\text{var}(C) = 0 \quad (7)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is greater than or equal to 1, the coefficient of variation for the mean discard rate is taken as:

$$CV = \frac{\sqrt{\text{var}(C)}}{C} \quad (8)$$

The C calculated above gives either the annual mean or the grand mean number of animals caught per set for the observed sets. To estimate annual discards, N , these rates are multiplied by the annual total number of logbook sets. With an assumption of effort (*number of logbook sets*) being a known constant, the coefficient of variation for the annual (or grand) mean discard rate is the same as the coefficient of variation for the annual discards. Approximate 95% confidence intervals (95% CI) were calculated assuming a log-normal distribution of annual discards as Nk and N/k for the upper and lower confidence bounds respectively where:

$$k = e^{\left[1.96\sqrt{\ln(1+CV^2)}\right]} \quad (9)$$

Total effort data reflects all gillnet trip reports received by the Coastal Fisheries Logbook Program (hereafter Logbook Program) in the southeast United States (Figure 1). Four gillnet types are reported to the Coastal Fisheries Logbook: Strike, Drift, Anchor, and Other. These types are coded and reflected in the summary as follows:

Strike – Gear code: ‘475’ - gear name: ‘GILL NETS, DRIFT, RUNAROUND’

Drift – Gear code: ‘470’ - gear name: ‘GILL NETS, DRIFT, OTHER’

Anchor – Gear code: ‘480’ gear name: ‘GILL NETS, STAKE’

Other – Gear code: ‘425’ gear name: ‘GILL NETS, OTHER’.

However, given the nature of the data and that most gillnet effort is reported as “OTHER”, bycatch estimates were derived for the gillnet fishery regardless of gillnet type.

Results and Discussion

Scalloped hammerhead and great hammerhead shark dead and live discards (in numbers of sharks) from the commercial gillnet fishery are provided in Tables 1-8. In all the estimates, data were pooled by either each observed year (tables denoted with an “a”) or all observed years (tables denoted with a “b”) without considering strata due to the sparse nature of the bycatch events and the fact that logbook data are reported by sampling grid (see Figure 1).

Pooling observed sets for all areas by either each observed year or all observed years without considering variance of areas and seasons, along with an assumption of effort (*number of logbook sets*) being a known constant, may cause the actual variance of discard estimate to be underestimated. This in turn will produce a narrower confidence interval, which may have a confidence level lower than desired. In addition, assuming the grand mean of discard rate based on all the pooled observed sets is a constant for the entire time series, and the trend of the discard estimates is solely driven by the logbook effort, which may need to be further evaluated in the future. The discard estimates and associated uncertainty estimates using the delta-lognormal

method presented in this report, however, are regarded as an improvement over the discard estimates and associated uncertainty estimates using the ratio method reported in SEDAR77-DW-21. Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates (tables denoted with a “b”).

Acknowledgments

The authors thank Guillermo Diaz and Craig Brown for sharing the code used for estimating the dead discards of Atlantic highly migratory species by the US Atlantic pelagic longline fleet for ICCAT.

References

- Brown C. 2001. Revised estimates of bluefin tuna dead discards by the U.S. Atlantic Pelagic Longline Fleet, 1992-1999. Col. Vol. Sci. Pap. ICCAT 52(3):1007-1021.
- Carlson, John, Alyssa Mathers and Kevin McCarthy. 2021. Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery. SEDAR77-DW21. SEDAR, North Charleston, SC. 13 pp.
- Mathers, A.N., B.M. Deacy, H.E. Moncrief-Cox, J.K. Carlson. 2018. Catch and Bycatch in U.S. Southeast Gillnet Fisheries, 2017. NOAA Technical Memorandum NMFS-SEFSC-728. 13 p.
- Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. *Biometrics* 39: 281-286.

Table 1a. Yearly calculated dead discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2515	0		
1999	54	1	1	0.019	0.019	1.000	1999	2077	38	194	7
2000	63	1	4	0.063	0.063	1.000	2000	2097	133	680	26
2001	109	0	0	0.000	0.000		2001	2034	0		
2002	107	15	48	0.439	0.140	0.320	2002	1953	858	1580	466
2003	65	0	0	0.000	0.000		2003	1633	0		
2004	57	2	4	0.070	0.055	0.790	2004	1602	112	436	29
2005	152	1	2	0.013	0.013	1.000	2005	1879	25	128	5
2006	215	0	0	0.000	0.000		2006	2471	0		
2007	170	0	0	0.000	0.000		2007	3748	0		
2008	204	0	0	0.000	0.000		2008	3756	0		
2009	421	3	7	0.017	0.011	0.640	2009	4422	75	237	24
2010	295	0	0	0.000	0.000		2010	2801	0		
2011	402	0	0	0.000	0.000		2011	3825	0		
2012	315	1	1	0.003	0.003	1.000	2012	3773	12	61	2
2013	225	0	0	0.000	0.000		2013	2173	0		
2014	236	1	1	0.004	0.004	1.000	2014	3932	17	87	3
2015	226	0	0	0.000	0.000		2015	3871	0		
2016	208	0	0	0.000	0.000		2016	3221	0		
2017	75	0	0	0.000	0.000		2017	2351	0		
2018	87	0	0	0.000	0.000		2018	3227	0		
2019	95	0	0	0.000	0.000		2019	3635	0		

Table 1b. Yearly calculated dead discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	25	68	0.018	0.004	0.250	1998	2515	44	71	27
1998-2019	3790	25	68	0.018	0.004	0.250	1999	2077	36	58	22
1998-2019	3790	25	68	0.018	0.004	0.250	2000	2097	37	60	23
1998-2019	3790	25	68	0.018	0.004	0.250	2001	2034	36	58	22
1998-2019	3790	25	68	0.018	0.004	0.250	2002	1953	34	55	21
1998-2019	3790	25	68	0.018	0.004	0.250	2003	1633	29	47	18
1998-2019	3790	25	68	0.018	0.004	0.250	2004	1602	28	45	17
1998-2019	3790	25	68	0.018	0.004	0.250	2005	1879	33	54	20
1998-2019	3790	25	68	0.018	0.004	0.250	2006	2471	43	70	27
1998-2019	3790	25	68	0.018	0.004	0.250	2007	3748	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2008	3756	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2009	4422	77	125	47
1998-2019	3790	25	68	0.018	0.004	0.250	2010	2801	49	80	30
1998-2019	3790	25	68	0.018	0.004	0.250	2011	3825	67	109	41
1998-2019	3790	25	68	0.018	0.004	0.250	2012	3773	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2013	2173	38	62	23
1998-2019	3790	25	68	0.018	0.004	0.250	2014	3932	69	112	43
1998-2019	3790	25	68	0.018	0.004	0.250	2015	3871	68	110	42
1998-2019	3790	25	68	0.018	0.004	0.250	2016	3221	56	91	35
1998-2019	3790	25	68	0.018	0.004	0.250	2017	2351	41	67	25
1998-2019	3790	25	68	0.018	0.004	0.250	2018	3227	56	91	35
1998-2019	3790	25	68	0.018	0.004	0.250	2019	3635	64	104	39

Table 2a. Yearly calculated live discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2515	0		
1999	54	0	0	0.000	0.000		1999	2077	0		
2000	63	0	0	0.000	0.000		2000	2097	0		
2001	109	0	0	0.000	0.000		2001	2034	0		
2002	107	0	0	0.000	0.000		2002	1953	0		
2003	65	0	0	0.000	0.000		2003	1633	0		
2004	57	1	1	0.018	0.018	1.000	2004	1602	28	143	5
2005	152	0	0	0.000	0.000		2005	1879	0		
2006	215	1	2	0.009	0.009	1.000	2006	2471	23	118	4
2007	170	0	0	0.000	0.000		2007	3748	0		
2008	204	1	1	0.005	0.005	1.000	2008	3756	18	92	4
2009	421	1	1	0.002	0.002	1.000	2009	4422	11	56	2
2010	295	0	0	0.000	0.000		2010	2801	0		
2011	402	0	0	0.000	0.000		2011	3825	0		
2012	315	1	1	0.003	0.003	1.000	2012	3773	12	61	2
2013	225	1	1	0.004	0.004	1.000	2013	2173	10	51	2
2014	236	0	0	0.000	0.000		2014	3932	0		
2015	226	0	0	0.000	0.000		2015	3871	0		
2016	208	0	0	0.000	0.000		2016	3221	0		
2017	75	0	0	0.000	0.000		2017	2351	0		
2018	87	2	2	0.023	0.016	0.700	2018	3227	74	256	21
2019	95	0	0	0.000	0.000		2019	3635	0		

Table 2b. Yearly calculated live discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	8	9	0.002	0.001	0.360	1998	2515	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	1999	2077	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2000	2097	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2001	2034	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2002	1953	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2003	1633	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2004	1602	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2005	1879	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2006	2471	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	2007	3748	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2008	3756	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2009	4422	10	20	5
1998-2019	3790	8	9	0.002	0.001	0.360	2010	2801	7	14	4
1998-2019	3790	8	9	0.002	0.001	0.360	2011	3825	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2012	3773	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2013	2173	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2014	3932	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2015	3871	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2016	3221	8	16	4
1998-2019	3790	8	9	0.002	0.001	0.360	2017	2351	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	2018	3227	8	16	4
1998-2019	3790	8	9	0.002	0.001	0.360	2019	3635	9	18	5

Table 3a. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2515	0		
1999	54	12	30	0.525	0.177	0.340	1999	2077	1090	2076	572
2000	63	5	48	0.453	0.333	0.740	2000	2097	950	3450	262
2001	109	7	11	0.100	0.040	0.400	2001	2034	204	436	96
2002	107	9	35	0.335	0.136	0.410	2002	1953	655	1407	305
2003	65	7	60	0.651	0.407	0.630	2003	1633	1062	3277	344
2004	57	12	186	3.458	1.768	0.510	2004	1602	5540	14244	2155
2005	152	7	7	0.046	0.017	0.370	2005	1879	87	176	43
2006	215	8	43	0.201	0.104	0.520	2006	2471	498	1293	192
2007	170	2	5	0.029	0.021	0.720	2007	3748	110	390	31
2008	204	3	3	0.015	0.008	0.570	2008	3756	55	157	19
2009	421	10	15	0.035	0.012	0.350	2009	4422	154	298	80
2010	295	4	12	0.040	0.025	0.630	2010	2801	111	344	36
2011	402	3	5	0.012	0.008	0.640	2011	3825	47	149	15
2012	315	11	43	0.103	0.046	0.450	2012	3773	387	896	167
2013	225	4	33	0.150	0.114	0.760	2013	2173	327	1226	87
2014	236	0	0	0.000	0.000		2014	3932	0		
2015	226	4	6	0.026	0.014	0.550	2015	3871	101	276	37
2016	208	3	4	0.019	0.012	0.600	2016	3221	62	185	21
2017	75	0	0	0.000	0.000		2017	2351	0		
2018	87	4	12	0.140	0.081	0.580	2018	3227	452	1295	158
2019	95	0	0	0.000	0.000		2019	3635	0		

Table 3b. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	115	558	0.114	0.017	0.150	1998	2515	287	386	213
1998-2019	3790	115	558	0.114	0.017	0.150	1999	2077	237	319	176
1998-2019	3790	115	558	0.114	0.017	0.150	2000	2097	239	321	178
1998-2019	3790	115	558	0.114	0.017	0.150	2001	2034	232	312	173
1998-2019	3790	115	558	0.114	0.017	0.150	2002	1953	223	300	166
1998-2019	3790	115	558	0.114	0.017	0.150	2003	1633	186	250	138
1998-2019	3790	115	558	0.114	0.017	0.150	2004	1602	183	246	136
1998-2019	3790	115	558	0.114	0.017	0.150	2005	1879	214	288	159
1998-2019	3790	115	558	0.114	0.017	0.150	2006	2471	282	379	210
1998-2019	3790	115	558	0.114	0.017	0.150	2007	3748	427	574	318
1998-2019	3790	115	558	0.114	0.017	0.150	2008	3756	428	575	318
1998-2019	3790	115	558	0.114	0.017	0.150	2009	4422	504	678	375
1998-2019	3790	115	558	0.114	0.017	0.150	2010	2801	319	429	237
1998-2019	3790	115	558	0.114	0.017	0.150	2011	3825	436	586	324
1998-2019	3790	115	558	0.114	0.017	0.150	2012	3773	430	578	320
1998-2019	3790	115	558	0.114	0.017	0.150	2013	2173	248	333	184
1998-2019	3790	115	558	0.114	0.017	0.150	2014	3932	448	602	333
1998-2019	3790	115	558	0.114	0.017	0.150	2015	3871	441	593	328
1998-2019	3790	115	558	0.114	0.017	0.150	2016	3221	367	493	273
1998-2019	3790	115	558	0.114	0.017	0.150	2017	2351	268	360	199
1998-2019	3790	115	558	0.114	0.017	0.150	2018	3227	368	495	274
1998-2019	3790	115	558	0.114	0.017	0.150	2019	3635	414	557	308

Table 4a. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2515	0		
1999	54	1	3	0.056	0.056	1.000	1999	2077	115	588	22
2000	63	0	0	0.000	0.000		2000	2097	0		
2001	109	0	0	0.000	0.000		2001	2034	0		
2002	107	2	2	0.019	0.013	0.700	2002	1953	37	128	11
2003	65	0	0	0.000	0.000		2003	1633	0		
2004	57	3	4	0.070	0.042	0.600	2004	1602	112	330	38
2005	152	9	9	0.059	0.019	0.320	2005	1879	111	206	60
2006	215	7	29	0.106	0.056	0.530	2006	2471	262	691	99
2007	170	2	2	0.012	0.008	0.710	2007	3748	44	153	13
2008	204	8	12	0.058	0.022	0.380	2008	3756	219	448	107
2009	421	6	8	0.019	0.008	0.430	2009	4422	84	187	38
2010	295	5	13	0.044	0.022	0.500	2010	2801	124	314	49
2011	402	9	12	0.030	0.010	0.350	2011	3825	114	221	59
2012	315	17	21	0.066	0.016	0.250	2012	3773	248	402	153
2013	225	9	24	0.103	0.043	0.410	2013	2173	224	488	103
2014	236	3	5	0.021	0.013	0.640	2014	3932	82	259	26
2015	226	4	14	0.053	0.036	0.680	2015	3871	204	686	61
2016	208	6	9	0.043	0.019	0.430	2016	3221	139	310	62
2017	75	1	1	0.013	0.013	1.000	2017	2351	31	159	6
2018	87	8	18	0.208	0.079	0.380	2018	3227	672	1377	328
2019	95	6	8	0.084	0.035	0.420	2019	3635	305	671	139

Table 4b. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	106	194	0.047	0.005	0.11	1998	2515	118	147	95
1998-2019	3790	106	194	0.047	0.005	0.11	1999	2077	98	122	79
1998-2019	3790	106	194	0.047	0.005	0.11	2000	2097	99	123	79
1998-2019	3790	106	194	0.047	0.005	0.11	2001	2034	96	120	77
1998-2019	3790	106	194	0.047	0.005	0.11	2002	1953	92	115	74
1998-2019	3790	106	194	0.047	0.005	0.11	2003	1633	77	96	62
1998-2019	3790	106	194	0.047	0.005	0.11	2004	1602	75	93	60
1998-2019	3790	106	194	0.047	0.005	0.11	2005	1879	88	110	71
1998-2019	3790	106	194	0.047	0.005	0.11	2006	2471	116	145	93
1998-2019	3790	106	194	0.047	0.005	0.11	2007	3748	176	219	141
1998-2019	3790	106	194	0.047	0.005	0.11	2008	3756	177	221	142
1998-2019	3790	106	194	0.047	0.005	0.11	2009	4422	208	259	167
1998-2019	3790	106	194	0.047	0.005	0.11	2010	2801	132	164	106
1998-2019	3790	106	194	0.047	0.005	0.11	2011	3825	180	224	144
1998-2019	3790	106	194	0.047	0.005	0.11	2012	3773	178	222	143
1998-2019	3790	106	194	0.047	0.005	0.11	2013	2173	102	127	82
1998-2019	3790	106	194	0.047	0.005	0.11	2014	3932	185	230	148
1998-2019	3790	106	194	0.047	0.005	0.11	2015	3871	182	227	146
1998-2019	3790	106	194	0.047	0.005	0.11	2016	3221	152	189	122
1998-2019	3790	106	194	0.047	0.005	0.11	2017	2351	111	138	89
1998-2019	3790	106	194	0.047	0.005	0.11	2018	3227	152	189	122
1998-2019	3790	106	194	0.047	0.005	0.11	2019	3635	171	213	137

Table 5a. Yearly calculated dead discards of scalloped hammerhead from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2403	0		
1999	54	12	30	0.525	0.177	0.340	1999	1855	973	1853	511
2000	54	3	3	0.056	0.031	0.570	2000	1945	108	304	38
2001	96	7	11	0.114	0.046	0.400	2001	1872	213	454	100
2002	86	9	35	0.417	0.168	0.400	2002	1874	782	1673	366
2003	65	7	60	0.651	0.407	0.630	2003	1558	1013	3126	328
2004	57	12	186	3.458	1.768	0.510	2004	1547	5350	13756	2081
2005	152	7	7	0.046	0.017	0.370	2005	1812	83	168	41
2006	206	8	43	0.210	0.109	0.520	2006	2379	500	1297	193
2007	170	2	5	0.029	0.021	0.720	2007	3658	108	383	30
2008	201	2	2	0.010	0.007	0.710	2008	3602	36	125	10
2009	393	9	14	0.035	0.013	0.370	2009	4108	143	287	71
2010	295	4	12	0.040	0.025	0.630	2010	2714	108	334	35
2011	398	3	5	0.012	0.008	0.640	2011	3467	43	136	14
2012	300	11	43	0.108	0.048	0.450	2012	3540	381	882	165
2013	209	4	33	0.162	0.123	0.760	2013	1876	304	1139	81
2014	225	0	0	0.000	0.000		2014	3354	0		
2015	191	4	6	0.031	0.017	0.550	2015	3125	96	262	35
2016	199	3	4	0.020	0.012	0.600	2016	2851	57	170	19
2017	66	0	0	0.000	0.000		2017	2151	0		
2018	78	4	12	0.156	0.090	0.580	2018	3063	478	1368	167
2019	94	0	0	0.000	0.000		2019	3370	0		

Table 5b. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3598	111	511	0.112	0.017	0.15	1998	2403	269	361	200
1998-2019	3598	111	511	0.112	0.017	0.15	1999	1855	207	278	154
1998-2019	3598	111	511	0.112	0.017	0.15	2000	1945	218	293	162
1998-2019	3598	111	511	0.112	0.017	0.15	2001	1872	209	281	156
1998-2019	3598	111	511	0.112	0.017	0.15	2002	1874	210	282	156
1998-2019	3598	111	511	0.112	0.017	0.15	2003	1558	174	234	130
1998-2019	3598	111	511	0.112	0.017	0.15	2004	1547	173	232	129
1998-2019	3598	111	511	0.112	0.017	0.15	2005	1812	203	273	151
1998-2019	3598	111	511	0.112	0.017	0.15	2006	2379	266	357	198
1998-2019	3598	111	511	0.112	0.017	0.15	2007	3658	409	549	305
1998-2019	3598	111	511	0.112	0.017	0.15	2008	3602	403	541	300
1998-2019	3598	111	511	0.112	0.017	0.15	2009	4108	459	616	342
1998-2019	3598	111	511	0.112	0.017	0.15	2010	2714	304	408	226
1998-2019	3598	111	511	0.112	0.017	0.15	2011	3467	388	521	289
1998-2019	3598	111	511	0.112	0.017	0.15	2012	3540	396	532	295
1998-2019	3598	111	511	0.112	0.017	0.15	2013	1876	210	282	156
1998-2019	3598	111	511	0.112	0.017	0.15	2014	3354	375	504	279
1998-2019	3598	111	511	0.112	0.017	0.15	2015	3125	350	470	261
1998-2019	3598	111	511	0.112	0.017	0.15	2016	2851	319	428	238
1998-2019	3598	111	511	0.112	0.017	0.15	2017	2151	241	324	179
1998-2019	3598	111	511	0.112	0.017	0.15	2018	3063	343	461	255
1998-2019	3598	111	511	0.112	0.017	0.15	2019	3370	377	506	281

Table 6a. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998	9	0	0	0.000	0.000		1998	2403	0		
1999	54	1	3	0.056	0.056	1.000	1999	1855	103	527	20
2000	54	0	0	0.000	0.000		2000	1945	0		
2001	96	0	0	0.000	0.000		2001	1872	0		
2002	86	2	2	0.023	0.016	0.700	2002	1874	44	152	13
2003	65	0	0	0.000	0.000		2003	1558	0		
2004	57	3	4	0.070	0.042	0.600	2004	1547	108	319	37
2005	152	9	9	0.059	0.019	0.320	2005	1812	107	199	58
2006	206	7	29	0.111	0.058	0.530	2006	2379	263	694	100
2007	170	2	2	0.012	0.008	0.710	2007	3658	43	149	12
2008	201	8	12	0.059	0.022	0.380	2008	3602	213	436	104
2009	393	5	6	0.015	0.007	0.460	2009	4108	62	147	26
2010	295	5	13	0.044	0.022	0.500	2010	2714	120	304	47
2011	398	9	12	0.030	0.010	0.350	2011	3467	104	202	54
2012	300	17	21	0.069	0.017	0.250	2012	3540	245	396	151
2013	209	9	24	0.111	0.046	0.410	2013	1876	209	455	96
2014	225	3	5	0.022	0.014	0.640	2014	3354	73	231	23
2015	191	4	14	0.062	0.043	0.680	2015	3125	195	655	58
2016	199	6	9	0.045	0.019	0.430	2016	2851	129	288	58
2017	66	0	0	0.000	0.000		2017	2151	0		
2018	78	8	18	0.232	0.088	0.380	2018	3063	711	1453	348
2019	94	6	8	0.085	0.036	0.420	2019	3370	286	629	130

Table 6b. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3598	104	191	0.049	0.006	0.110	1998	2403	117	146	94
1998-2019	3598	104	191	0.049	0.006	0.110	1999	1855	90	112	72
1998-2019	3598	104	191	0.049	0.006	0.110	2000	1945	95	119	76
1998-2019	3598	104	191	0.049	0.006	0.110	2001	1872	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2002	1874	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2003	1558	76	95	61
1998-2019	3598	104	191	0.049	0.006	0.110	2004	1547	75	94	60
1998-2019	3598	104	191	0.049	0.006	0.110	2005	1812	88	110	70
1998-2019	3598	104	191	0.049	0.006	0.110	2006	2379	116	145	93
1998-2019	3598	104	191	0.049	0.006	0.110	2007	3658	178	222	143
1998-2019	3598	104	191	0.049	0.006	0.110	2008	3602	176	220	141
1998-2019	3598	104	191	0.049	0.006	0.110	2009	4108	200	250	160
1998-2019	3598	104	191	0.049	0.006	0.110	2010	2714	132	165	106
1998-2019	3598	104	191	0.049	0.006	0.110	2011	3467	169	211	135
1998-2019	3598	104	191	0.049	0.006	0.110	2012	3540	173	216	139
1998-2019	3598	104	191	0.049	0.006	0.110	2013	1876	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2014	3354	164	205	131
1998-2019	3598	104	191	0.049	0.006	0.110	2015	3125	152	190	122
1998-2019	3598	104	191	0.049	0.006	0.110	2016	2851	139	174	111
1998-2019	3598	104	191	0.049	0.006	0.110	2017	2151	105	131	84
1998-2019	3598	104	191	0.049	0.006	0.110	2018	3063	149	186	119
1998-2019	3598	104	191	0.049	0.006	0.110	2019	3370	164	205	131

Table 7a. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998							1998	112			
1999							1999	222			
2000	9	2	45	5.000	4.876	0.980	2000	152	760	3773	153
2001	13	0	0	0.000	0.000		2001	162	0		
2002	21	0	0	0.000	0.000		2002	79	0		
2003							2003	75			
2004							2004	55			
2005							2005	67			
2006	9	0	0	0.000	0.000		2006	92	0		
2007							2007	90			
2008	3	1	1	0.333	0.333	1.000	2008	154	51	261	10
2009	28	1	1	0.036	0.036	1.000	2009	314	11	56	2
2010							2010	87			
2011	4	0	0	0.000	0.000		2011	358	0		
2012	15	0	0	0.000	0.000		2012	233	0		
2013	16	0	0	0.000	0.000		2013	297	0		
2014	11	0	0	0.000	0.000		2014	578	0		
2015	35	0	0	0.000	0.000		2015	746	0		
2016	9	0	0	0.000	0.000		2016	370	0		
2017	9	0	0	0.000	0.000		2017	200	0		
2018	9	0	0	0.000	0.000		2018	164	0		
2019	1	0	0	0.000	0.000		2019	265	0		

Table 7b. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	192	4	47	0.161	0.131	0.810	1998	112	18	73	4
1998-2019	192	4	47	0.161	0.131	0.810	1999	222	36	146	9
1998-2019	192	4	47	0.161	0.131	0.810	2000	152	24	97	6
1998-2019	192	4	47	0.161	0.131	0.810	2001	162	26	105	6
1998-2019	192	4	47	0.161	0.131	0.810	2002	79	13	53	3
1998-2019	192	4	47	0.161	0.131	0.810	2003	75	12	49	3
1998-2019	192	4	47	0.161	0.131	0.810	2004	55	9	36	2
1998-2019	192	4	47	0.161	0.131	0.810	2005	67	11	44	3
1998-2019	192	4	47	0.161	0.131	0.810	2006	92	15	61	4
1998-2019	192	4	47	0.161	0.131	0.810	2007	90	14	57	3
1998-2019	192	4	47	0.161	0.131	0.810	2008	154	25	101	6
1998-2019	192	4	47	0.161	0.131	0.810	2009	314	51	206	13
1998-2019	192	4	47	0.161	0.131	0.810	2010	87	14	57	3
1998-2019	192	4	47	0.161	0.131	0.810	2011	358	58	234	14
1998-2019	192	4	47	0.161	0.131	0.810	2012	233	37	150	9
1998-2019	192	4	47	0.161	0.131	0.810	2013	297	48	194	12
1998-2019	192	4	47	0.161	0.131	0.810	2014	578	93	376	23
1998-2019	192	4	47	0.161	0.131	0.810	2015	746	120	485	30
1998-2019	192	4	47	0.161	0.131	0.810	2016	370	60	243	15
1998-2019	192	4	47	0.161	0.131	0.810	2017	200	32	129	8
1998-2019	192	4	47	0.161	0.131	0.810	2018	164	26	105	6
1998-2019	192	4	47	0.161	0.131	0.810	2019	265	43	174	11

Table 8a. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998							1998	112			
1999							1999	222			
2000	9	0	0	0.000	0.000		2000	152	0		
2001	13	0	0	0.000	0.000		2001	162	0		
2002	21	0	0	0.000	0.000		2002	79	0		
2003							2003	75			
2004							2004	55			
2005							2005	67			
2006	9	0	0	0.000	0.000		2006	92	0		
2007							2007	90			
2008	3	0	0	0.000	0.000		2008	154	0		
2009	28	1	2	0.071	0.071	1.000	2009	314	22	112	4
2010							2010	87			
2011	4	0	0	0.000	0.000		2011	358	0		
2012	15	0	0	0.000	0.000		2012	233	0		
2013	16	0	0	0.000	0.000		2013	297	0		
2014	11	0	0	0.000	0.000		2014	578	0		
2015	35	0	0	0.000	0.000		2015	746	0		
2016	9	0	0	0.000	0.000		2016	370	0		
2017	9	1	1	0.111	0.111	1.000	2017	200	22	112	4
2018	9	0	0	0.000	0.000		2018	164	0		
2019	1	0	0	0.000	0.000		2019	265	0		

Table 8b. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	192	2	3	0.016	0.012	0.740	1998	112	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	1999	222	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2000	152	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	2001	162	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2002	79	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2003	75	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2004	55	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2005	67	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2006	92	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2007	90	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2008	154	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	2009	314	5	18	1
1998-2019	192	2	3	0.016	0.012	0.740	2010	87	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2011	358	6	22	2
1998-2019	192	2	3	0.016	0.012	0.740	2012	233	4	15	1
1998-2019	192	2	3	0.016	0.012	0.740	2013	297	5	18	1
1998-2019	192	2	3	0.016	0.012	0.740	2014	578	9	33	2
1998-2019	192	2	3	0.016	0.012	0.740	2015	746	12	44	3
1998-2019	192	2	3	0.016	0.012	0.740	2016	370	6	22	2
1998-2019	192	2	3	0.016	0.012	0.740	2017	200	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2018	164	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2019	265	4	15	1

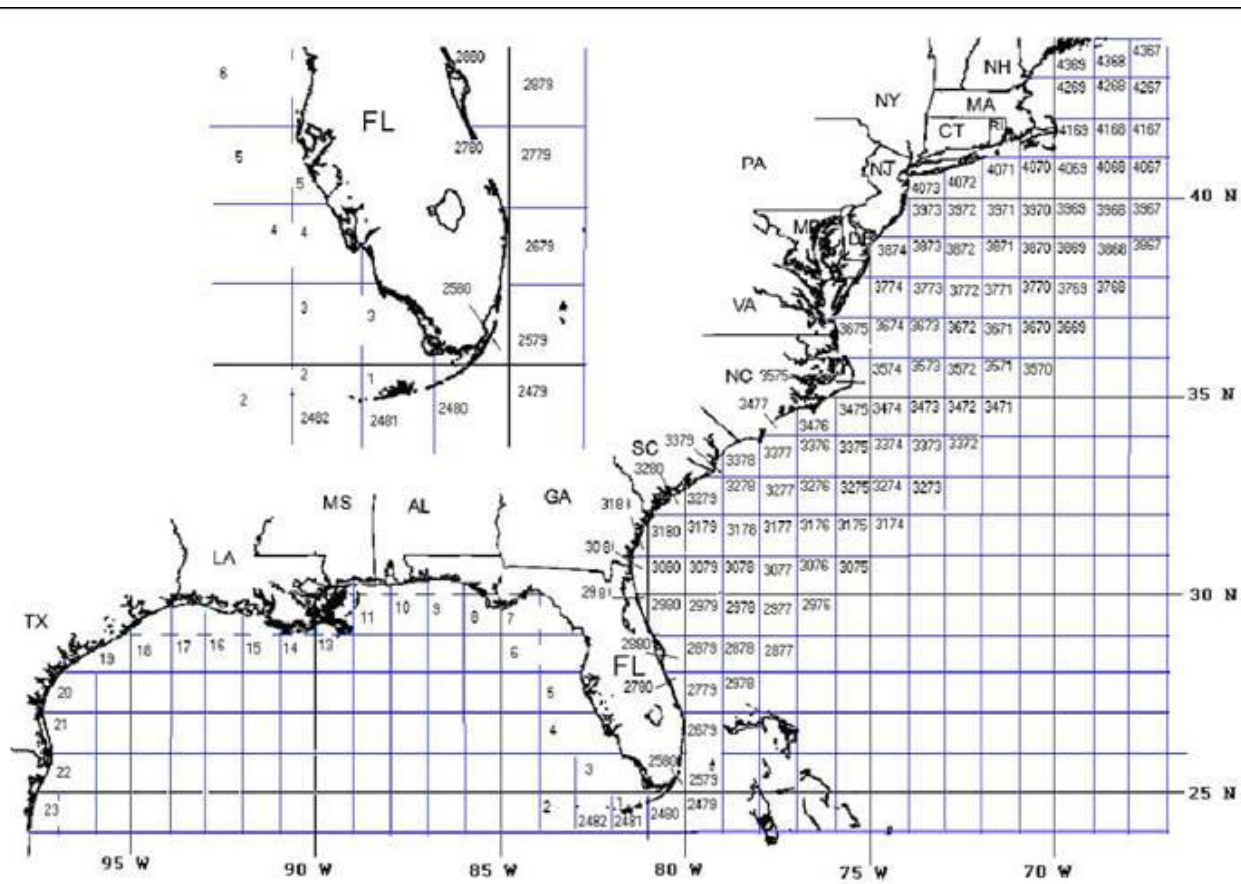


Figure 1. Coastal logbook statistical areas.