Estimated Marine Mammal and Turtle Bycatch in Shark Gillnet Fisheries Along the Southeast U.S. Atlantic Coast: 2000-2006

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Background

Gillnet fisheries operate along the southeastern U.S. Atlantic coast between central Florida and Cape Hatteras, North Carolina and target a variety of finfish and shark species. The fished gear is typically monofilament gillnet with stretched mesh sizes ranging from 2.5 to 10 inches. The gear is fished in a variety of ways depending upon the operator, region, and target species. Drift gillnets are used exclusively in coastal waters of Florida and Georgia and target coastal shark species, with catches dominated by Atlantic sharpnose shark (*Rhizoprionodon terraenovae*). The drift fishery off the coast of Florida and Georgia developed during the early 1990s and has declined in recent years to a small fleet of 4-6 vessels (Carlson and Bethea, 2007; Trent et al., 1997). The same vessels conducting drift operations began to employ "strike" sets also targeting coastal sharks during the late 1990's. These sets are of much shorter duration with soak times of less than one hour, use larger mesh sizes, and the nets are deeper than drift sets. The strike sets typically target blacktip shark (*Carchinus limbatus*), and 99% of the catch of these sets is comprised of sharks (Carlson and Bethea, 2007).

In addition, sink gillnets targeting sharks and a variety of finfish occur throughout southeast U.S. coastal waters south of Cape Hatteras, North Carolina. The primary finfish species caught include Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*Scomberomorus sp.*), king whiting (*Menticirrhus sp.*), and bluefish (*Pomatomus saltatrix*). Shark catches are dominated by Atlantic sharpnose shark, blacktip shark, and blacknose shark (*Carchinus acronotus*). The sink sets are targeted on schooling fish or sharks and typically have relatively short soak durations of one to four hours. Sets targeting fish generally have smaller mesh sizes (typically 3.5 inches) than those targeting sharks.

Protected species bycatch has been a concern for gillnets targeting shark species, most notably the larger mesh drift net fishery operating off of Florida and Georgia. Bycatch of endangered sea turtles (Leatherback [*Dermochelys coricea*] and loggerhead [*Caretta caretta*] turtles) and protected marine mammals (Bottlenose dolphin [*Tursiops truncatus*] and Atlantic spotted dolphin [*Stenella frontalis*]) has been documented in this fishery. The shark drift gillnet fishery was regulated by the Atlantic Large Whale Take Reduction Plan and a Biological Opinion under the Endangered Species Act due to the potential for interactions with North

Atlantic Right Whale (*Eubalaena glacialis*). The primary calving area for right whales occurs in this region during winter months. Therefore, drift net fishing was prohibited north of 27° 51' N latitude during November – March, and 100% observer coverage of the fishing effort was required beginning in 2001.

Outside of this season and area, there was very little observer coverage of drift or strike gillnetting until 2003, when the coverage levels were increased in response to a requirement under the Fisheries Management Plan for Highly Migratory Species. More recently, beginning in 2005, the gillnet observer program expanded its efforts to include sink net sets and broadened the universe of selected vessels to include those that do not participate in the drift/strike fishery (Carlson and Bethea, 2007).

In this document, I estimate the total bycatch of marine turtles and mammals in the gillnet fishery operating along the U.S. Atlantic coast south of Cape Hatteras, North Carolina. Reported fishing effort data from logbooks are examined to characterize fishing effort and evaluate the amount of the reported effort that is targeting shark versus finfish species. Bycatch rates (number of animals per gillnet set) are calculated for each species and are extrapolated by the reported effort to estimate the total bycatch with associated measures of uncertainty.

Methods

Observer Data and Bycatch Rate Estimation

Observer data for gillnets targeting sharks is collected by the Shark Gillnet Observer program administered at the SEFSC Panama City laboratory. The program deploys trained observers aboard selected gillnet vessels. The observers record data on gear and effort characteristics and collect biological information on the catch. Due to the requirements of relevant regulations, the majority of observer coverage has focused on the drift and strike net vessels operating off the central Florida and Georgia coasts. During the "right whale season" (November 15 – March 30) all trips made by drift/strike vessels have been targeted for observer coverage. There has been lower observer coverage of drift/strike vessels during the "non right whale season" (April 1 – November 14) and no coverage of vessels using sink gillnets until 2005. In addition to the previously targeted universe of drift/strike vessels, the observer program currently targets vessels that have an active directed shark permit and reported >25% of sharks in their landings. The observer program also covers sink nets deployed by the drift/strike vessels. Additional detail on the observer program and data collection methods is contained in Carlson and Bethea (2007) and associated reports available from http://www.sefscpanamalab.noaa.gov/shark/observers.htm.

All observer data collected between 2000 and 2006 were used for this analysis including 758 gillnet sets. The protected species (loggerhead turtle, leatherback turtle, bottlenose dolphin, and Atlantic spotted dolphin) bycatch data were characterized by 722 sets with zero bycatch, 30 sets with one animal, and 6 sets with two animals. These very sparse data are not adequately represented by standard probability distributions.

Several approaches were explored to develop robust estimates of the bycatch rates and associated uncertainty. Binomial estimators were considered (logistic regression and/or a binomial estimator with associated 95% confidence interval [Brown et al., 2001]); however, these approaches ignore the fact that several of the observations included more than one animal per set and therefore underestimated overall bycatch rates. In addition, the very low rate violated many of the asymptotic assumptions required to make estimated binomial confidence intervals reliable (Brown et al., 2001). Zero-inflated binomial (ZIB) and zero-inflated Poisson (ZIP) estimators were also examined within the framework of Bayesian approaches (Martin et al., 2005). However, the associated models did not converge and could not be used to provide meaningful measures of parameters or uncertainty. This is probably because the ZIB model ignores variability in the number of animals captured in non-zero sets, and the Poisson component of the ZIP model does not effectively describe the distribution of the non-zero observations. Finally, multinomial categorical models were evaluated; however, the number of positive observations of bycatch for any particular species or season was too low to support meaningful statistical tests, parameter estimates, or measures of uncertainty.

Ultimately, a simple ratio estimator (number of animals / number of observed sets) was used to represent bycatch rates. An estimate of uncertainty in these estimates was derived from bootstrap resampling of the observed data set. For each analytical stratum, a sample was drawn from the data (with replacement) with the same sample size as in the original data set. The ratio estimator was calculated from this sample, and this procedure was repeated 5,000 times to generate a distribution for the estimate. As these distributions were highly skewed (as expected), the median of the bootstrap distribution was used as the measure of central tendency and the sample values larger than 2.75% and 97.5% of the bootstrap distribution were used as the lower and upper bounds of the 95% confidence interval for the parameter estimate.

In this manner, bycatch rates were estimated separately for the “right whale” and “non-right whale” seasons for each species given the differences in observer coverage and fishery activity between seasons. Bycatch rates were estimated for each of the four gear types observed including drift nets, strike nets, sink nets targeting sharks (Sink-Shark), and sink nets targeting fish (Sink-Fish). Data across all years were combined for each gear type, again due to low sample size and the small number of non-zero values.

Categorizing Reported Fishery Effort

Reported gillnet fishery effort for 2000-2006 was obtained from the Fisheries Logbook System (FLS) maintained by the Southeast Fisheries Science Center. Fishing vessel captains are required to report these data, and logbooks include fishing effort, characteristics of the fishing gear, and the catch. Among the primary gear characteristics recorded in the logbooks for gillnet sets are the type of set (e.g., drift, sink, etc.), the stretched mesh size, soak time, net length, and gillnet depth. The fishing area (1 degree latitude and longitude squares) where catch was made is also included. Only fishing effort reported on the Atlantic coast between 24 and 35 degrees latitude were used in this analysis. Sadly, the vast majority of gillnet sets reported on the logbooks were coded generically as “Gillnet, Other”, and therefore it was not possible to directly distinguish among the four types of sets represented by the observer program.

Based on the observer data, it should be possible to distinguish between the four possible types of sets as a function of reported gear characteristics and the composition of the catch. Therefore, the species composition (both overall, finfish vs. sharks, species composition of shark catch, etc.) was summarized and examined using multivariate approaches. However, for both the observer data and the reported data, these methods were unable to distinguish between set types other than to separate those capturing predominantly fish from those capturing predominantly sharks. Gear characteristics were also examined in both data sets to identify correlations with shark catch and the separation between gear types. The results of these fruitless analyses are summarized below.

In the end, it was not possible to identify the type of gillnet used in a particular reported set based on catch or gear information provided in the logbooks. Therefore, a more blunt instrument was used. I first assumed that only those vessels observed as drift/strike vessels conducted drift or strike sets. For the remaining vessels reporting gillnet effort, if less than 20% of the reported catch for a set was sharks, then the set was identified as a sink gillnet targeting fish (Sink-Fish) and those with > 20% sharks in the catch were considered sink gillnets targeting sharks (Sink-Shark). For the remaining vessels included in the drift/strike observer program, I assumed that any set with less than 20% sharks was a Sink-Fish set. The remaining sets were then apportioned among drift, strike, and Sink-Shark based upon the observed proportions of those sets by seasons (right whale vs. non right whale). Thus, the observed effort was assumed to be representative of the relative amount of effort of each type reported to the logbook program.

While extremely imperfect and unsatisfying, this approach does capture the trend of decreasing numbers of drift sets and increasing numbers of strike sets as a proportion of total effort across time, which is clearly apparent in the observer data. This approach also effectively captures the seasonal variation in the type of fishing prosecuted with approximately 53% of observed sets (in 2005 and 2006) during the non right whale season comprising sink sets while only 15% of sets observed during the right whale season were sink sets. Finally, it captures the fact that the vast majority of gillnet fishing effort reported is for sets targeting fish, rather than sharks.

Extrapolating Bycatch Rates

For a given species, the bycatch estimate (N_y) for each year (y) for a given gear type was calculated as:

$$N_y = (E_{ry} \times R_r) + (E_{ny} \times R_n),$$

where the subscript r refers to the right whale season and the subscript n refers to the non right whale season, E is the estimated effort and R is the bycatch rate for the season. However, in many cases, the observed effort (particularly for the right whale season) actually exceeded the amount of reported effort. In these cases, the observed number of animals taken in a season was substituted for the appropriate term in the above equation.

Results and Discussion

The observer data set includes a total of 758 sets, with the majority of those being drift sets (307) and strike sets (211) reflecting both the history of the program and the high level of observer coverage required for this segment of the fleet. As mentioned previously, there has been a considerable decline in the amount of drift effort in recent years, particularly during the right whale season, with a concurrent increase in the number of strike sets (Table 1). A relatively small number of sink nets for shark and fish were observed during 2005-2006. The majority of the fishing effort observed occurred in central Florida and southern Florida and off the Georgia coast during the non right whale season (Figure 1). To date, there have only been a few sets observed off the coast of North Carolina.

The observer data demonstrate that the drift/strike component of the fishing fleet remains a very small component of the overall fishing effort with between 6-8 vessels of this type observed (Table 2). An average of 80 vessels reported gillnet fishing effort each year indicating both that the overall universe represented by the observer program is a small proportion of the fleet, and the vast majority of fishing effort is sink nets. It should be noted that the drift/strike vessels were also observed sink net fishing for both sharks and fish.

There were a total of 36 sets with observed bycatch of sea turtles or marine mammals (Table 3). The majority (32 of 36) of these interactions were observed during the right whale season. For loggerhead turtles, eight animals (6 alive, 2 dead) were taken in drift nets, four (one dead) were taken in strike sets, and one (alive) was taken in a sink net targeting sharks. There were 17 observed leatherback turtles captured (2 dead), and all of these occurred during the right whale season in drift nets. Four (1 dead) Atlantic spotted dolphins were observed taken and eight bottlenose dolphins (7 dead) were observed taken. All marine mammal bycatch occurred in drift nets, and two of the bottlenose dolphin interactions occurred during the non right whale season (Table 3). The vast majority of these takes occurred in the southern portion of the Florida coast reflecting the distribution of drift net effort during the right whale season (Figure 2).

A total of 12,431 gillnet sets were reported to the FLS system between 2000-2006 within the spatial extent considered for this analysis. There were many obvious errors in these data with many records reporting invalid information for gear characteristics including soak time, net length, mesh size, and gillnet depth. There was missing or invalid data for at least one of these parameters in 22% of these records. The majority of the reported fishing effort was reported in the fishing areas off the central Florida coast (areas 2780, 2880, and 2980) and near Cape Hatteras, NC (area 3575, Figure 3). Sets identified as shark sets (i.e., greater than 20% of reported catch was sharks) accounted for 2,393 (19%) of these sets, and the shark effort was concentrated along the central Florida coast with significant concentrations in southern Georgia, South Carolina, and near Cape Hatteras (Figure 4).

The observer data showed clear differences in the fishing gear characteristics between drift, strike, sink-shark and sink-fish gillnet sets. For example, strike sets were of very short duration, had large mesh sizes, and deeper nets than other types of nets (Figure 5). Drift sets should be distinguishable from sink-shark sets because they have longer soak times, longer net lengths, and deeper nets. Sink-fish sets are characterized by short soak times, small mesh sizes,

smaller nets, and shallower nets. However, none of these clear indicators of fishing type were apparent in the reported data. When categorized by the gross measure of the proportion of sharks in the catch, the only apparent distinction among gear types is in the reported stretched mesh size (Figure 6). However, even within this parameter there is overlap between sets catching almost entirely fish and those catching a significant amount of sharks. Thus, the reported effort is not a reliable indicator of the characteristics of the fished gear.

Even more troubling, there is direct evidence of under-reporting of effort. For example, direct comparisons of the reported and observed data sets were made for several fishing vessels at various seasons and years. There are numerous examples of observed sets that were not reported even within this heavily observed segment of the fleet. In fact, for both strike and drift nets the number of observed sets exceeded the number of reported sets in all but two years during the right whale season (Table 4a-b). Outside of the right whale season, the percentage of reported sets covered by the observer program averaged 39% of drift sets and 51% of strike sets. Percentage coverage of sink-shark sets in the non right whale season was 10% during 2005 and 20% during 2006 (Table 4c). However, the estimated effort levels are very unreliable both due to the assumptions that had to be made to identify gear types and because of the under-reporting of effort.

The observed and estimated total bycatch for drift, strike, and sink-shark sets is given in tables 5-7, respectively. For leatherback turtles, Atlantic spotted dolphins, and bottlenose dolphins the observed bycatch is the best estimate of total bycatch since the takes occurred in strike and drift gillnets during the right whale season (Table 5 and 6). For loggerhead turtles, the majority of the observed take was also in the heavily observed gear and seasons. However, the estimated bycatch in sink-shark sets during the non right whale season was also substantial (Table 7).

There are many obvious flaws in the data entering this analysis and the resulting bycatch estimates. Most notable are the fundamental problems of having no reliable way to identify the type of fishing gear used in the reported effort and the apparent under-reporting of effort. Considering that the drift/strike fleet is heavily observed and has been heavily impacted by regulation, I would expect that their reporting rates would be higher than the rest of the fleet that has been entirely unobserved prior to the last two years. Yet the data suggest that as much as 50% of their effort is not reported to the logbooks. In the absence of reliable effort data, the estimates presented here should be considered highly uncertain and most likely minimum estimates of the total bycatch.

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Table 1. Observed gillnet sets between 2000 and 2006 by gear type and season. "Sink-Shark" and "Sink-Fish" indicate sink sets targeting shark species and fish species, respectively.

Right Whale Season (January - March)					
Year	Drift Net	Strike Net	Sink - Shark	Sink - Fish	Total
2000	40	6	0	0	46
2001	70	12	0	0	82
2002	41	24	0	0	65
2003	2	26	0	0	28
2004	0	14	0	0	14
2005	12	26	2	0	40
2006	0	42	13	37	92

Non - Right Whale Season (April - November)					
Year	Drift Net	Strike Net	Sink - Shark	Sink - Fish	Total
2000	15	1	0	0	16
2001	22	5	0	0	27
2002	28	14	0	0	42
2003	22	14	0	0	36
2004	32	11	0	0	43
2005	19	7	29	51	106
2006	4	9	45	63	121
Total	**307**	**211**	**89**	**151**	**758**

Table 2. Number of vessels observed and reporting gillnet fishing effort along the U.S. southeast Atlantic coast between Florida and North Carolina. Most vessels observed as drift and strike vessels also have observed or reported sink net effort.

Year	Observed Drift/Strike	Observed Sink Net Vessels	Vessels Reporting Gillnet Effort
2000	6	0	91
2001	6	0	85
2002	7	0	82
2003	6	0	76
2004	6	0	62
2005	8	3	83
2006	7	7	84

Table 3. Observed incidental catch of protected species in southeast gillnet fisheries.

Gear Type	Set Date	Season	Net Length (ft.)	Net Depth (ft.)	Min. Mesh Size (in.)	Latitude	Longitude	Species	Number Dead	Number Alive
Drift	1/31/2000	Right whale	9000	30	10	27.269	-80.0935	Caretta caretta	1	0
Drift	8/8/2000	Non Right Whale	2450	10	5-10	31.09067	-81.3008	Caretta caretta	0	1
Drift	3/1/2001	Right whale	7500	35	5-8	27.69033	-80.254	Caretta caretta	0	1
Drift	2/8/2002	Right whale	6000	30	5-10	27.30867	-80.105	Caretta caretta	0	1
Drift	2/8/2005	Right whale	1200	40	5	27.3045	-80.0587	Caretta caretta	0	1
Drift	2/15/2005	Right whale	7900	40	5	27.39033	-80.1328	Caretta caretta	0	1
Drift	2/20/2005	Right whale	1500	40	7	27.62117	-80.2703	Caretta caretta	1	1
Drift	1/31/2001	Right whale	7200	40	6-9	27.40083	-80.189	Dermochelys coriacea	0	2
Drift	2/1/2001	Right whale	2100	45	5-9	27.8215	-80.3393	Dermochelys coriacea	0	1
Drift	2/6/2001	Right whale	7000	35	7-10	27.39467	-80.1452	Dermochelys coriacea	0	1
Drift	2/13/2001	Right whale	7800	35	4-10	27.4835	-80.1853	Dermochelys coriacea	0	2
Drift	2/14/2001	Right whale	7500	35	5-9	27.63383	-80.2383	Dermochelys coriacea	0	1
Drift	2/21/2001	Right whale	7200	40	6-9	27.22467	-80.107	Dermochelys coriacea	0	2
Drift	2/22/2001	Right whale	7200	40	6-9	27.38867	-80.1413	Dermochelys coriacea	0	1
Drift	2/26/2001	Right whale	5400	35	5-8	27.83683	-80.2998	Dermochelys coriacea	0	1
Drift	2/26/2001	Right whale	6000	35	4-10	27.32433	-80.1413	Dermochelys coriacea	2	0
Drift	2/28/2001	Right whale	5400	35	5-8	27.686	-80.2928	Dermochelys coriacea	0	1
Drift	1/20/2002	Right whale	7500	35	5-8	27.25683	-80.0927	Dermochelys coriacea	0	1
Drift	2/18/2002	Right whale	5400	30	5-10	27.38383	-80.1253	Dermochelys coriacea	0	1
Drift	2/15/2005	Right whale	7900	40	5	27.39033	-80.1328	Dermochelys coriacea	0	1
Drift	2/10/2000	Right whale	6000	30	6-10	27.28167	-80.1017	Stenella frontalis	0	1
Drift	2/15/2001	Right whale	6900	35	7-10	27.3265	-80.1345	Stenella frontalis	0	2
Drift	2/26/2001	Right whale	6000	35	4-10	27.32433	-80.1413	Stenella frontalis	1	0
Drift	2/20/2000	Right whale	7500	35	5.5-8	27.6525	-80.2708	Tursiops truncatus	1	0
Drift	2/13/2001	Right whale	7800	35	4-10	27.4835	-80.1853	Tursiops truncatus	1	0
Drift	2/22/2001	Right whale	7200	40	6-9	27.38867	-80.1413	Tursiops truncatus	1	0
Drift	2/28/2001	Right whale	5400	35	5-8	27.686	-80.2928	Tursiops truncatus	1	0
Drift	2/28/2001	Right whale	6000	35	4-10	27.507	-80.2253	Tursiops truncatus	1	0
Drift	7/1/2002	Non Right Whale	6900	50	5-5	25.75183	-80.4907	Tursiops truncatus	1	0
Drift	2/28/2003	Right whale	3300	40	5	27.3495	-80.1718	Tursiops truncatus	1	0
Drift	6/25/2003	Non Right Whale	8400	40	5	27.3245	-80.0812	Tursiops truncatus	0	1
Strike	1/27/2005	Right whale	950	90	9	27.2565	-80.1292	Caretta caretta	0	1
Strike	1/12/2006	Right whale	2400	90	9.25	27.10533	-80.0525	Caretta caretta	0	1
Strike	2/17/2006	Right whale	3900	90	9.25	27.32583	-80.107	Caretta caretta	1	0
Strike	3/1/2006	Right whale	4500	90	9	27.42583	-80.1185	Caretta caretta	0	1
Sink-Shark	9/23/2005	Non Right Whale	6000	14	7	27.399	-80.1055	Caretta caretta	0	1

Table 4. Estimated number of sets of each gear type (Drift, Strike, Sink-Shark, and Sink-Fish) by year and season based upon effort reported in logbooks. The observed effort of each type is shown and highlighted where observed effort exceeds reported effort.

A. Drift Sets

Year	Non Right Whale		Right Whale	
	Observed	Reported	Observed	Reported
2000	15	65	**40**	23
2001	22	66	**70**	26
2002	28	40	**41**	21
2003	22	46	2	2
2004	32	49	0	0
2005	19	41	**12**	3
2006	4	8	0	0

B. Strike Sets

Year	Non Right Whale		Right Whale	
	Observed	Reported	Observed	Reported
2000	1	4	**6**	3
2001	5	15	**12**	4
2002	14	20	**24**	12
2003	14	29	26	28
2004	11	17	14	19
2005	7	15	**26**	6
2006	9	19	**42**	38

C. Sink - Shark

Year	Non Right Whale		Right Whale	
	Observed	Reported	Observed	Reported
2000	0	239	0	30
2001	0	280	0	20
2002	0	192	0	41
2003	0	157	0	10
2004	0	180	0	20
2005	29	293	2	11
2006	54	267	13	34

Table 4. continued

D. Sink - Fish

Year	Non Right Whale		Right Whale	
	Observed	Reported	Observed	Reported
2000	0	1239	0	302
2001	0	1146	0	290
2002	0	1217	0	302
2003	0	1079	0	190
2004	0	1093	0	151
2005	51	1218	0	174
2006	63	1417	37	220

Table 5. Estimated bycatch of protected species for drift gillnets. Cells where the observed effort exceeds the reported effort are highlighted. In those cases, the observed bycatch (Observed N) is the best estimate of total bycatch.

A. Loggerhead turtles (*Caretta caretta*)

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Non Right Whale Season						
2000	15	65	0.007	0.5	0-1.4	1
2001	22	66	0.007	0.5	0-1.4	0
2002	28	40	0.007	0.3	0-0.9	0
2003	22	46	0.007	0.3	0-1	0
2004	32	49	0.007	0.3	0-1	0
2005	19	41	0.007	0.3	0-0.9	0
2006	4	8	0.007	0.1	0-0.2	0
Right Whale Season						
2000	**40**	23	0.042	1.7	0.5-3.2	**1**
2001	**70**	26	0.042	3	0.8-5.5	**1**
2002	**41**	21	0.042	1.7	0.5-3.2	**1**
2003	**2**	2	0.042	0.1	0-0.2	**0**
2004	**0**	0	0.042	0	0-0	**-**
2005	**12**	3	0.042	0.5	0.1-0.9	**4**
2006	**0**	0	0.042	0	0-0	**-**

B. Leatherback turtles (*Dermochelys coriacea*)

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Non Right Whale Season						
2000	15	65	0	0	-	0
2001	22	66	0	0	-	0
2002	28	40	0	0	-	0
2003	22	46	0	0	-	0
2004	32	49	0	0	-	0
2005	19	41	0	0	-	0
2006	4	8	0	0	-	0
Right Whale Season						
2000	**40**	23	0.103	4.1	1.9-6.5	**0**
2001	**70**	26	0.103	7.2	3.4-11.5	**14**
2002	**41**	21	0.103	4.2	2-6.7	**2**
2003	**2**	2	0.103	0.2	0.1-0.3	**0**
2004	**0**	0	0.103	0	-	**-**
2005	**12**	3	0.103	1.2	0.6-2	**1**
2006	**0**	0	0.103	0	-	**-**

C. Bottlenose dolphins (*Tursiops truncatus*)

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Non Right Whale Season						
2000	15	65	0.014	0.9	0-2.3	0
2001	22	66	0.014	0.9	0-2.3	0
2002	28	40	0.014	0.6	0-1.4	1
2003	22	46	0.014	0.7	0-1.6	1
2004	32	49	0.014	0.7	0-1.7	0
2005	19	41	0.014	0.6	0-1.5	0
2006	4	8	0.014	0.1	0-0.3	0
Right Whale Season						
2000	**40**	23	0.036	1.5	0.5-2.7	**1**
2001	**70**	26	0.036	2.5	0.8-4.7	**4**
2002	**41**	21	0.036	1.5	0.5-2.7	**0**
2003	**2**	2	0.036	0.1	0-0.1	**1**
2004	**0**	0	0.036	0	-	**-**
2005	**12**	3	0.036	0.4	01-0.8	**0**
2006	**0**	0	0.036	0	-	**-**

D. Atlantic spotted dolphins (*Stenella frontalis*)

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Non Right Whale Season						
2000	15	65	0	0	-	0
2001	22	66	0	0	-	0
2002	28	40	0	0	-	0
2003	22	46	0	0	-	0
2004	32	49	0	0	-	0
2005	19	41	0	0	-	0
2006	4	8	0	0	-	0
Right Whale Season						
2000	**40**	23	0.024	1	0-2.2	**1**
2001	**70**	26	0.024	1.7	0-3.8	**3**
2002	**41**	21	0.024	1	0-2.2	**0**
2003	**2**	2	0.024	0	0-0.1	**0**
2004	**0**	0	0.024	0	-	**-**
2005	**12**	3	0.024	0.3	0-0.7	**0**
2006	**0**	0	0.024	0	-	**-**

Table 6. Estimated bycatch of protected species for strike gillnets. Only bycatch of loggerhead turtles (*Caretta caretta*) was observed, and no bycatch was observed outside of the right whale season (January-March). Cells where the observed effort exceeds the reported effort are highlighted. In those cases, the observed bycatch (Observed N) is the best estimate of total bycatch.

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Right Whale Season						
2000	**6**	3	0.027	0.2	0 – 0.3	**0**
2001	**12**	4	0.027	0.3	0.1 – 0.6	**0**
2002	**25**	12	0.027	0.6	0.2 – 1.3	**0**
2003	26	28	0.027	0.7	0.2 – 1.5	0
2004	**14**	19	0.027	0.5	0.1 – 1.0	**0**
2005	**26**	6	0.027	0.7	0.2 – 1.4	**1**
2006	**42**	38	0.027	1.1	0.3 – 2.2	**3**

Table 7. Estimated bycatch of protected species for sink gillnets targeting sharks. Only bycatch of loggerhead turtles (*Caretta caretta*) was observed, and bycatch was observed only during the "non right whale" season (April - November).

Year	Observed Sets	Reported Sets	Rate (N/set)	Estimated N	Bootstrap 95% Confidence Interval	Observed N
Non Right Whale Season						
2000	0	239	0.014	3.3	0 – 9.7	-
2001	0	280	0.014	2.9	0 – 11.4	-
2002	0	192	0.014	2.7	0 – 7.8	-
2003	0	157	0.014	2.2	0 – 6.4	-
2004	0	180	0.014	2.5	0 – 7.3	-
2005	29	293	0.014	4.1	0 – 11.9	1
2006	54	267	0.014	3.7	0 – 10.8	0

Figure 1. Observed gillnet sets along the southeast U.S coast. Observed effort included sink nets targeting sharks and fish only in 2005 and 2006. Nine strike sets observed in the central Gulf of Mexico during 2006 are not shown.

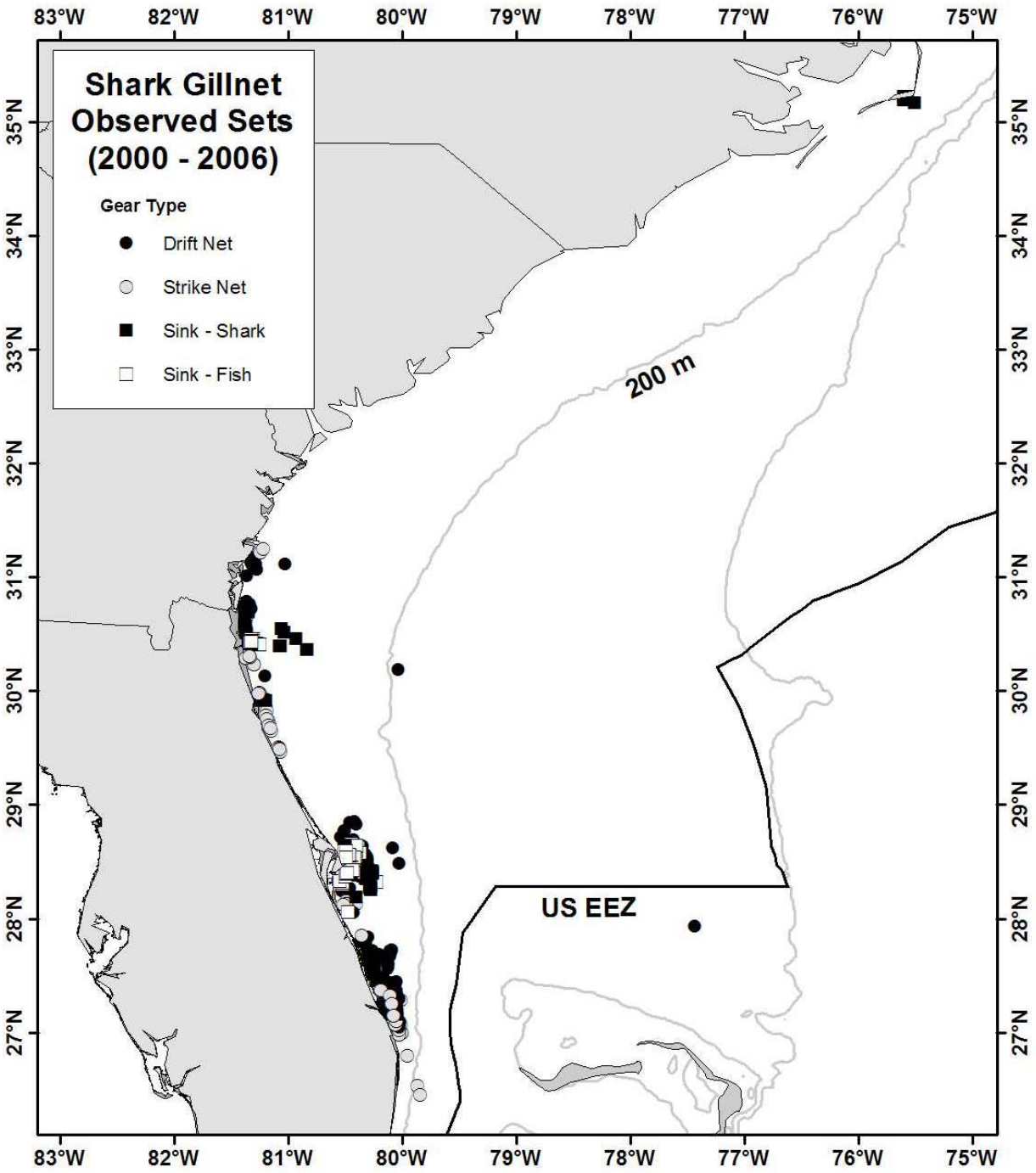

Figure 2. Observed interactions with protected species in south Atlantic gillnets.

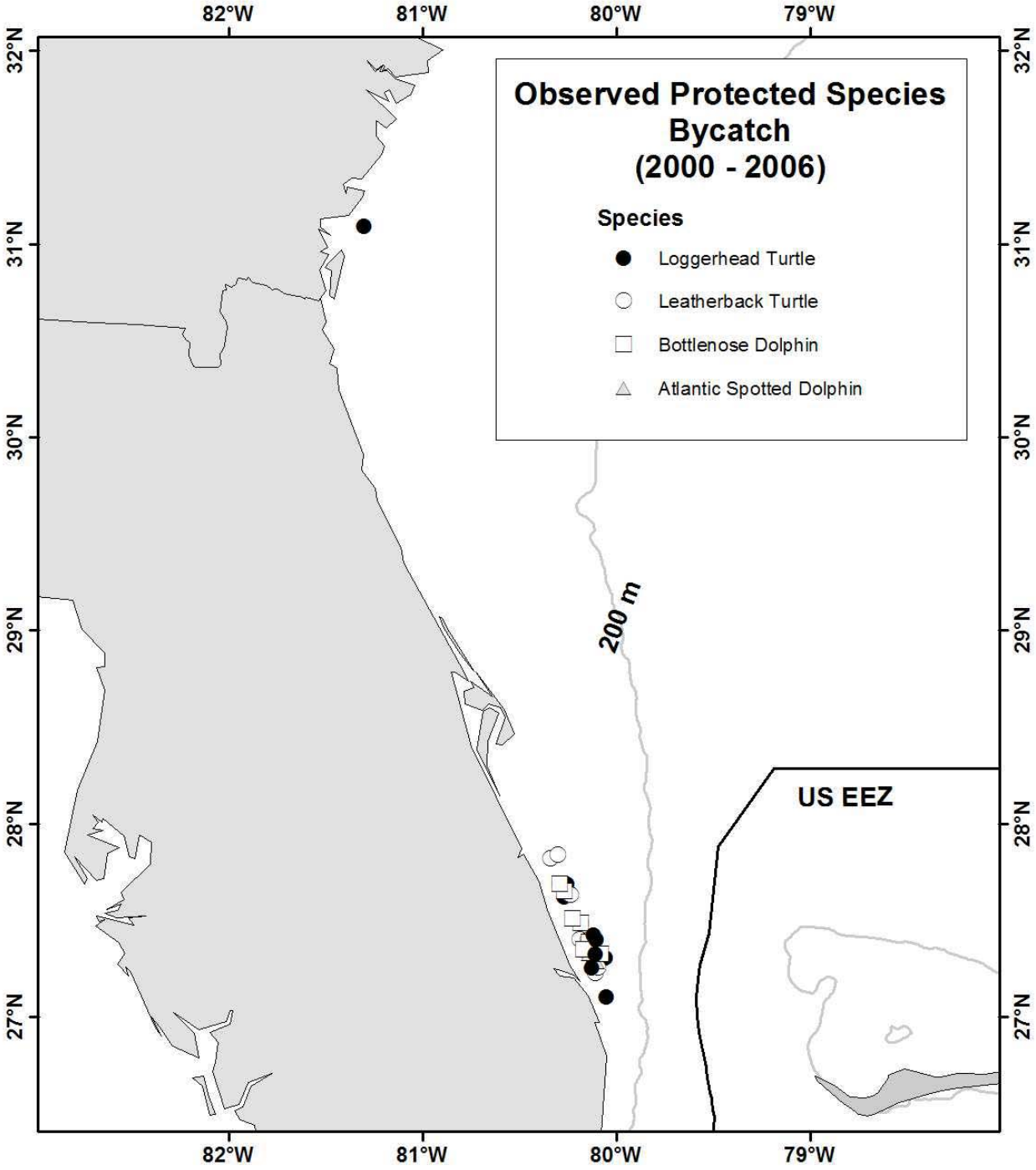

Figure 3. Reported gillnet fishing effort by 1-degree fishing area between 2000 and 2006.

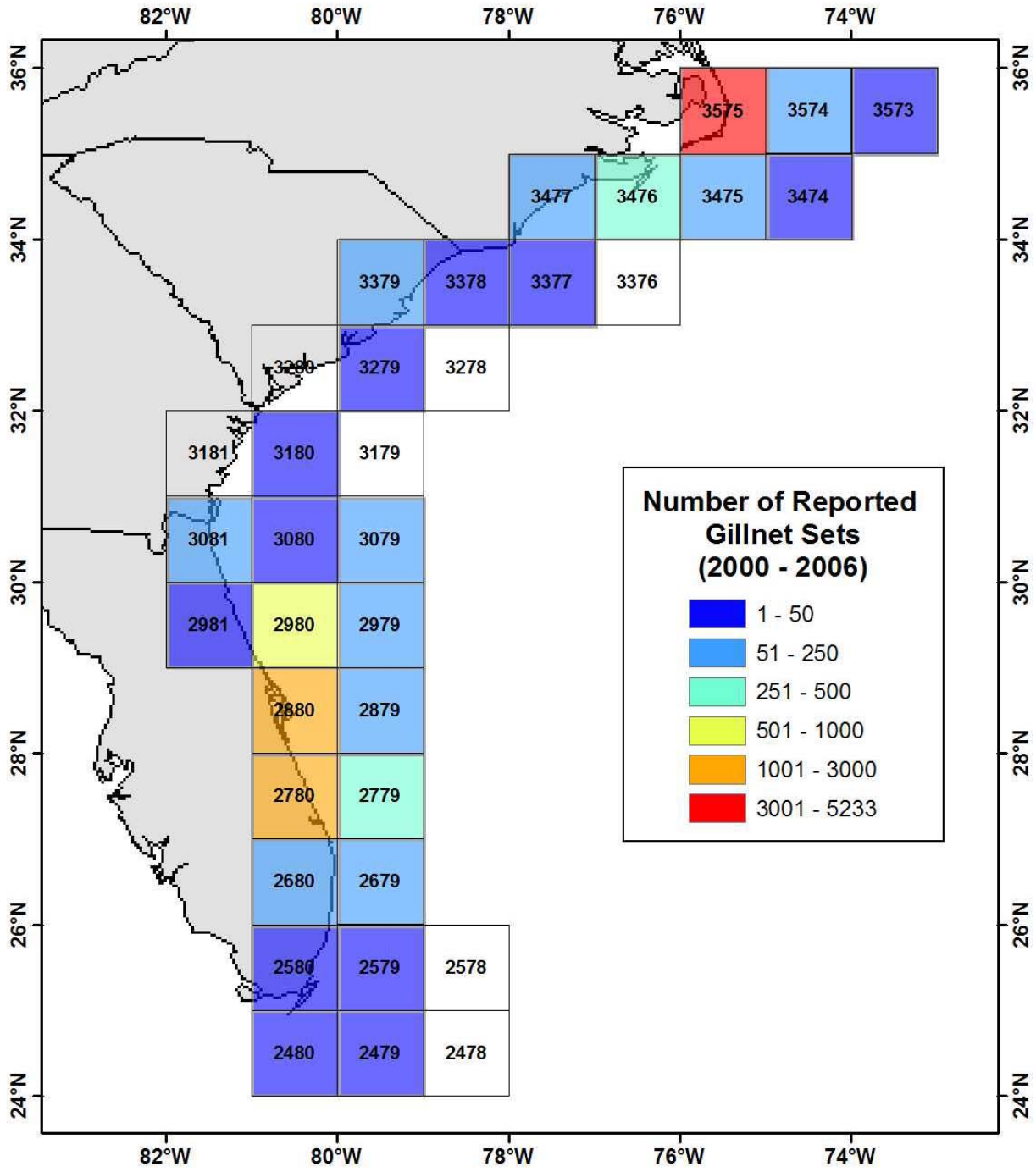

Figure 4. Reported gillnet fishing effort by 1-degree fishing area between 2000 and 2006 for sets with greater than 20% shark catch by weight.

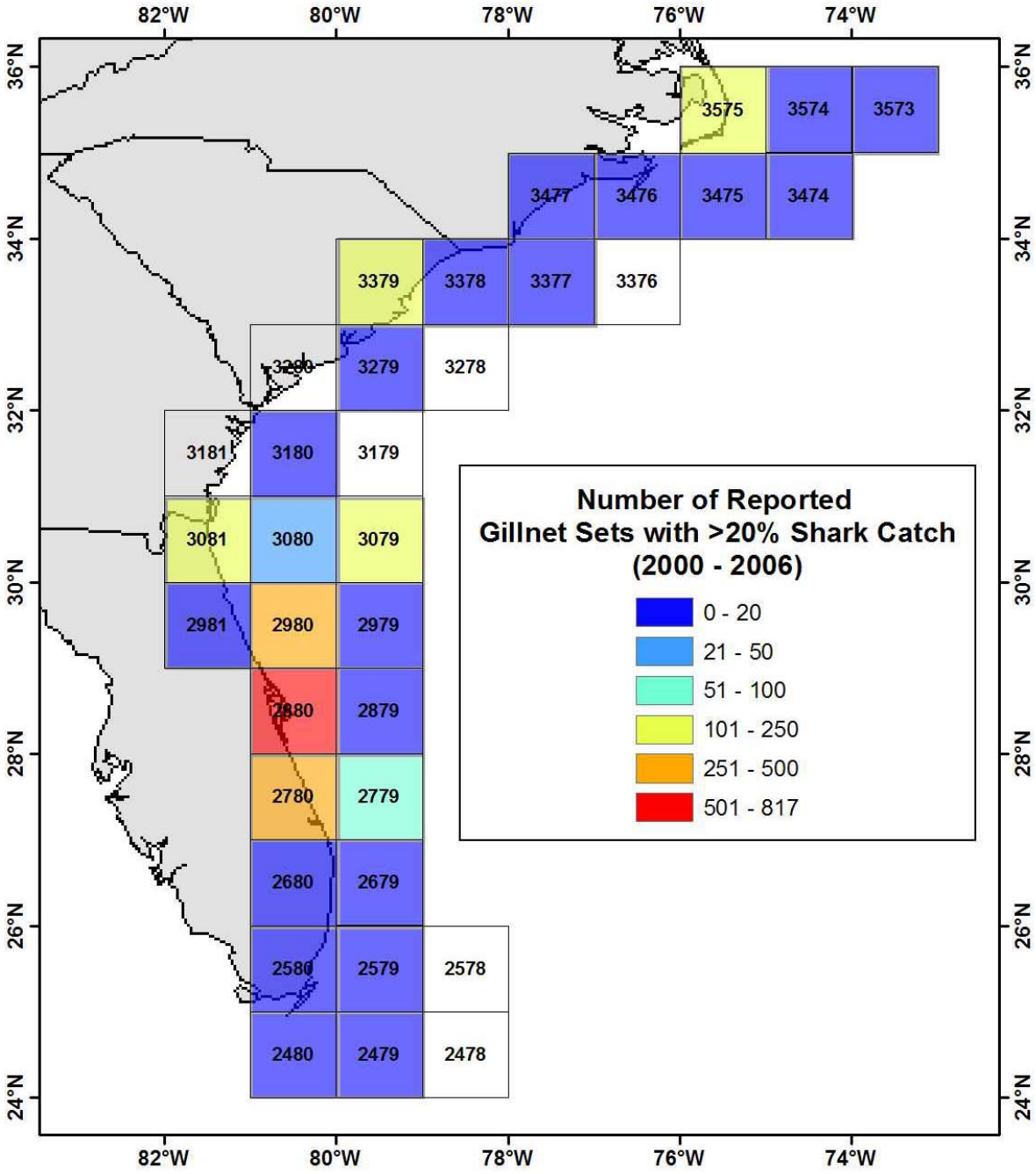

Figure 5. Box-whisker plots of fishing gear characteristics of observed gillnet sets by the type of set. The dark line indicates the median of each parameter, the bars indicate the range between the first and third quartiles, and whiskers indicate data range excluding outliers that are indicated by points. Only observed data for 2003-2006 since net depth and mesh size were recorded as ranges in earlier years.

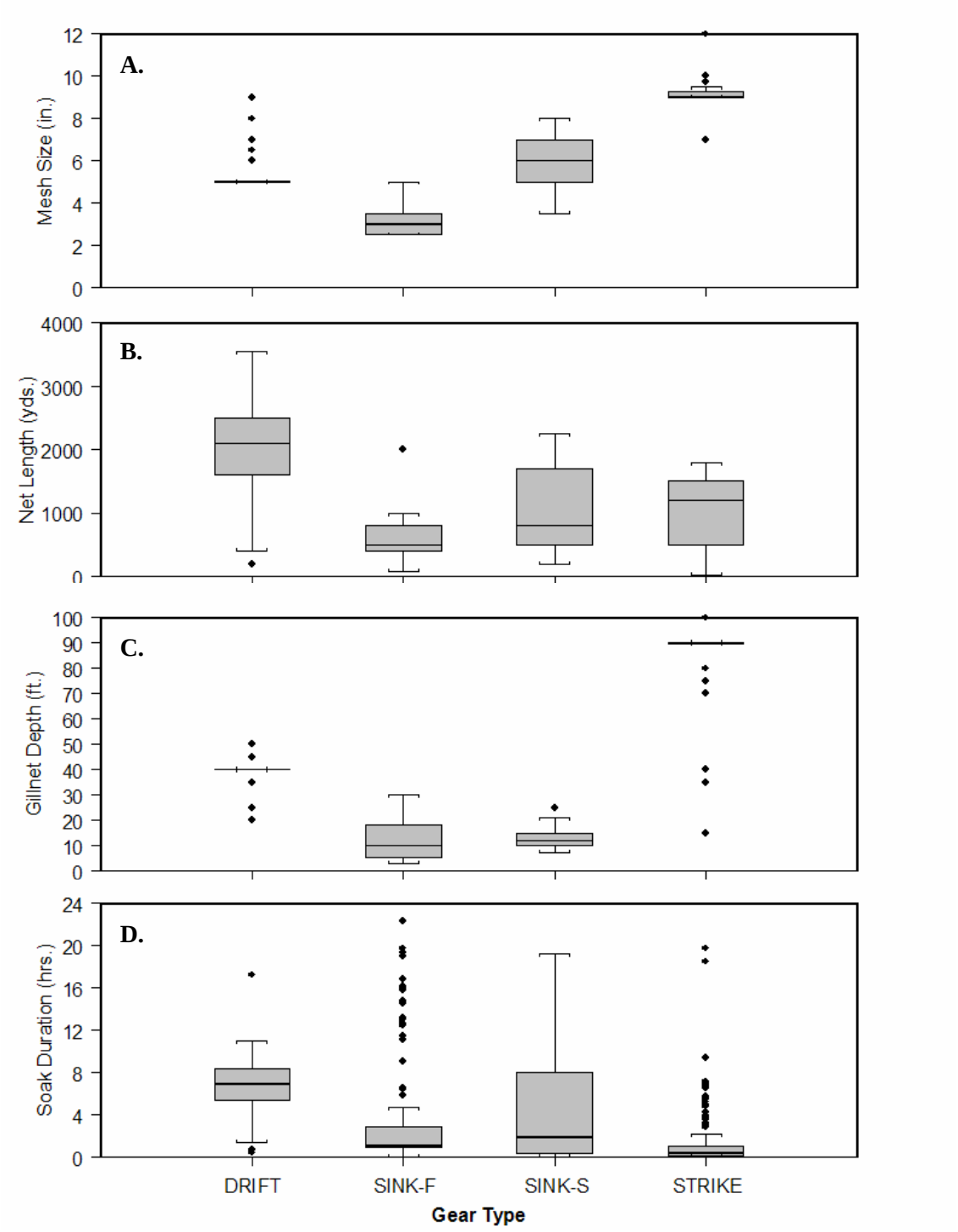

Figure 6. Box-whisker plots of reported fishing gear characteristics of gillnet sets and the percentage of sharks in the catch (% of total weight). The dark line indicates the median of each parameter, the bars indicate the range between the first and third quartiles, and whiskers indicate data range excluding outliers that are indicated by points.