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Estimated Bycatch of Sea Turtles in Sink Gillnet Gear

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Northeast Fisheries Science Center
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ABSTRACT

This document describes characteristics of observed turtle bycatch in gillnet fisheries from 2012-2016; estimates loggerhead bycatch, mortality, and adult equivalents in Mid-Atlantic sink gillnet gear from 2012-2016; and extends estimates to include Georges Bank. In addition, this document reports total estimates of Kemp's ridley and leatherback turtle bycatch for the first time in these 2 regions. Estimated bycatch for each species is reported for the entire gear type and also by managed fish species landed to aid in ESA Section 7 consultations on management actions targeting specific fisheries. Lastly, uncertainty around bycatch rates (CVs) is used to project the amount of observer coverage needed in future years to achieve a 30% precision rate around bycatch rates. Bycatch rates for each turtle species were estimated with stratified ratio estimators, stratified by region, season, and mesh size. From 2012-2016, total estimated bycatch of sea turtles in sink gillnet gear in the Georges Bank and Mid-Atlantic regions was 705 loggerheads (of which 557 were mortalities) (CV = 0.29, 95% CI over all years: 335-1116), 145 Kemp's ridleys (115 mortalities) (CV=0.43, 95% CI over all years: 44-292), 27 leatherbacks (21 mortalities) (CV=0.71, 95% CI over all years: 0-68), and 112 unidentified hard-shelled turtles (88 mortalities) (CV=0.37, 95% CI over all years: 64-321). Total estimated loggerhead bycatch was equivalent to 19 adults. From 2012 – 2016, VTR trips catching monkfish, skates, or spiny dogfish accounted for 87% of the estimated bycatch of all sea turtles. A total of 887 sea days per year are needed to achieve a 30% CV precision around loggerhead bycatch rates over Mid-Atlantic and Georges Bank strata. Sea days for non-loggerhead species will be evaluated in the future.

I. INTRODUCTION

Bycatch of turtles in commercial fishing gear is considered a threat to the recovery of several species of turtles, including loggerheads (*Caretta caretta*), greens (*Chelonia mydas*), Kemp's ridleys (*Lepidochelys kempii*), and leatherbacks (*Dermochelys coriacea*). All of these species are protected under the US Endangered Species Act (ESA) of 1973, which aims to reduce or eliminate threats to the species to aid in their recovery.

Close to 100 loggerheads per year were estimated to have been caught incidentally (i.e., bycatch) in sink gillnet gear operating in the US Mid-Atlantic from 2007-2011 (Murray 2013). Less is known about the magnitude and characteristics of bycatch of Kemp's ridleys, greens, and leatherback turtles in gillnet gear because observed bycatch of these species has been relatively rare compared to loggerheads. Historically, interaction rates between loggerheads and several types of commercial fishing gear have been higher in the southern Mid-Atlantic (i.e., waters off of Maryland to North Carolina) when surface water temperatures are warm (Murray and Orphanides 2013) and rates with gillnets tend to be highest in large mesh nets (≥7 in stretched mesh) (Murray 2013). Conservation measures have been implemented in the southern Mid-Atlantic to reduce the likelihood of commercial fishery interactions with sea turtles. For instance, fishers are prohibited from using gillnets with mesh sizes ≥7 in during certain times and areas that overlap with the seasonal occurrence of loggerheads (US Department of Commerce 2002, 2006). Despite these conservation measures, fisheries observers continue to document interactions between sea turtles and gillnet gear in the Mid-Atlantic during times and areas outside of the large mesh closure restrictions or in mesh sizes smaller than 7 in.

This document describes characteristics of observed turtle bycatch in gillnet fisheries from 2012-2016, estimates loggerhead bycatch in Mid-Atlantic sink gillnet gear from 2012-2016, and extends estimates to include Georges Bank. In addition, this document reports total estimates of Kemp's ridley and leatherback turtle bycatch for the first time in these 2 regions. This document also reports adult equivalent (AE) loggerhead bycatch. Adult equivalence considers a turtle's reproductive value (RV), defined as the contribution of an individual in an age class to current and future reproduction (Fisher 1930), and is an important metric for understanding population-level impacts of fisheries interactions (Haas 2010). Estimated bycatch for each species is reported for the entire gear type and also by managed fish species landed (Murray 2009b) to aid in ESA Section 7 consultations on management actions targeting specific fisheries. Lastly, uncertainty around bycatch rates, i.e., coefficient of variation (CV) is used to project the amount of observer coverage needed in future years to achieve 30% precision around bycatch estimate rates.

2. METHODS

2.1 Study Region

The extent of the study region was defined by the boundaries of the Georges Bank and Mid-Atlantic Ecological Production Units (EPU), characterized by distinct patterns in oceanographic properties, fish distributions, and primary production (Ecosystem Assessment Report 2012). The study region extended eastward from the continental coastline (excluding internal sounds in North Carolina) to the Exclusive Economic Zone (EEZ) and southward to the southern extent of Northeast Fisheries Observer Program (NEFOP) data collection (~34^{0}N) (Figure 1).

2.2 Data Sources

2.2.1 Observer Data

Data collected by NEFOP observers and at-sea monitors (ASM) aboard commercial sink gillnet vessels from 2012 through 2016 were used to compute bycatch rates of loggerhead, Kemp's ridley, leatherback, and unidentified hard-shelled turtles. A total of 9,554 trips were observed encompassing 37,369 hauls from 2012-2016 in Northeast-region sink-gillnet fisheries (Maine to North Carolina) (Figure 2). Of those, 4,902 trips (51%) were in the Georges Bank and Mid-Atlantic regions (Table 1) and used for this analysis; 4,470 (47%) trips were in the Gulf of Maine, and 182 (2%) were inside North Carolina sounds. ASM and NEFOP trips comprised 26% and 74%, respectively, of the trips used in this analysis.

2.2.2 Commercial Data

VTR data were the primary data used in estimating total bycatch because most VTRs contained the information on fishing location and characteristics (i.e., mesh size) necessary to derive total bycatch in this analysis. However, a comparison of VTR landings with Northeast dealer landings from the Northeast region's state and federal waters revealed that ~34% of the commercial gillnet landings were not reflected in the VTR database. Therefore, VTR landings were scaled by an adjustment factor (Murray 2015; Orphanides and Hatch in press) so that VTR landings equaled the landings reported in the dealer database, which is assumed to be a near census of commercial catch (Wigley et al. 2007). Commercial fishing effort for gillnet trips in North Carolina were poorly represented in the dealer database, so for vessels landing catch in North Carolina, VTR landings were scaled by using oceanside landings reported by the North Carolina Division of Marine Fisheries (NCDMF) trip ticket program (Murray 2015; Orphanides and Hatch in press).

To adjust VTR data to match the magnitude of landings in the dealer data, VTR and dealer landings were first totaled by each state, year, and season combination, where seasons were defined to match those in this analysis (July-October, November-June). Next, an adjustment factor (AF) for each combination was calculated as:

$$AF_i = \frac{\sum \text{Dealer landings}_{ijk}}{\sum \text{VTR landings}_{ijk}}$$

where i = year, j = state, and k = season in which catch was landed. VTR data in North Carolina and NCDMF data were further stratified depending on whether catch was landed inside or outside of NC internal waters (internal effort was excluded from the analysis).

For each VTR trip in stratum *ijk*, the landed catch was multiplied by the AF of stratum *ijk*.

Adjustment factors ranged between 1.0 and 5.5, with the highest AF in North Carolina (median AF = 1.1).

2.3 Bycatch Rates

Bycatch rates for each turtle species were estimated with stratified ratio estimators. This method differs from previous approaches (Murray 2009a, 2013), where loggerhead bycatch rates in gillnet gear were estimated with generalized additive models (GAMs). However, ratio estimators have the advantage of being computationally simple with general application to many sampling designs (Cochran 1977) and can yield results similar to those using GAM or generalized linear models (GLM) if ratio estimators are stratified based on the same explanatory variables in a GAM or GLM model (Murray 2007, 2013; Orphanides 2009).

Observer and commercial data were stratified by region, season, and mesh size, based on factors associated with loggerhead bycatch rates in previous gillnet bycatch analyses (latitude, sea surface temperature [SST], mesh size) (Murray 2009a, 2013). Regions included Georges Bank and Mid-Atlantic, with the boundaries of Georges Bank and the Mid-Atlantic matching these respective EPUs (Figure 1). The Mid-Atlantic EPU was further divided into the northern Mid-Atlantic (>37^0N to the Georges Bank boundary) and southern Mid-Atlantic (<= 37^0N to 34^0N). Season was used as a proxy for SST. Seasonal groups were created based on warm (>= 15^0C) and cold (< 15^0C) sea surface temperature patterns in each respective region based on hydrographic surveys conducted in 2012-2014 (Fratantoni et al. 2013, 2015a, 2015b) and defined as summer (July – October) or winter (November – June). Mesh groups were defined as small (< 7”) or large (>= 7”) and corresponded to sizes associated with low and high bycatch rates, respectively, in previous bycatch analyses (Murray 2009a, 2013).

There have been no previous bycatch analyses of sea turtle species besides loggerheads to inform a stratification scheme for this analysis. The stratification for loggerheads was maintained for the other turtle species (Kemp’s ridley and leatherback) because it was assumed to capture the temporal and spatial presence of each species on the Northeast continental shelf while distinguishing between large and small mesh gillnet fisheries.

Within each stratum (*j*), bycatch rates (*R*) were defined as:

$$\boldsymbol{R}_{j} = \sum_{i=1}^{n} \frac{\textbf{observed turtles}_{j}}{\textbf{observed tons landed}_{j}}$$

where n = the number of observed NEFOP hauls

Bootstrap resampling was used to estimate uncertainty CV and confidence intervals [CIs]) around bycatch rates within each stratum, using trips as the resampling unit (Orphanides and Hatch, in press). Bootstrap replicates were generated by resampling trips with replacement 1000 times from the original observer dataset, and then bycatch rates within each stratum were computed for each replicate. The 95% CI for the bycatch rates were computed from the upper 97.5% and lower 2.5% quartiles of the bootstrap replicates. CVs and CIs for all strata combined were obtained in the same manner through the summation of stratum-specific bycatch estimates.

2.4 Estimated Bycatch: Total & Adult Equivalents

Total estimated bycatch (TB) for each turtle species from 2012-2016 was the sum over all strata (*h*) of the product of the bycatch rate and total adjusted VTR fishing effort within each stratum (*j*):

$$TB = \sum_{j=1}^{h} R_j * \ Adjusted\,VTR\,Effort_j$$

The number of mortalities was estimated by applying the most recent mortality rate determined for sink gillnet gear (79%, Upite et al. in review) to the total estimated bycatch. This mortality rate was determined by members of a working group who applied injury guidelines to 44 observed turtle interactions in sink gillnet gear between 2011 and 2015 (2016 records have not been analyzed by the working group yet, so a 5-year average from 2012-2016 was not available).

The finite population correction factor (fpc) was applied to CVs in strata where observer coverage was >10% (Cochran 1977). The fpc adjusts standard errors to be more precise when greater than 10% of the population is sampled. It is defined as:

$$fpc_j = \sqrt{\frac{N-n}{N-1}}$$

where N = total adjusted VTR fishing effort in stratum j and
n = observed tons in stratum j

To estimate loggerhead bycatch in terms of adult equivalents, each observed loggerhead turtle with a curved carapace measurement was assigned an RV value based on slow-growth high fecundity RVs in Wallace (2008). It would have been desirable to estimate an average RV in each stratum or even by region (as in Murray 2015); however, almost all of the recorded turtle sizes (10 out of 11) were from a single stratum (Mid-Atlantic north, July-October, >= 7” mesh). Therefore, the total estimated loggerhead bycatch was multiplied by the average RV of all turtles (0.0268) to compute adult equivalent (AE) bycatch. AEs were only computed for loggerheads because RVs are not available for the other turtle species.

2.5 Estimated Bycatch by Managed Fish Species Landed

To estimate the total bycatch by managed fish species landed, the estimated bycatch in stratum *j* was prorated across the species based on the proportion (by weight) of the species landed in that stratum (Murray 2009b; Warden 2011). Turtle bycatch (b) for fish species *k* in stratum *j* was multiplied by the proportion of reported landings of species *k* caught in stratum *j*:

$$b_{kj} = b_j * t_{kj}/T_j$$

Where b_j is the total estimated turtle bycatch in stratum *j*, t_{kj} is the amount of tons landed of species *k* in stratum *j*, and T_i is the amount of tons landed in stratum *j*.

Total estimated bycatch of each turtle species for managed species *k* over all strata was then:

$$B_k = \sum_{i=1}^{h} b_{kj}$$

Where *h* = total number of strata.

2.6 Estimated Sea Day Needs

Uncertainty (CVs) around the loggerhead bycatch rates in this analysis was used to estimate the amount of observer sea days needed in 2018 to achieve 30% CV precision around the bycatch rate. A 30% precision goal has been recommended by the National Working Group on Bycatch (NMFS 2004), and is the standard used for sea-day estimation needs under the Standardized Bycatch Reporting Methodology Omnibus Amendment (Wigley et al. 2012). Sea days for Kemp’s ridley and leatherback turtles were not projected because of the low encounter rate of these species. More work needs to be done to evaluate sufficient levels of sampling for these rare encounters, to ensure that monitoring is cost-effective and practical while meeting ESA and Magnuson-Stevens Act **(**MSA) objectives for turtles, as well as MSA objectives for other fish stocks.

The number of observed sea days needed to achieve a 30% CV around bycatch rates from 2012-2016 was derived from Rossman (2007):

$$n_{proj} = (CV_{obs} * \sqrt{n_{obs}}/CV_{proj})^2$$

where n_{proj}= the amount of projected effort (converted to sea days[1]); CV_{obs} = the precision levels around estimated bycatch rates in this analysis; n_{obs}= the observed effort (tons) underlying the bycatch rates; and CV_{proj} = the projected precision levels.

3. RESULTS

3.1 Bycatch Characteristics

NEFOP and ASM observers reported a total of 27 loggerheads, 7 Kemp's ridleys, 2 leatherbacks, and 8 unidentified hard-shelled species in Mid-Atlantic and Georges Bank gillnet gear from 2012-2016 (Table 1; Figure 2). Turtles not identified to species fell from the net before they could be adequately identified or photographed. In addition, 1 Kemp's ridley, 2 greens, and 1 unidentified hard-shelled species were observed inside the sounds in North Carolina but were excluded from the bycatch rate calculations because they were outside the boundaries of the study region (however, these 4 turtles are included in the descriptions below).

3.1.1 Temporal and Spatial Distribution

Most (93%) of the loggerhead interactions occurred between 40ºN and 41.5ºN during June through September. Five Kemp's ridley interactions occurred in this same region during July through November, and 3 interactions occurred around 35ºN, with 1 occurring inside sounds in North Carolina during April. Both green turtle interactions occurred inside North Carolina sounds, 1 in March and the other in September. Both leatherbacks were observed around 40°N in November and December. Unidentified hard-shelled turtle interactions occurred between 35ºN and 41.6ºN from May to September.

3.1.2 Fishing Method

Almost all (96%) of the loggerheads were captured in 11" or 12" mesh size nets catching monkfish (*Lophius americanus)* or skates (*Leucoraja and Raja spp.)*, soaking from 24 to 264 hours. Kemp's ridleys were captured in gillnet mesh sizes ranging from 3.25 – 12" mesh, soaking from 0.2 to 168 hours, and catching skate, monkfish, smooth dogfish (*Mustelus canis*) , Spanish mackerel (*Scomberomorus maculatusa*), and Atlantic menhaden (*Brevoortia tyrannus*). Green turtles were captured in 5" and 3" mesh gear catching southern flounder and shad, soaking for 12 and 24 hours. Leatherbacks were captured in 12" mesh catching monkfish, soaking 72 hours. Unidentified hard-shelled turtle species were captured in gillnet mesh sizes that ranged from 3.5 to 12" mesh, soaking from 0.2 to 196 hours.

3.1.3 Turtle Sizes

Sizes of observed loggerheads (n=11) ranged from 54.0 to 69.0 cm curved carapace length (CCL; i.e., notch to tip) which are sizes considered to be Stage II or Stage III juveniles (sexually immature) (TEWG 2009). Kemp's ridley turtles ranged from 29.5 to 37.0 cm CCL (n = 5 animals), sizes also considered to be juveniles (Bjorndal et al. 2014). Green turtles measured

[1] The conversion from tonnage to sea days used 1.3 mean landed tons/trip, and 1.3 mean days absent/trip, and 1 day absent = 1 sea day. Conversions were based on characteristics of observed trips in 2012 – 2016.

26.0 and 30.0 cm CCL, also juveniles (Bjorndal et al. 2013). Leatherback and unidentified hard-shelled species sizes were not recorded.

3.2 Bycatch Rates

The highest bycatch rate of loggerhead turtles occurred in the southern Mid-Atlantic stratum in large mesh gear during November to June (Figure 3). Though only 1 turtle was observed in this stratum, observed effort was low, leading to a high bycatch rate. Bycatch rates of all other species were lower relative to loggerheads. Mean loggerhead bycatch rates were 10x those of Kemp’s ridley bycatch rates in large mesh gear in the northern Mid-Atlantic from July to October.

3.3 Total Estimated Bycatch

From 2012-2016, total estimated bycatch of sea turtles in sink gillnet gear in the Georges Bank and Mid-Atlantic regions was 705 loggerheads (of which 557 were mortalities) (CV = 0.29, 95% CI over all years: 335-1116), 145 Kemp’s ridleys (115 mortalities) (CV = 0.43, 95% CI over all years: 44-292), 27 leatherbacks (21 mortalities) (CV = 0.71, 95% CI over all years: 0-68), and 112 unidentified hard-shelled turtles (88 mortalities) (CV = 0.37, 95% CI over all years: 64-321) (Table 2). Total estimated loggerhead bycatch was equivalent to 19 adults.

Highest loggerhead bycatch occurred in the northern Mid-Atlantic from July to October in large mesh gear (Figure 4). While this stratum did not have the highest bycatch rate, total estimated bycatch was highest because there was more commercial effort in this stratum compared to others.

3.4 Estimated Bycatch by Managed Fish Species Landed

From 2012 – 2016, VTR trips catching monkfish, skates, or spiny dogfish accounted for 87% of the estimated bycatch of all sea turtles (Table 3). Trips catching monkfish and skate comprised 80% of the estimated loggerhead bycatch, with the majority of these concentrated in the northern Mid-Atlantic stratum during July-October in large mesh (>=7”) gear.

3.5 Estimated Sea Day Needs

A total of 887 sea days per year are needed to achieve a 30% CV precision around loggerhead bycatch rates over Mid-Atlantic and Georges Bank combined strata (Figure 5). Roughly 500 days per year would be needed to achieve a 40% precision and 325 days per year to achieve a 50% precision.

4. DISCUSSION

Unlike previous analyses in which a non-linear regression model was used to estimate turtle bycatch in sink gillnet gear (Murray 2009a; 2013), this analysis uses a ratio-estimator approach. The ratio-estimator approach uses the ratio of observed bycaught turtles per unit fishing effort (the bycatch rate) to estimate total bycaught turtles over all fishing effort in the sampling frame. It is different from a model-based estimator in that the bycatch rate is not estimated as a function of covariates pertaining to gear or environmental characteristics. Total estimated bycatch may not be significantly different using the 2 different approaches (Murray 2007, 2013; Orphanides 2009); however, model-based estimates can be more precise (Cochran, 1977; Orphanides 2009). The precision of the loggerhead bycatch estimate over all strata in this analysis (CV = 0.29) was close to the model-based CVs in previous analyses (CV = 0.20 in Murray 2009a, and CV = 0.26 in Murray 2013), indicating that precision of the estimate was not sacrificed in resorting to a simpler estimation method.

Less than half of the observed loggerhead bycatch had recorded size measurements. The missing measurements occurred when an animal was not brought on board for sampling or when the interaction was observed by an at-sea monitor (33% of observed turtles), who is not required to collect biological information from observed bycatch. As a result of the low sample of measured turtles, less information was available to compute adult equivalent bycatch, which is derived by assigning reproductive values to ages of turtles inferred from curved carapace length. Larger turtles have been observed in gillnet and trawl fisheries in the Mid-Atlantic (Murray 2009, 2013, 2015; Warden 2011). A larger sample of measured turtles including turtles from other strata besides the northern Mid-Atlantic in summer, would have helped provide a more accurate measure of adult equivalents in this analysis.

This analysis reports, for the first time, total estimated bycatch of non-loggerhead turtle species in sink gillnet gear. In past analyses, non-loggerhead species have been excluded because there have been too few observed to support the modeling approach taken in the analysis (Murray 2009a, 2013). Estimates are reported here by using a different approach (a stratified ratio-estimator), though CVs are high for both species (>0.70) in all strata because non-loggerhead species still remain relatively rare bycatch events. Similarly, total loggerhead bycatch was estimated for the Georges Bank region, where loggerheads have not typically been observed in sink gillnet gear. Precision around bycatch rates may improve depending on levels of observer coverage and the abundance and distribution of turtles in the bycatch strata.

While bycatch of Kemp's ridley and green turtles was documented inside North Carolina internal sounds, total bycatch was not estimated inside the sounds for several reasons. First, the stratification used in this analysis was based on characteristics of fisheries operating in oceanside waters; a finer stratification scheme would likely have been warranted for internal waters because the fisheries operate differently there, and turtles are not present in the sounds in some winter months (Epperly et al. 1995). Second, total bycatch estimates allocated to managed fish species inside North Carolina sounds would not have been accurate because species regulated in state waters are not well represented in VTR landings. Lastly, the NCDMF periodically analyzes and estimates bycatch of Kemp's ridley and green turtles in the sounds for incidental take permits (NCDMF 2013).

In this analysis, estimated turtle bycatch in each stratum is apportioned across catch of managed fish species to support ESA Section 7 consultations for various Fishery Management Plans (FMPs). The approach both recognizes that mesh size, season, and region are correlated with bycatch rates rather than with the fish species caught or targeted in a net, and it also accounts for the multispecies nature of kept catch. However, estimates allocated to managed fish species will reflect the composition of catch as reported in VTR data. If non-federally regulated fish species are sold and the vessel does not possess a permit for a federally regulated species, a VTR logbook record is not required to be filed (Murray 2009b). If this or other factors result in some species being underrepresented in the VTR data, estimated bycatch will be underestimated in these fisheries and possibly overestimated in other fisheries.

Uncertainty around bycatch rates in this analysis have been used to estimate sea day needs in future years to increase or maintain precision around loggerhead bycatch rates. Projected sea-day needs for loggerheads in this analysis are lower than those projected in previous years mainly because of the different approach used to project sea-day needs (see Murray 2012). The approach taken here is preferred over the previous approach (which was designed around the CVs of turtle bycatch allocated to managed fish species) because it is linked directly to the CVs of the stratified turtle bycatch rates. Over both Georges Bank and Mid-Atlantic regions, a minimum of 887 days would be needed to monitor loggerhead bycatch with 30% CV precision. The rate of increase in CV precision per sea day appears to diminish as sea-day coverage increases beyond a certain point.

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Table 1. Observed sea turtle bycatch by analytical strata and observer coverage (% of trips) in sink gillnet gear used in this analysis, 2012-2016. *Caretta caretta* [Cc] = loggerhead; *Lepidochelys kempii* [Lk] = Kemp's ridley; *Dermochelys coriacea* [Dc] = leatherback; Unid = unidentified species.

Region	Season	Mesh Group	Obs Cc	Obs Lk	Obs Dc	Obs Unid	Obs trips	VTR trips	% Cov
Georges Bank	July – Oct	>= 7"	3	1	0	1	747	4109	18%
Georges Bank	July – Oct	< 7"	0	0	0	0	424	1910	22%
Georges Bank	Nov - Jun	>= 7"	0	0	0	0	139	834	17%
Georges Bank	Nov – Jun	< 7"	0	0	0	0	64	347	18%
Mid-Atlantic North	Jul – Oct	>= 7"	18	2	0	3	120	2882	4%
Mid-Atlantic North	July – Oct	< 7"	0	0	0	0	445	8023	6%
Mid-Atlantic North	Nov – Jun	>= 7"	4	2	2	2	1260	17690	7%
Mid-Atlantic North	Nov – Jun	< 7"	0	0	0	0	554	9258	6%
Mid-Atlantic South	Jul – Oct	>= 7"	0	0	0	0	0	3	0%
Mid-Atlantic South	July – Oct	< 7"	1	0	0	0	241	794	30%
Mid-Atlantic South	Nov – Jun	>= 7"	1	0	0	0	8	76	11%
Mid-Atlantic South	Nov - Jun	< 7"	0	2	0	2	900	5607	16%
Total			27	7	2	8	4902	51533	10%

Table 2. Total estimated sea turtle bycatch (Coefficient of Variation, 95% Confidence Intervals) in sink gillnet gear, 2012-2016. *Caretta caretta* [Cc] = loggerhead; *Lepidochelys kempii* [Lk] = Kemp's ridley; *Dermochelys coriacea* [Dc] = leatherback; Unid = unidentified species.

Region	Season	Mesh Group	Est. Cc	Est. Lk	Est. Dc	Est. Unid.
Georges Bank	Jul–Oct	>= 7”	20 (0.67) (0–52)	7 (0.93) (0-21)	0	6 (0.88) (0-21)
Georges Bank	Jul–Oct	< 7”	0	0	0	0
Georges Bank	Nov–Jun	>= 7”	0	0	0	0
Georges Bank	Nov–Jun	< 7”	0	0	0	0
Mid-Atlantic North	Jul–Oct	>= 7”	457 (0.35) (181–806)	51 (0.71) (0-133)	0	67 (0.56) (0-176)
Mid-Atlantic North	Jul–Oct	< 7”	0	0	0	0
Mid-Atlantic North	Nov–Jun	>= 7”	55 (0.61) (0-120)	27 (0.70) (0-68)	27 (0.71) (0-68)	22 (0.71) (0-68)
Mid-Atlantic North	Nov–Jun	< 7”	0	0	0	0
Mid-Atlantic South	Jul–Oct	>= 7”	0	0	0	0
Mid-Atlantic South	Jul–Oct	< 7”	65 (1.02) (0-225)	0	0	0
Mid-Atlantic South	Nov–Jun	>= 7”	109 (0.94) (0-345)	0	0	0
Mid-Atlantic South	Nov–Jun	< 7”ou40	0	60 (0.71) (0-169)	0	16 (0.68) (0-169)
Total			705 (0.29) (335-1116)	145 (0.43) (44-292)	27 (0.71) (0-68)	112 (0.37) (64-321)
5 year annual average			141 (67-223)	29 (9-58)	5 (0-14)	22 (13-64)

Table 3. Estimates of loggerhead (*Caretta caretta* [Cc]), Kemp's ridley (*Lepidochelys kempii* [Lk]), Leatherback (*Dermochelys coriacea* [Dc]), and unidentified hard-shelled (Unk) turtle bycatch by managed species landed in Georges Bank and Mid-Atlantic gillnet gear, 2012-2016. Only those managed species with estimated turtle bycatch are reported. Managed species listed are: albacore tuna (*Thunnus alalunga*), bluefish (*Pomatomus saltatrix*), Atlantic cod (*Gadus morhua*), Atlantic croaker (*Micropogonias undulates*), king mackerel (*Scomberomorus cavalla*), Atlantic menhaden (*Brevoortia tyrannus),* monkfish *(Lophius americanus),* scup (*Stenotomus chrysops*), sharp-nosed shark (*Rhizoprionodon terraenovae*), skates (*Leucoraja and Raja* spp.), smooth dogfish (*mustelus canis*), Spanish mackerel (*Scomberomorus maculatusa*), spot (*Leiostomus xanthurus*), striped bass (*Morone saxatilis*), and summer flounder (*Paralichthys dentatus*).

Managed Species	Cc	Lk	Dc	Unk	Total	% of Total
Albacore tuna	3	0	0	0	3	<1%
Bluefish	10	7	0	3	20	2%
Cod	1	0	0	0	1	<1%
Croaker	30	19	0	5	54	5%
King mackerel	2	0	0	0	2	<1%
Menhaden	0	1	0	0	1	<1%
Monkfish	217	25	11	27	280	28%
Scup	2	0	0	0	2	<1%
Sharp-nosed shark	1	0	0	0	1	<1%
Skates[2]	345	52	15	58	470	48%
Smooth dogfish	2	2	0	1	5	<1%
Spanish mackerel	8	0	0	0	8	<1%
Spiny dogfish	52	38	1	17	108	11%
Spot	17	0	0	0	17	2%
Striped bass	10	0	0	0	10	1%
Summer flounder	5	1	0	1	7	<1%
Total	**705**	**145**	**27**	**112**	**989**	

[2] While all species of skates are grouped together for this group, 52% of skate catch was recorded as generic "skate," and 35% was recorded as winter skate.

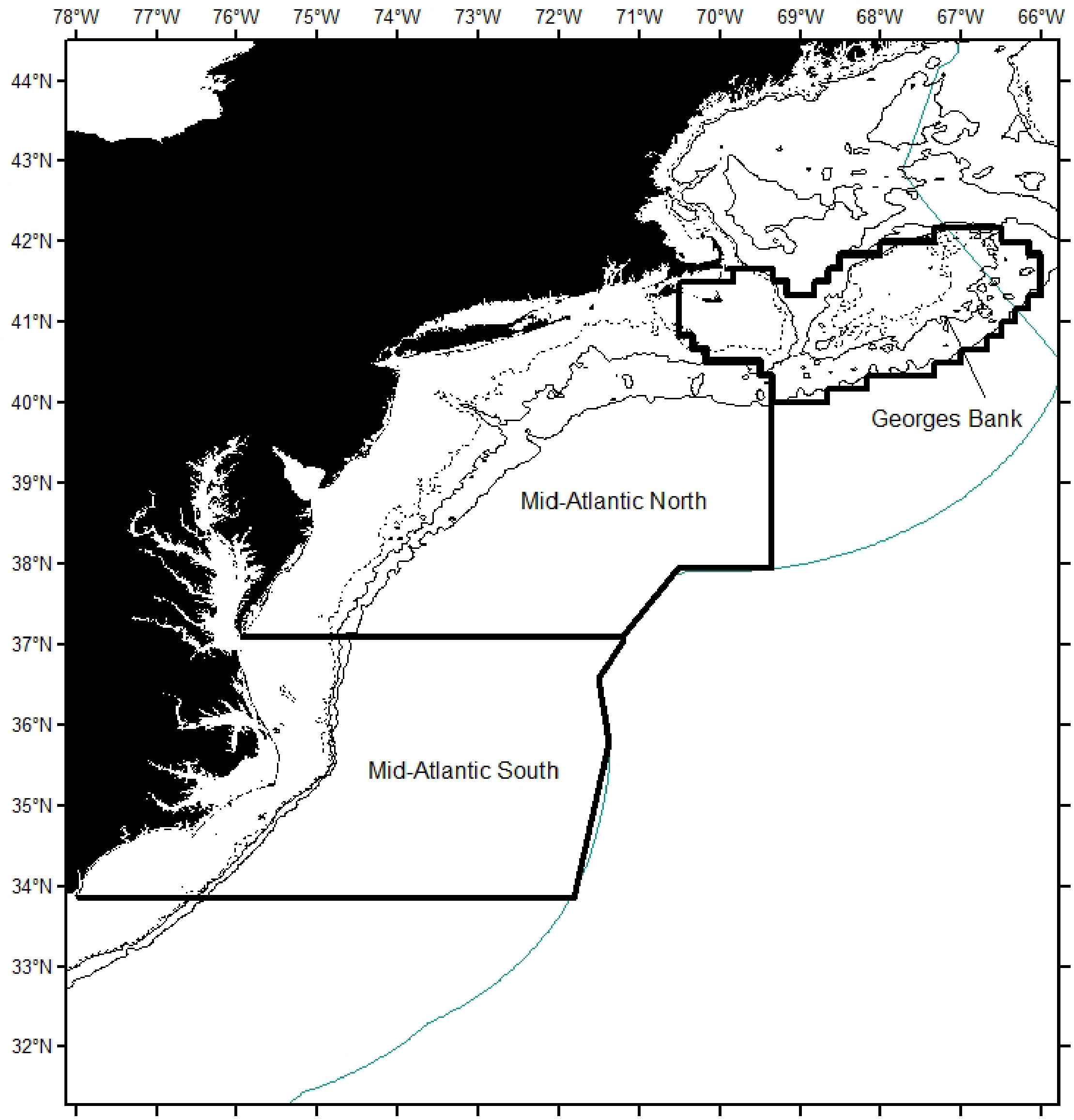


Figure 1. Spatial strata used in the analysis of sea turtle bycatch rates in sink gillnet gear, 2012-2016. Regions were further stratified by season (July-Oct; Nov-June) and mesh group (<7" and >=7").

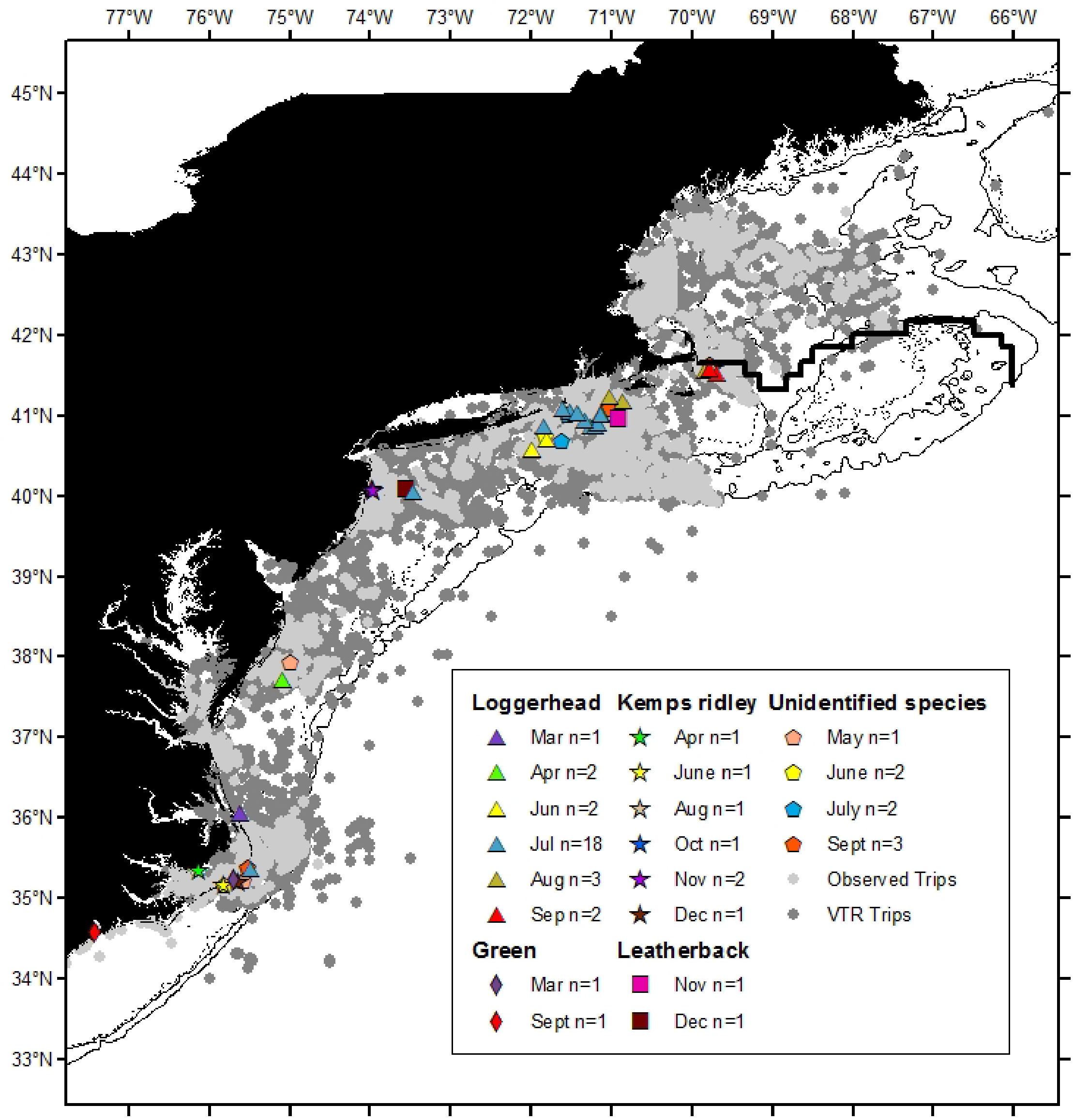
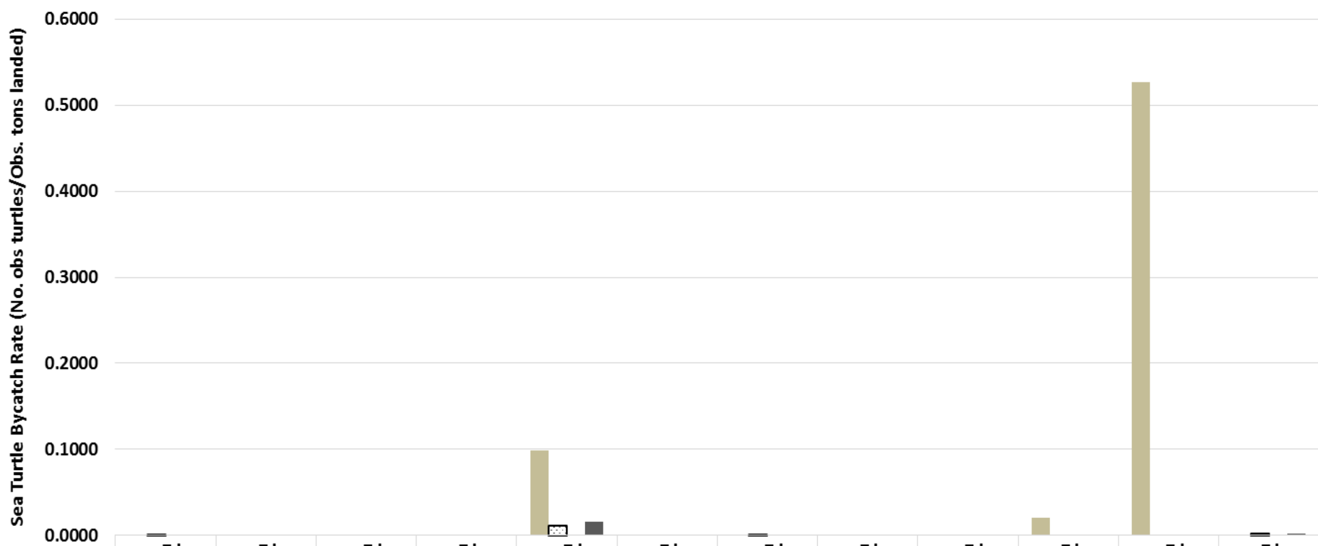


Figure 2. Observed turtle bycatch and commercial fishing trips using sink gillnet gear, 2012-2016. The solid black line depicts the northern boundary of the Georges Bank Ecological Production Unit as well as the northern boundary of the study region. Turtle species include: loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*).



	GB				MAN				MAS			
	July-Oct		Nov-June		July-Oct		Nov-June		July-Oct		Nov-June	
	>= 7 in	< 7 in	>= 7 in	< 7 in	>= 7 in	< 7 in	>= 7 in	< 7 in	>= 7 in	< 7 in	>= 7 in	< 7 in
Cc rates	0.0015	0.0000	0.0000	0.0000	0.0986	0.0000	0.0014	0.0000	0.0000	0.0204	0.5263	0.0000
Lk rates	0.0005	0.0000	0.0000	0.0000	0.0110	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0020
Dc rates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
Unk rates	0.0005	0.0000	0.0000	0.0000	0.0164	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0020

Figure 3. Sea turtle bycatch rates in Georges Bank (GB) and Mid-Atlantic North (MAN) and South (MAS) gillnet gear, 2012-2016. *Caretta caretta* [Cc] = loggerhead; *Lepidochelys kempii* [Lk] = Kemp's ridley; *Dermochelys coriacea* [Dc] = leatherback; Unk = Unidentified species.

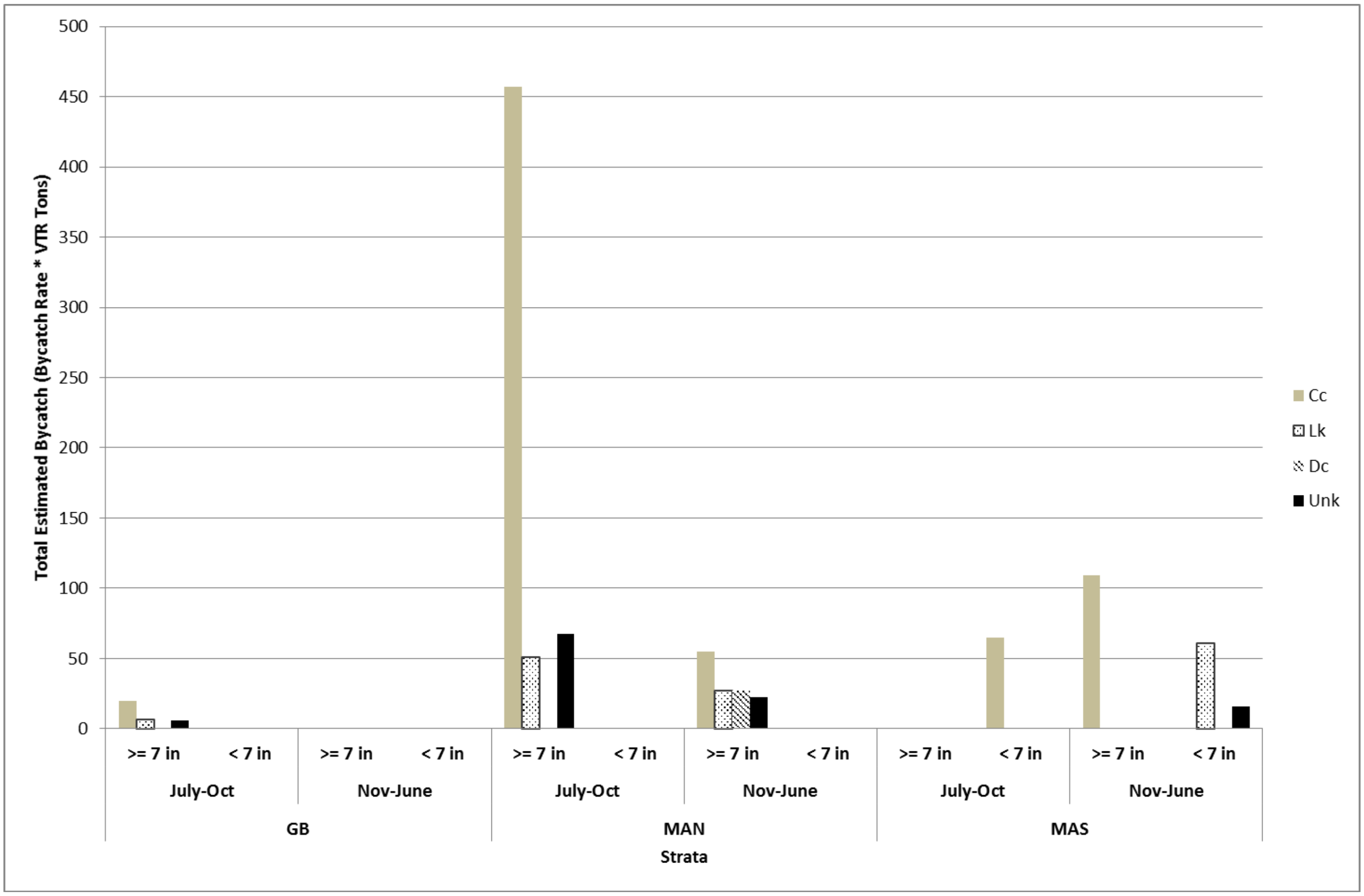


Figure 4. Total estimated sea turtle bycatch in Georges Bank (GB), Mid-Atlantic North (MAN), and South (MAS) gillnet gear, 2012-2016. *Caretta caretta* [Cc] = loggerhead; *Lepidochelys kempii* [Lk] = Kemp's ridley; *Dermochelys coriacea* [Dc] = leatherback; Unk = Unidentified species

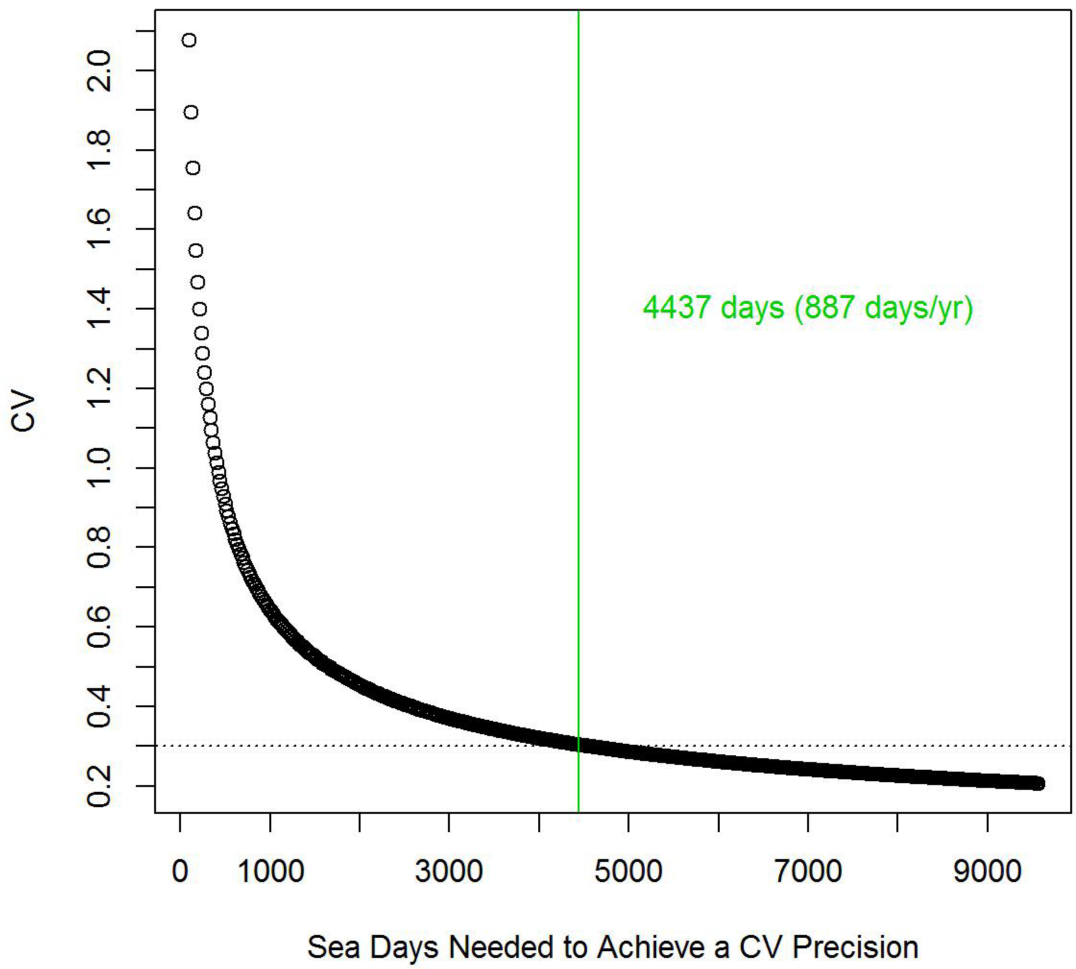


Figure 5. Estimated sea days needed to achieve a coefficient of variation (CV) precision level around loggerhead bycatch rates in sink gillnet gear. To achieve a 30% CV precision, 887 sea days/year (4437 sea days over 5 years) would be needed throughout Mid-Atlantic and Georges Bank combined strata, based on loggerhead (*Caretta caretta*) bycatch rates in gillnet gear from 2012-2016.

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