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Estimated Loggerhead (*Caretta caretta*) Interactions in the Mid-Atlantic Sea Scallop Dredge Fishery, 2015-2019

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ABSTRACT

This paper reports total loggerhead (*Caretta caretta*) turtle interactions, adult equivalent interactions, and mortality in the Atlantic sea scallop (*Placopecten magellanicus*) fishery from 2015 to 2019 by using data collected by the Northeast Fisheries Observer Program. Most vessels fishing with dredges in the Atlantic sea scallop fishery are required to use chain mats and turtle deflector dredges when fishing west of 71°W from May 1 to November 30. These gear modifications are designed to exclude turtles from being captured in the dredge bag or cutting bar frame, rendering many interactions unobservable. From 2015 to 2019, only 4 loggerhead interactions were observed in sea scallop dredge gear when an observer was on watch. To estimate loggerhead interaction rates in the fishery, observer data from 2015 to 2019 were pooled with data from 2001 to 2014. Rates from the pooled time period were then applied to vessel trip report fishing effort from 2015 to 2019 to estimate observable and unobservable (yet quantifiable interactions). Interaction rates were estimated with a ratio estimator, where rates were stratified by ecological production unit, season, and whether dredges were modified (having a chain mat and/or a turtle deflector dredges) or standard (no chain mat or turtle deflector dredge). From 2015 to 2019, 155 loggerheads per year (CV = 0.27, 95% CI: 99-219) interacted with fishing gear. Of these interactions, 53 were lethal. The 155 interactions equate to 31 adult equivalents per year and 11 adult equivalent mortalities. These average interaction estimates include annual observable turtle interactions, plus unobserved, quantifiable interactions.

INTRODUCTION

The US Mid-Atlantic region is important foraging habitat for the Northwest Atlantic distinct population segment of loggerhead sea turtle (*Caretta caretta*) in summer months (Griffin et al. 2013; Patel et al. 2016; Winton et al. 2018). This region is also prime habitat for Atlantic sea scallops (*Placopecten magellanicus*), and interactions between sea scallop dredge fishing and both loggerhead and Kemp's ridley (*Lepidochelys kempii*) turtles have been documented for several years (Murray 2011, 2015). All sea turtles found in US waters are protected under the federal Endangered Species Act (ESA). Any interaction between a sea turtle and commercial fishing gear is considered a "take" under the act, defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA 1973).

To help minimize the impact of fishery interactions on sea turtles in the Atlantic sea scallop dredge fishery, dredge gear modifications are required at certain times and in certain areas. Chain mats and turtle deflector dredges (TDDs) must be used when fishing for sea scallops in waters west of 71° W longitude, from the shoreline to the outer boundary of the Exclusive Economic Zone, from May 1 to November 30 (FR 2015).

A properly configured chain mat consists of a grid of horizontal and vertical chains connected together in a specific form to prevent turtles from entering the dredge bag (CFR 2021). The TDD consists of specific modifications to the dredge frame (FR 2012) to allow turtles to go up and over the dredge frame rather than be caught underneath it. Together, the use of chain mats and TDDs increases the conservation benefit to turtles. Chain mats help reduce the impact of gear interactions in the water column, while the TDD helps reduce the impact of gear interactions on the sea bottom.

The chain mat requirements apply to any vessel with a sea scallop dredge and a federal Atlantic sea scallop fishery permit. The TDD requirements apply to any limited access sea scallop vessel using a dredge regardless of dredge size or vessel permit category or to any limited access

individual fishing quota sea scallop vessel fishing with a dredge width of 10.5 ft (3.2 m) or greater. Chain mats have been required in the fishery since 25 September 2006; TDDs have been required since 1 May 2013. Since the implementation of the chain mat and TDD regulations, the number of observed turtles captured in sea scallop dredge gear has decreased (Murray 2015).

While the chain mat and TDD are expected to reduce impacts to turtles, they do not eliminate takes because subsurface interactions with the gear could still be occurring. Turtles could come in contact with the gear but are not brought to the surface where they can be observed, as a result of the gear modifications. Some of these unobservable interactions can be quantified (Warden and Murray 2011), and in this paper these unobservable and quantifiable interactions are called "inferred interactions."

To help assess the impact of sea scallop dredge fishing activity on turtle populations, information is needed on the anticipated magnitude of sea turtle interactions in commercial dredge fishing gear. This analysis estimates the total number of loggerhead interactions (observable and inferred) and mortalities that occurred in the Atlantic sea scallop dredge fishery from 2015 to 2019. Estimated interactions and mortalities are also expressed in terms of adult-equivalent losses. Adult equivalents are the number of estimated turtle mortalities converted into the number of adults that could have been added to the population had they survived and reproduced. Compared to individual losses, monitoring adult-equivalent losses from fisheries interactions can be a more informative metric to assess population-level impacts (Haas 2010; Warden et al. 2015).

METHODS

The study region was defined by the boundaries of the Mid-Atlantic ecological production unit (Ecosystems Assessment Program 2012; Figure 1), which is characterized by distinct patterns in oceanographic properties, fish distributions, and primary production. Within the Mid-Atlantic, loggerhead interaction rates were further stratified by season (May–December) and whether dredges were modified (equipped with a chain mat and/or TDD) or standard (not modified). Dredges with chain mats have a different observed interaction rate than standard dredges (Murray 2011). Dredges with chain mats were grouped with dredges that have a TDD because there is no information on interaction rates with dredges that only have TDDs (Murray 2015), and most (80%) of the observed hauls with modified dredges in the Mid-Atlantic ecological production unit had both a chain mat and a TDD.

Only 4 loggerhead interactions were observed from 2015 to 2019, so observer data from 2001 to 2014 were pooled with data collected from 2015 to 2019 to derive sea turtle interaction rates. Interaction rates were not estimated for Kemp's ridley turtles, because only 2 Kemp's ridley turtles were observed in the Mid-Atlantic (and 1 on Georges Bank) in the entire pooled time series. Loggerhead interaction rates were applied to commercial dredge fishing effort from 2015 to 2019 to estimate the total number of loggerhead interactions from 2015 to 2019.

Data Sources

Observer Data

From May to December, 2015–2019, Northeast Fisheries Science Center fisheries observers monitored 67,402 fishing hours in the Mid-Atlantic aboard commercial sea scallop dredge vessels, which was roughly 6% of total dredge fishing effort (Table 1). "Fishing hour" is the total number of hours a dredge fishes in the water. Dredge fishing hours per haul were calculated from observer data as:

Dredge fishing hours per haul = number of dredges * average haul duration

Observable interaction rates were estimated based on turtles reported via standard Northeast Fisheries Observer Program (NEFOP) sampling protocols when an observer was on watch (i.e., systematically collecting data on the haul characteristics, the catch, and details of any protected species interaction). Observable interaction rates were based on turtles captured in or on the dredge gear, or observed interacting with the gear. Observers may collect data opportunistically when they are off watch, but these data are not used in the calculation of interaction rates because the fraction of off-watch interactions that are reported is unknown.

Commercial Data

Vessel trip reports (VTRs) completed by commercial sea scallop fishermen from 2015 to 2019 provided a measure of total fishing effort. Effort from VTRs was considered a census of sea scallop dredge fishing activity because VTR reporting is mandatory in the fishery and enforced via vessel monitoring systems. Dredge fishing hours per trip (t) were calculated from VTRs as:

$$\text{Dredge hours}_t = \text{number of dredges}_t \text{ x average haul duration x number of hauls}_t$$

Trips were coded for chain mat or TDD usage based on sea scallop fishery regulations rather than the required VTR gear code ("DSC" for chain mats and "DTC" or "DTS" for TDDs) because an examination of VTRs with matching observer reports revealed that some trips with modified dredges were still using the standard dredge code ("DRS"). Therefore, this analysis assumed 100% compliance with the chain mat and TDD regulations. Chain mats are required on all sea scallop dredge vessels fishing west of 71°W from 1 May to 30 November. The TDDs are required on all sea scallop dredge vessels fishing with a limited access (LA) permit fishing west of 71°W from 1 May to 30 November, and on vessels fishing under limited access general category (LAGC) permits in this area and time with a dredge width greater than 10.5 ft.

Because VTRs do not record permit type, the amount of landed sea scallops was used as a proxy for permit type. Vessels fishing with a LAGC permit are limited to catching 600 lb sea scallops plus observer compensation (see Amendment 15 to the Atlantic Sea Scallop Fishery Management Plan[1]), which has varied over the years from 150 to 400 lb/trip. Therefore, all dredge trips were coded as using a chain mat if they fished west of 71°W from 1 May to 30 November. Vessels were coded as having both a chain mat and TDD if they fished in this time and area and captured more than 1,000 lb of sea scallop meat (LA vessels), or captured more than 1,000 lb sea scallop meat (LAGC vessels) and fished a dredge greater than 10.5 ft. Based on these criteria, 70% of trips fishing in the Mid-Atlantic used modified dredges. Had VTR codes been used for the criteria, the reported percentage would be 27%.

Loggerhead Interaction Rates

Interaction rates were stratified based on fishing practices found to be historically correlated with loggerhead interaction rates and sea scallop dredge gear (use of a chain mat or

[1] https://www.nefmc.org/library/amendment-15

TDD) (Murray 2011, 2015) and the seasonal occurrence (May–December) of loggerheads in the Mid-Atlantic (Winton et al. 2018). Within the May–December period, rates were stratified into whether vessels used standard dredges or modified dredges. Because some form of modified dredge has been required from May to November in the Mid-Atlantic dredge fishery since 2006, the interaction rate for standard dredges is mostly informed by conditions in the earlier part of the 2001–2019 time series.

Within each stratum (j), observable interaction rates (R) were defined as:

$$R_j = \sum_{i=1}^{n} \frac{observed\ turtles_j}{observed\ dredge\ hours_j}$$

where n = the number of observed NEFOP hauls.

Bootstrap resampling was used to estimate uncertainty (coefficient of variation [CV] and confidence intervals [CIs]) around interaction rates within each stratum, with trips as the resampling unit (Orphanides and Hatch 2017). Bootstrap replicates were generated by resampling trips with replacement 1,000 times from the original observer dataset, and then bycatch rates within each stratum were computed for each replicate. The 95% CIs for the bycatch rates were computed from the upper 97.5% and lower 2.5% quartiles of the bootstrap replicates. To combine the modified (m) and standard (s) dredge CVs, an overall CV was calculated as:

$$\text{Overall CV} = \sqrt{\frac{CV_m^2 + CV_s^2}{2}}$$

Total Interactions

Observable interaction rates within each stratum were applied to VTR trip effort to estimate total observable loggerhead interactions. Inferred interactions were estimated by applying the interaction rate in standard dredges to dredges with chain mats and TDDs (Murray 2011, 2015). This estimate assumes that interactions between turtles and dredges in times and areas where they overlap continue to occur below the surface at the same rate as when chain mats and TDDs were not required, but that these modifications prevent the turtles from being captured and subsequently seen by an observer. Total interactions were the sum of observable and inferred interactions.

Mortality Rates

Different mortality rates were applied to the total estimated observable and inferred interactions. A 66% mortality rate was applied to estimated observable interactions, per evaluations by the NMFS Northeast Sea Turtle Injury Workgroup (Upite et al. 2018) for data from 2006 to 2019. This time series of evaluations is the longest currently available. A 28% mortality rate was applied to inferred interactions, based on experimental trials (Smolowitz et al. 2010) and the latest sea scallop biological opinion (NMFS 2012).

Adult Equivalency

Adult-equivalent loggerhead interactions were estimated based on the methods in Murray (2011, 2015). Observed loggerheads from 2001 to 2019 were grouped into size classes based on 6 loggerhead life stages (TEWG 2009), and reproductive values (RVs) were assigned to each respective stage class based on Wallace et al. (2008). These stage classes (curved carapace length [CCL] sizes, RV values) were as follows:

- Stage I (<= 16.2 cm CCL, 0.002)
- Stage II (> 16.21 – 60.45 cm CCL, 0.008)
- Stage III (> 60.45 cm – 75.72 cm CCL, 0.040)
- Stage IVa (> 75.72 – 88.61 cm CCL , 0.124)
- Stage IVb (> 88.61 – 101.5 cm CCL, 0.547)
- Stage V (> 101.5 cm CCL, 1.0).

The number of estimated adult equivalent interactions (AEI) with loggerheads over all 6 life stages and all 5 years (2015-2019) was calculated as:

$$\text{AEI} = \sum_{j=1}^{5} \sum_{i=1}^{6} T_j * P_i * RV_i$$

where: T = total estimated loggerhead interactions in dredge gear in year *j*

P = the proportion of loggerheads observed in life stage *i,* based on all turtles observed from 2001 to 2019

RV_i = the reproductive value for life stage *i*.

Adult equivalent mortality (AEM) was computed by using the same mortality rates as those for estimated interactions.

RESULTS

Observed Loggerhead Interactions

From 2015 to 2019, observers recorded 4 loggerhead interactions in sea scallop dredge gear (Table 2; Figure 1). Three additional loggerheads and an unidentified turtle species were observed but were removed from the analysis because these interactions could either not be attributed to the dredge fishing event, or the interaction occurred while the observer was off-watch. One loggerhead was captured in a standard dredge, the other 3 turtles were captured in dredges with a chain mat or TDD, and found inside the chain bag. Some of the chain mat gear was not properly configured and may have contributed to the turtles being captured (Table 2). Two Kemp's ridley turtles were also observed being captured in modified gear. All turtles were observed in the Mid-Atlantic region, from July to December.

Loggerhead Interaction Rates

Loggerhead interactions in sea scallop dredge gear have neither been observed outside of the Mid-Atlantic nor from January to April, so interaction rates are only reported here for 2 different dredge types within the Mid-Atlantic from May to December (Table 3). In the expanded sampling frame from 2001 to 2019, 45 turtles were observed in standard dredges over 74,187

hours, for a rate of 0.0006 (CV = 0.18) turtles per fishing hour. In dredges equipped with a chain mat or TDD, 10 turtles were observed over 161,090 hours, for a rate of 0.00006 (CV = 0.33) turtles per fishing hour. Therefore, the observable interaction rate in modified dredges was roughly one-tenth the interaction rate in standard dredges.

Total Interactions, Adult Equivalency, and Mortality

From 2015 to 2019, the average number of total observable and inferred interactions was 155 turtles/year (CV = 0.27, 95% CI = 99–219), of which 53 were estimated to result in mortality (Table 4). The total number of interactions is equivalent to 31 adults and 11 adult mortalities.

DISCUSSION

The expanded sampling frame in this analysis increased the sample size of loggerhead turtle interaction events amongst standard and modified dredges, such that interaction rates could be computed between the 2 different designs. In the last analysis of loggerhead interactions in dredge gear from 2009 to 2014 (Murray 2015), there was only 1 take after 2009 and no observed takes of turtles in dredges with TDDs. Despite pooling data with observer data back to 2001 in the last analysis, interaction rates were still poorly estimated because there were not enough data to estimate differences in interaction rates after 2009. As a result there was high uncertainty around estimated bycatch, and annual CVs were close to or exceeded 1.0 in some cases (Murray 2015).

The average annual number of estimated loggerhead interactions from 2009 to 2014 was 22 loggerheads, compared with 155 from 2015 to 2019. The estimated number of interactions in 2015–2019 is higher than in 2009–2014 for a number of reasons. In this analysis, rates are computed without respect to year over a 19-year time period. In the 2009–2014 analysis, year was included as a variable in the interaction rate model to help account for changes in dredge types used in the Mid-Atlantic after 2008. As a result, this analysis borrows information from the earlier part of the time series (2001–2008) to inform the interaction rate in standard style dredges. This rate was used to compute the number of inferred interactions, so there is a larger number of inferred interactions than estimated from 2009 to 2014.

Pooling data across years improves (lowers) the CV around the interaction rates because there are more takes to estimate the rates; however, it assumes that the interaction rates between loggerheads and sea scallop dredge gear are constant across years. Observer coverage has been steady (~3–6%) since 2001, and there is no evidence to suggest that loggerhead abundance has changed in the Mid-Atlantic since 2001 (Ceriani et al. 2019). However, the density of loggerheads may change from year to year on the Mid-Atlantic foraging grounds (Ceriani et al. 2017), which could cause interannual variation in observed bycatch rates.

Estimated interactions may be also be higher because there was more fishing effort on average in the Mid-Atlantic in 2015–2019 than in 2009–2014. There were roughly 50,000 more dredge hours fished on average in the Mid-Atlantic region[2] from May to December from 2015 to 2019 compared with 2009–2014. In particular, dredge fishing effort in 2016 was the highest since 2009, a result of annual fishing specifications that pushed effort into the Mid-Atlantic, among other factors.

[2] As defined by the boundaries of the 2009-2014 analysis, which was west of 71°W and south of 42°N

Estimated interactions could be higher in 2015–2019 than in 2009–2014 because the boundaries of the "Mid-Atlantic" were slightly enlarged in this analysis. I chose the new boundary so that the study region is defined by ecological properties rather than regulatory lines (i.e., turtle chain mat rule) and is consistent across other analyses of gear types (i.e., gillnets, bottom trawls) interacting with loggerheads in the region (Murray 2020, 2018). However, the change in the geographic region did not increase the number of interactions significantly because there was not much more fishing effort in the enlarged boundary. Had the previous bounds of the Mid-Atlantic been used (i.e., west of 71°W and south of 42°N), the number of estimated interactions in 2015–2019 would have decreased by 3 animals.

The method used in this analysis may also have changed the estimated interactions. A stratified ratio estimator was used in this analysis to compute observed interaction rates, whereas in previous years a generalized additive model (GAM) was used to estimate rates as a function of gear and environmental covariates (Murray 2011, 2015).

Ratio estimators are computationally simple with general application to many sampling designs (Cochran 1977) and can yield results similar to those using GAMs 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). To validate this approach, both a GLM and a GAM were also used to estimate interaction rates in this analysis. The GLM, which specified loggerhead interaction rates in the Mid-Atlantic from May to December as a function of gear modifications, yielded the same results as did the ratio estimator. The GAM specified loggerhead interaction rates as a function of sea surface temperature (SST), depth, and gear modifications, the same model used in (Murray 2011). The GAM resulted in an average annual increase in the total number of estimated loggerheads from 2015 to 2019 by 30 animals and was within the 95% confidence limits of the number of interactions predicted by the ratio estimator. Therefore, the factors discussed here likely influenced the estimated number of interactions from 2015 to 2019 compared to 2009 to 2014, rather than the choice to use a ratio estimator.

Observable interactions remain low in the sea scallop dredge fishery (25 on average from 2015 to 2019) because the chain mat and deflector dredge reduce the likelihood that turtles are captured and brought on board. While subsurface interactions are estimated to still be occurring, the impact to turtles is reduced because the mortality rate of modified dredges (28%) is estimated to be lower than the observable mortality rate (66%). The average annual mortality of loggerheads from 2015 to 2019 was 54, but would have been almost double that (107) without dredge modifications.

Continued outreach is needed to encourage fishermen to record the appropriate gear code on VTR fishing logs. This analysis coded VTR trips as using modified gear based on regulatory requirements, rather than using the prescribed gear codes which appeared to be underutilized, and assumed 100% compliance. As a result, significantly more effort was coded as having modified dredge gear, which then influenced the total number of estimated interactions. Accurate recording of the different dredge gear codes ("DSC" for chain mats, "DTS" for deflector dredges, or "DTC" for both chain mat and deflector dredges) will help improve the estimation process.

REFERENCES CITED

Ceriani SA, Casale P, Brost M, Leone EH, Witherington BE. 2019. Conservation implications of sea turtle nesting trends: elusive recovery of a globally important loggerhead population. Ecosphere 10(11):e02936. 10.1002/ ecs2.2936.

Ceriani SA, Weishampel JF, Ehrhart LM, Mansfield KL, Wunder MB. 2017. Foraging and recruitment hotspot dynamics for the largest Atlantic loggerhead turtle rookery. Scientific Reports 7: 16894 | DOI:10.1038/s41598-017-17206-3.

CFR. 2021. Exceptions to prohibitions relating to sea turtles. 50 C.F.R. Sect. 223:206.

Cochran WG. 1977. Sampling techniques (3rd ed.). New York: John Wiley & Sons. 448p.

Ecosystem Assessment Report 2012. Ecosystem status report for the northeast shelf large marine ecosystem -2011. U.S. Dept Commer, Northeast Fisheries Science Center Reference Document. 12-07; 32 p.

ESA. 1973. Endangered Species Act of 1973, Pub. L. No. 93-205, 87 Stat. 884 (Dec. 28, 1973).

FR. 2015. Framework adjustment 26 to Atlantic sea scallop and multispecies fishery management plans. Fed Regist. 80(76): 22119-22135.

FR. 2012. Framework adjustment 23 to the Atlantic sea scallop fishery management plan. Fed Regist. 77(67):20728-20742.

Griffin DB, Murphy SR, Frick MG, Broderick AC, Coker JW, Coyne MS, Dodd MG, Godfrey MH, Godley BJ, Hawkes LA, Murphy TM, Williams KL, Witt MJ. 2013. Foraging habitats and migration corridors utilized by a recovering subpopulation of adult female loggerhead sea turtles: implications for conservation. Mar Biol 160:3071–3086.

Haas HL. 2010. Using observed interactions between sea turtles and commercial bottom-trawling vessels to evaluate the conservation value of trawl gear modifications. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2: 263−276.

Murray KT. 2007. Estimated bycatch of loggerhead sea turtles (*Caretta caretta*) in U.S. Mid-Atlantic scallop trawl gear, 2004-2005, and in sea scallop dredge gear, 2005. U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc. 07-04; 30 p.

Murray KT. 2011. Interactions between sea turtles and dredge gear in the U.S. sea scallop (*Placopecten magellanicus*) fishery, 2001-2008. Fisheries Research 107:137-146.

Murray KT. 2013. Estimated loggerhead and unidentified hard-shelled turtle interactions in Mid-Atlantic sink gillnet gear, 2007-2011. US Dept Commer, NOAA Tech. Memo NMFS-NE-225; 20p

Murray KT. 2015. Estimated loggerhead (*Caretta caretta*) interactions in the Mid-Atlantic scallop dredge fishery, 2009-2014. Northeast Fish Sci Cent Ref Doc. 15-20. 15 p. https://doi.org/10.7289/V5GT5K5W

Murray KT. 2018. Estimated bycatch of sea turtles in sink gillnet gear. NOAA Technical Memorandum, NMFS-NE-242. 26p.

Murray KT. 2020. Estimated magnitude of sea turtle interactions and mortality in US bottom trawl gear, 2014-2018. NOAA Technical Memorandum, NMFS-NE-260. 24p.

National Marine Fisheries Service (NMFS). 2012. Endangered Species Act (ESA) Section 7 Consultation on the Atlantic Sea Scallop Fishery Management Plan. Consultation No. F/NER/2012/01461. Greater Atlantic Regional Fisheries Organization. July 12, 2012.

Orphanides CD. 2009. Protected species bycatch estimating approaches: estimating harbor porpoise bycatch in U. S. northwestern Atlantic gillnet fisheries. J Northw Atl Fish Sci 42:55–76.

Orphanides C, Hatch J. 2017. Estimates of cetacean and pinniped bycatch in the 2015 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc 17-18; 21 p.

Patel SH, Dodge KL, Haas HL Smolowitz RJ. 2016. Videography reveals in-water behavior of loggerhead turtles (*Caretta caretta*) at a foraging ground. Front Mar Sci 3:254.

Smolowitz R, Haas H, Milliken HO, Weeks M, Matzen E. 2010. Using sea turtle carcasses to assess the conservation potential of a turtle excluder device. North American Journal of Fisheries Management, 30:993-1000.

Turtle Expert Working Group (TEWG) 2009. As assessment of the loggerhead turtle population in the Western North Atlantic Ocean. NOAA Technical Memorandum NMFS-SEFSC-575, 131p.

Upite CM, Murray KT, Stacy BM, Weeks SE. 2018. Post-interaction Mortality Determinations for Sea Turtles in US Northeast and Mid-Atlantic Fishing Gear, 2011-2015. US Dept Commer, NOAA Tech Memo NMFS-NE-248.

Wallace BP, Heppell SS, Lewison RL, Kelez S, Crowder LB. 2008. Impacts of fisheries bycatch on loggerhead turtles worldwide inferred from reproductive value analyses. Journal of Applied Ecology, 45: 1076-1085.

Warden MW, Murray KT. 2011. Reframing protected species interactions in commercial fishing gear: moving toward estimating the unobservable. Fisheries Research 110: 387-390.

Warden M, Haas HL, Rose KA, Richard PM. 2015. A spatially explicit population model of simulated fisheries impact on loggerhead sea turtles (*Caretta caretta*) in the Northwest Atlantic Ocean. Ecological Modelling 299:23-39.

Winton MV, Fay G, Haas HL, Arendt M, Barco S, James MC, Sasso C, Smolowitz R. 2018. Estimating the distribution and relative density of satellite-tagged loggerhead sea turtles using geostatistical mixed effects models. Mar Ecol Prog Ser 586: 217–232.

Table 1. Mid-Atlantic scallop dredge vessel trip report (VTR) fishing effort and observer sampling, 2015–2019. Cc = Loggerhead (*Caretta caretta*); Lk = Kemp's ridley (*Lepidochelys kempii*).

Year	Observed Dredge Hours (full year)	Observed Dredge Hours (May–Dec)	VTR Dredge Hours (full year)	VTR Dredge Hours (May–Dec)	% Observer Coverage (May–Dec) (Dredge Hours)	Number of Observed Turtle Interactions
2015	17,421	12,262	281,395	213,355	5.7%	1 Cc; 1 Lk
2016	31,394	24,987	477,853	418,013	6.0%	0 Cc; 1 Lk
2017	23,579	15,696	383,875	271,725	5.8%	0 Cc; 0 Lk
2018	12,300	6,665	216,588	131,864	5.0%	2 Cc; 0 Lk
2019	9,741	7,792	173,967	133,300	5.8%	1 Cc; 0 Lk
Total	94,435	67,402	1,533,678	1,168,257	5.8%	4 Cc; 2 Lk

Table 2. Turtle Interactions in scallop dredge gear 2015–2019. Animals listed in the shaded cells were removed from the bycatch rate analysis because takes could either not be attributed to the fishery or occurred during an off-watch haul. Lk = Kemp's ridley (*Lepidochelys kempii*); Cc = Loggerhead (*Caretta caretta*); TDD = turtle deflector dredge; unk = unknown; NA=Not available.

Species	Year	Month	Modified dredge (Y/N)	Entanglement situation	Animal condition	Curved carapace length (cm)/Width	Observer notes
Lk	2015	10	Y	Turtle caught inside dredge chain bag	Alive	29.0/NA	
Cc	2015	12	Y	Turtle caught inside dredge chain bag	Alive	70.0/69.0	Chain mat configuration was neither standard nor turtle chains
Lk	2016	11	Y	Turtle caught inside dredge chain bag	Alive	33.0/32.0	
Cc	2018	08	N	Turtle caught inside dredge bag	Alive	88.0/83.5	
Cc	2018	10	Y	Turtle caught inside dredge chain bag	Alive	89.0/NA	Turtle chain shackles detached. TDD dredge with chains connecting center bale bar to frame
Cc	2019	07	Y	Turtle caught inside dredge chain bag	Alive	139.5/99.1	
Cc	2016	07	Y	Entangled in different fishing gear	Moderately decomposed		Turtle entangled in gillnet
Cc	2016	08	Y	Turtle caught inside dredge chain bag	Severely decomposed		5th rock chain detached at 1st tickler, and 6th rock chain at sweep were detached which was probably why dredge caught dead turtle
Cc	2017	08	Y	Turtle caught inside dredge chain bag	Alive		Event occurred during an off-watch haul
Unk	2017	09	Y	Entangled in different fishing gear	Dead – state of decomposition unknown		Captain reported turtle wrapped in gillnet gear

Table 3. Expanded sampling frame to derive observable interaction rates in the Mid-Atlantic from May to December, 2001–2019. A modified dredge means a dredge that is equipped with a chain mat and/or turtle deflector dredge. CV = coefficient of variation.

	Standard dredge	Modified dredge
Observed dredge hours	74,187	161,090
Number of loggerhead interactions	45	10
Interaction rate (turtles/dredge hour)	0.00060658	0.00006208
CV around interaction rate	0.18	0.33

Table 4. Estimated loggerhead turtle (*Caretta caretta*) interactions each year in the Mid-Atlantic sea scallop (*Placopecten magellanicus*) dredge fishery from May to December, based on observed rates in the fishery from 2001 to 2019. CI = confidence interval; AEI = adult equivalent interactions; AEM = adult equivalent mortality.

Year	Observable interactions (95% CI)	Inferred interactions (95% CI)	Total interactions (95% CI)	Total mortality	AEI	AEM
2015	22 (11-34)	120 (79-167)	142 (90-201)	48	28	10
2016	43 (22-67)	235 (154-326)	278 (177-393)	94	55	19
2017	25 (12-39)	156 (103-217)	181 (115-256)	60	36	12
2018	17 (10-26)	70 (46-97)	87 (56-123)	31	17	6
2019	21 (12-31)	67 (44-93)	88 (56-124)	32	17	6
Average annual interactions	25 (13-39)	130 (85-180)	155 (99-219)	53	31	11

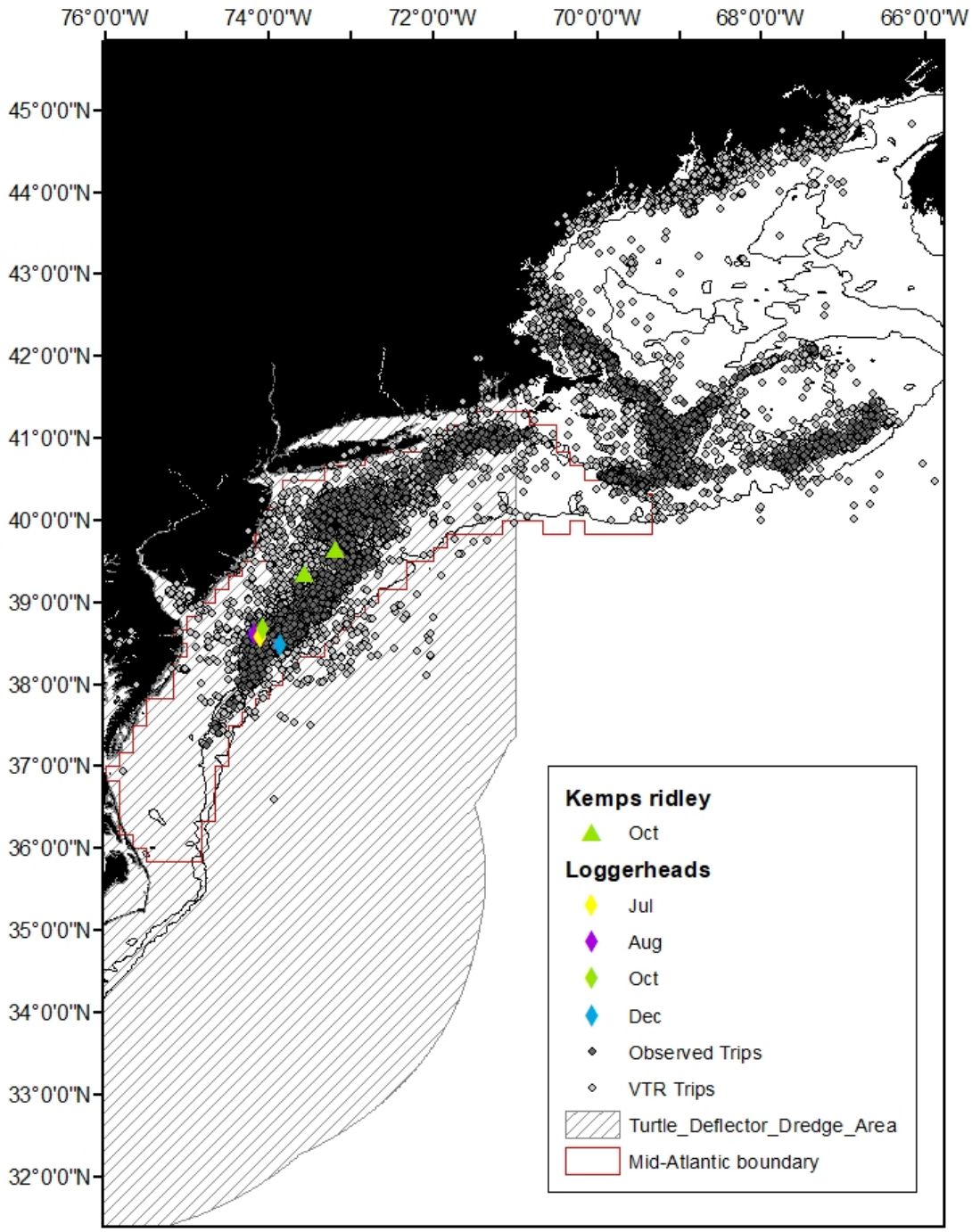

Figure 1. Observed and vessel trip report (VTR) sea scallop dredge trips from 2015 to 2019, including observed Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) turtle interactions. Boundaries of the Mid-Atlantic ecological production unit and the turtle chain mat and turtle deflector dredge requirements are shown.

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