Northeast Fisheries Science Center Reference Document 15-20

doi:10.7289/V5GT5K5W

Estimated Loggerhead (*Caretta caretta*) Interactions in the Mid-Atlantic Scallop Dredge Fishery, 2009-2014

by Kimberly T. Murray

September 2015

Northeast Fisheries Science Center Reference Document 15-20

doi:10.7289/V5GT5K5W

Estimated Loggerhead (*Caretta caretta*) Interactions in the Mid-Atlantic Scallop Dredge Fishery, 2009-2014

by Kimberly T. Murray

NOAA National Marine Fisheries Service, Northeast Fisheries Science Center,
166 Water Street, Woods Hole, MA 02543

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
September 2015

Northeast Fisheries Science Center Reference Documents

This series is a secondary scientific series designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review, and most receive copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

All documents issued in this series since April 2001, and many documents issued prior to that date, are available online at *http://www.nefsc.noaa.gov/publications/*. The electronic version is available in PDF format to permit printing of a paper copy directly from the Internet. If you do not have Internet access, or if a desired document is one of the pre-April 2001 documents available only in the paper version, you can obtain a paper copy by contacting the senior Center author of the desired document. Refer to the title page of the document for the senior Center author's name and mailing address. If there is no Center author, or if there is corporate (*i.e.*, nonindividualized) authorship, then contact the Center's Woods Hole Laboratory Library (166 Water St., Woods Hole, MA 02543-1026).

Information Quality Act Compliance: In accordance with section 515 of Public Law 106-554, the Northeast Fisheries Science Center completed both technical and policy reviews for this report. These predissemination reviews are on file at the NEFSC Editorial Office.

This document may be cited as:

Murray KT. 2015. Estimated loggerhead (*Caretta caretta*) interactions in the Mid-Atlantic scallop dredge fishery, 2009-2014. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-20; 15 p. Available at: http://www.nefsc.noaa.gov/publications/
doi:10.7289/V5GT5K5W

TABLE OF CONTENTS

ABSTRACT

This paper estimates total loggerhead (*Caretta caretta*) turtle interactions, adult equivalent interactions, and mortality in the Mid-Atlantic sea scallop (*Placopecten magellanicus*) dredge fishery from 2009-2014 using data collected by the Northeast Fisheries Observer Program. During this time period, some vessels were equipped with chain mats and turtle deflector dredges designed to exclude turtles from being captured in the dredge bag or cutting bar frame, rendering many interactions to be "unobservable." As a result, observer data from 2009-2014 were pooled with data from 2001-2008 to estimate observable and unobservable yet quantifiable interactions. A Generalized Additive Model was developed describing interaction rates as a function of sea surface temperature, chain mats, depth, and year, and was then applied to commercial Vessel Trip Report data to estimate total loggerhead interactions. The average annual observable turtle interactions in the Mid-Atlantic scallop dredge fishery plus unobserved, quantifiable interactions was 22 loggerheads per year (coefficient of variation = 0.73, 95% confidence interval: 4-67), 9-19 of which were lethal. The 22 interactions equate to 2 adult equivalents per year and 1-2 adult equivalent mortalities. Estimated interactions in the fishery have decreased relative to 2001-2008, and the utility of observers as a monitoring tool for turtle interactions in the fishery appears to be decreasing.

INTRODUCTION

Loggerhead turtles (*Caretta caretta*) and Atlantic sea scallops (*Placopecten magellanicus*) overlap seasonally in the US Mid-Atlantic region stretching from Cape Cod to southern Virginia when turtles migrate to the area to forage. Roughly 200 interactions between loggerheads and scallop dredge fishing gear were estimated to have occurred on average annually from 2001 to mid-2006 in the Mid-Atlantic (defined as west of 71°W), mainly from June to November (Murray 2011). Fishing effort reductions and gear modifications have been implemented in the fishery to reduce the magnitude and impact of these interactions, which declined to <100 estimated interactions per year from late 2006 to 2008 (Murray 2011). Fisheries observers continue to monitor the scallop dredge fishery for turtle interactions and to measure the effectiveness of gear modifications.

Many vessels operating in the current fishery are required to fish with dredges modified to exclude turtle capture or to minimize harm from the interaction. Chain mats have been required in the fishery since 25 September 2006 for all dredge vessels operating south of 41°9.0′N from 1 May – 30 November (US DOC 2006). Turtle deflector dredges (TDDs) have been required since 1 May 2013 for scallop vessels, with the exception of limited access general category vessels that use a dredge less than 10 ft 6 in wide (126 in), west of 71° W from 1 May – 31 October (US DOC 2012). The purpose of the chain mat is to prevent captures and injury in the dredge bag, while the purpose of the TDD is to deflect sea turtles over the dredge frame and bag rather than under the cutting bar, to reduce turtle injuries on the ocean bottom. Together, the use of chain mats and TDDs increase the conservation benefit to turtles, because chain mats help reduce the impact to turtles from water column interactions, while the TDD helps reduce the impact to turtles from benthic interactions.

While the chain mat is intended to reduce those interactions in which animals are landed or observed from the deck, other “unobservable” interactions may still be occurring (i.e., those in which animals come in contact with the gear but either are not captured or escape from the gear before it is brought to the surface where they can be observed) (Warden and Murray 2011). Roughly 85% of the total estimated interactions from 2006-2008, after chain mats were required in the fishery, were “unobservable” yet quantifiable based on estimated captured rates in dredges without chain mats (Murray 2011). Mortality rates of unobservable interactions quantified from fisheries observer data are unknown.

Roughly a third of the estimated loggerhead interactions in dredge gear from 2001-2008 were considered “adult equivalent” interactions. Adult equivalent losses are a more informative metric to evaluate population impact than total interactions (Haas 2010), because adult equivalency translates the loss of individual turtles into adults based on expected chances of surviving to adulthood and reproducing. An adult equivalent loggerhead is the reproductive

value (RV) of the turtle scaled to adults, where the RV for adults is equal to 1 (Wallace et al. 2008).

The purpose of this analysis is to estimate total loggerhead interactions (observable and unobservable/quantifiable), adult equivalent interactions, and mortality in Mid-Atlantic (as defined in Murray 2011) dredge gear from 2009-2014. Additional information may be gleaned from the analysis regarding the practicality of using observers to monitor turtle interactions in a gear where most interactions are unobservable.

METHODS

Observable interaction rates in the dredge fishery from 2001-2008 were previously modeled as a function of SST, depth, and use of a chain mat (Murray 2011). In this analysis, fisheries observer data from 2001-2008 were pooled with data collected from 2009-2014 to derive sea turtle interaction rates, because only 4 loggerhead interactions were observed from 2009-2014. A new model developed from the updated time series (2001-2014) was then applied to commercial fishing effort to estimate the total number of observable interactions as well as unobservable/quantifiable interactions.

Data Sources

Observer Data

From 2009-2014, Northeast Fisheries Science Center (NEFSC) observers aboard commercial scallop dredge vessels observed over 130,000 fishing hours in the Mid-Atlantic, which was roughly 6% of total dredge fishing effort (Table 1). “Fishing hour” was the total amount of hours a dredge was 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

The proportion of observed dredge hours on vessels using standard dredges, chain mats, and combined chain mats/TDDs varied across years, with TDD requirements becoming mandatory in May 2013 (Figure 1). These data were pooled with observed effort from 2001-2008 (Murray 2011) to derive sea turtle interaction rates, expressed as the number of observed turtles per fishing hour. Data from 2009-2014 were pooled with data from 2001-2008 because there were too few observed interactions from 2009-2014 to develop a robust model of loggerhead interaction rates in the recent fishery.

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 either 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 it is not known what fraction of off-watch interactions are reported.

Commercial Data

Mandatory Vessel Trip Reports (VTRs) completed by commercial scallop fishermen during 2009-2014 provided a measure of total fishing effort. Because VTR reporting is mandatory in the fishery and also enforced via Vessel Monitoring Systems, effort from VTRs was considered to be a census of scallop dredge fishing activity. Dredge fishing hours per trip were calculated from VTRs as:

Dredge fishing hours on a trip = number of dredges on a trip * average haul duration on a trip * number of hauls on trip

Trips used either 1 dredge (47%) or 2 dredges (53%). This analysis assumed 100% compliance with the chain mat and TDD regulations. So, after 25 September 2006, dredge trips were coded as using a chain mat if they fished south of 41º 9.0'N during 1 May to 30 November (55% of all trips). After 1 May 2013, when TDDs became mandatory in the fishery, dredge trips were coded as using a TDD if they fished west of 71 ºW from 1 May to 31 October and fished dredges with frames larger than 126 in (7% of all trips). Trips were coded for chain mat or TDD usage based on regulatory time period rather than the required VTR gear code ('DSC' for chain mats and 'DTC' or 'DTS' for TDDs) because too few VTRs actually reported these codes (1% and 0%, respectively).

Sea Surface Temperature (SST)

Previous estimates of loggerhead interactions in the scallop dredge fishery depended on SST, depth, and use of a chain mat (Murray 2011). VTRs do not require collection of SST data, so these data were obtained for all VTR scallop dredge trips from GOES satellites at a 0.05° resolution over an 8-day period[1]. Images were retrieved for each eighth day starting on 4 January of each year, and were "spatially synced" to 10x10km grid cells in an oblique Mercator projection (R, spatial tools package, version 3.1.2), then stacked into annual raster bricks. Sea surface temperature values were then extracted from the multi-layer raster brick (R, raster package, version 3.1.2) at the geographic positions of the trip reported on VTRs. This source and scale of satellite SST data made the dataset a good proxy for *in-situ* SST (Palka et al. in prep).

[1] Data downloaded from http://coastwatch.pfeg.noaa.gov/erddap/griddap/erdGAssta8day.graph

Loggerhead Interaction Rate Model

Observable interaction rates were expressed as:

$$R = \frac{\text{Number of Observed Turtles}}{\text{Observed Fishing Hour}}$$

A Generalized Additive Model (GAM) with a Poisson distribution (GAM function, SPLUS 7.0) was used to model the expected turtle interaction rate. The form of the GAM can be written as:

$$Log(E[y_j]) = \log(\textit{fishing hours}_j) + \alpha + \sum_{i=1}^{n} f_i(x_{ij}) + \xi$$

where:

$E[y_j]$ = the expected number of loggerhead turtles observed on the *j*th haul

α = a constant intercept term

f_j = a series of smoothing functions for each predictor variable

x_i = environmental or fishing characteristics at each haul

ξ = unexplained error

In the updated time series (2001-2014), there were only 4 additional loggerhead interactions, so the historical model was used as a baseline candidate model to estimate loggerhead interaction rates from 2009-2014. Two additional variables were tested to account for changes in the fishery over time: 'year' and 'regulatory time period,' where the latter referred to the different periods when standard dredges were used (2001 to 25 September 2006), when chain mats were used (26 September 2006 to 30 April 2013), and when both TDDs and chain mats were used (1 May 2013 to 31 December 2014). The models were evaluated with respect to Akaike's Information Criterion (AIC) and the percent of additional deviance explained compared to the baseline model.

Total Interactions

The preferred loggerhead interaction rate model was applied to VTR trip effort to estimate an "observable" loggerhead interaction per trip; the total number of "observable" interactions was the sum over all trips.

Unobserved, quantifiable interactions were estimated by applying the interaction rate of dredges with no chain mats to dredges with chain mats and TDDs (Murray 2011). This 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 were not required, but chain mats or TDDs prevented the turtles from being captured and subsequently seen by an observer. The loggerhead model for VTR trips coded as having no chain mat or TDD (i.e., fishing with a standard dredge) was applied to all trips to estimate the total number of interactions, both observed and unobserved but quantifiable. The difference between the total estimate and the observable estimates represents the estimated number of turtle captures avoided due to the chain mat and TDD (i.e., the unobserved but quantifiable interactions).

Bootstrap resampling was used to derive coefficients of variation (CVs) around both the annual and average annual interaction estimates. Bootstrap replicates were generated by sampling hauls with replacement 1000 times from the original observer dataset, and then the preferred model parameterized with each replicate. Estimated interactions each year were calculated by applying each replicate dataset to annual VTR dredge effort and then averaged over all years. CVs and 95% confidence intervals (CIs) around the annual and average annual estimates were computed from the bootstrap replicates.

Mortality Rates

Different mortality rates were applied to the estimated observable and unobservable but quantifiable interactions based on whether the dredge was equipped with a standard dredge, a chain mat, or both a TDD and chain mat (Table 2). An 80% mortality rate was applied to estimated observable interactions on dredges with standard dredges or with chain mats (no TDDs), per evaluations by the Serious Injury Working Group (Upite 2011) for data from 2008-2012[2]. Because mortality rates of unobservable/quantifiable interactions in dredges with chain mats are unknown (Murray 2011), 2 mortality rates representing extreme scenarios (0% mortality and 100% mortality) were applied to unobservable/quantifiable interactions in dredges with chain mats. A 28% mortality rate was applied to estimated observable and unobservable/quantifiable interactions of turtles in dredge gear equipped with both a chain mat and TDD, based on experimental trials (Smolowitz et al. 2010) and the latest Sea Scallop Biological Opinion (NMFS 2012).

[2]This is the most recent time series evaluated by the Serious Injury Group which had observed turtle interactions in dredge gear.

Adult Equivalency

Adult equivalent loggerhead interactions from 2009-2014 were estimated based on the methods in Murray (2011). Observed loggerheads were grouped into size classes based on 6 loggerhead life stages (TEWG 2009), and RVs were assigned to each respective stage class based on Wallace et al. (2008). These stage classes (sizes, RV values) were as follows: Stage 1 (<=16.2 cm curved carapace length [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); and Stage V (>101.5 cm CCL, 1.0). An alternative method to estimate adult equivalents is to multiply estimated interactions in a region by that region's average RV value (Warden 2011), which is useful to report spatial differences in adult equivalent interactions. The approach taken here was preferred because it was not necessary to compare adult equivalent interactions across broad geographic regions, the method uses RV values specific to individual turtles, rather than mean RV values, and it offers the ability to compare estimated adult equivalent interactions to a previous time series in the fishery (Murray 2011).

The number of estimated adult equivalent (AEI) loggerhead interactions over all 6 life stages and all 6 years (2009-2014) was calculated as:

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

where:

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

P = the proportion of loggerheads observed in life stage *i*

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

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

RESULTS

Observed Loggerhead Interactions

From 2009-2014, observers recorded 5 loggerhead interactions in scallop dredge gear (Table 3, Figure 2). One of these turtles was severely decomposed and wrapped in gillnet gear so was excluded from the analysis because it is unlikely the event occurred on the scallop dredge haul. Of the 4 remaining, 3 occurred in 2009 and 1 in 2011. One turtle interaction was observed in December, a month in which loggerhead interactions in dredge gear typically are not

observed. All 4 observed loggerhead interactions occurred on dredges equipped with chain mats and none were observed on dredges using TDDs. No turtles were observed when an observer was "off-watch."

Loggerhead Interaction Rate Model

Loggerhead interaction rates in dredge gear from 2001-2014 were modeled as a function of SST, depth, use of a chain mat, and year (Table 4; Figure 3). Because there were no observed turtles on dredges with TDDs, the estimated observable interaction rate of dredges with TDDs was considered to be the same as estimated observable interaction rates in dredges with chain mats. The model explained 24% of the variation in bycatch rates over 2001-2014. Accounting for year in the model was slightly better than regulatory time period, which did not explain additional variation in rates beyond the baseline candidate model. Although year did not account for a large additional amount of variation in the model, it was necessary to include year to account for changes in dredge types used in the Mid-Atlantic during 2001-2014.

Total Interactions, Adult Equivalency, and Mortality

The average annual estimate of observable turtle interactions in the Mid-Atlantic scallop dredge fishery from 2009-2014 was 11 loggerheads per year (CV=0.46, 95% CI: 3-22) (Table 5). When the observable interaction rate from dredges without chain mats was applied to trips that used chain mats and turtle deflector dredges, the estimated number of observed interactions, plus unobserved, quantifiable interactions, was 22 loggerheads per year (CV=0.73, 95% CI: 4-67). Nine to 19 of these interactions would have been lethal depending on whether loggerheads which interacted with chain mats without being captured (the unobservable but quantifiable interactions) survived. The 22 interactions equates to 2 adult equivalents per year and 1-2 adult equivalent mortalities.

DISCUSSION

Estimated observable interactions between loggerheads and dredge gear in the Mid-Atlantic have declined from 218 loggerheads per year in the early 2000s (Murray 2011) to just 1 animal in 2014. Commercial effort in the Mid-Atlantic fluctuated with rotational area management throughout 2001-2014, yet observable interactions continued to decrease. This decrease in observed interactions is likely due to the modifications on dredges to exclude turtles from being captured, and not necessarily to the absence of turtles from the area because many of them are sighted (NEFSC and SEFSC 2014) or observed in other gear types in the area (Murray 2015). While unobservable but quantifiable interactions also occurred, they are poorly estimated

in this analysis because of a lack of data (there were no observed turtles in TDDs to estimate an observable interaction rate in this gear type, which is necessary for estimating unobservable but quantifiable interactions based on methods in Murray 2011). Still, the impact of dredge interactions on the turtle population has likely been reduced because the estimated mortality rate associated with TDDs (28%) is lower than the mortality rate in standard dredges or dredges with chain mats.

The lack of observed turtle interactions in dredges with chain mats and TDDs suggests that the utility of observers as a monitoring tool is decreasing for this fishery. Still, observers continue to monitor the fishery for turtle interactions, documenting the use of chain mats and TDDs, and recording turtle interactions outside of the gear-regulated time and areas. In this analysis, the estimated observable interaction rate (from the pooled model) after TDDs were implemented was 0.000007 loggerhead turtles per dredge hour, suggesting that one would need to observe on average over 140,000 dredge hours to observe 1 turtle interaction if similar conditions existed in 2015 and beyond. This level of coverage is likely not feasible given available resources and competing monitoring needs for other bycatch species. Managers currently monitor dredge fishing hours in the Mid-Atlantic scallop fishery as an indicator of whether elevated turtle interactions may be occurring compared to baseline conditions (NMFS 2012). Effort monitoring could be combined with presence/absence information from turtle tagging data or experimental work on TDD interaction rates, if such information were available, to develop a stronger indication that turtle interactions may or may not be occurring.

Improved data collection on VTR logs is needed with regard to the gear type used in the fishery. Gear codes exist to indicate whether dredges are equipped with chain mats (‘DSC’), TDDs (‘DTS’), or both (‘DTC’), yet these codes are not commonly recorded; instead, gear codes to indicate a standard dredge are recorded (‘DRS’). These codes are extremely important in acquiring accurate information on selective fishing practices, especially those designed to reduce bycatch of the subject being studied. This analysis assigned gear codes to VTR effort based on regulatory requirements and assumptions of 100% compliance, yet many fishermen used chain mats and TDDs voluntarily either before they were required or outside of the time/area regulatory boundaries. Estimated bycatch on these trips would therefore have been overestimated. On the other hand, bycatch is underestimated if fishermen were not in compliance with chain mat and TDD requirements.

REFERENCES CITED

Haas HL. 2010. Using observed interactions between sea turtles and commercial bottom-trawling vessels to evaluate the conservation value of trawl gear modifications. Mar Coast Fish. 2: 263-276.

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

Murray KT. 2015. The importance of location and operational fishing factors in estimating and reducing loggerhead turtle (*Caretta caretta*) interactions in U.S. bottom trawl gear. Fish. Res. 172:440-451.

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.

Northeast Fisheries Science Center (NEFSC), Southeast Fisheries Science Center (SEFSC). 2014. Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the Western North Atlantic Ocean. Available at: http://nefsc.noaa.gov/psb/AMAPPS/docs/NMFS_AMAPPS_2014_annual_report_Final.pdf

Palka D, Chavez S, Warden M, Murray K, Josephson E, Garrison L, Hatch J, Orphanides C, Ortega-Ortez J. In prep. An overview of data sources and assessment for AMAPPS modeling.

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. N Am J Fish Manage. 30:993-1000.

Turtle Expert Working Group (TEWG). 2009. As assessment of the loggerhead turtle population in the Western North Atlantic ocean. NOAA Tech Memo NMFS-SEFSC-575; 131p. Available at: www.sefsc.noaa.gov.

Upite C. 2011. Evaluating sea turtle injuries in northeast fishing gear. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 11-10; 26 p. Available at: http://nefsc.noaa.gov/publications/.

US Department of Commerce (US DOC). 2006. Endangered and threatened wildlife; sea turtle conservation. Fed Reg. 71: 50361-50373.

US DOC. 2012. Fisheries of the Northeastern United States; Atlantic Sea Scallop Fishery; Framework Adjustment 23. Fed Reg. 67: 20728-20742.

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

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

Table 1. Observed and commercial scallop (Vessel Trip Report [VTR]) dredge hours in the Mid-Atlantic scallop dredge fishery, 2009-2014

Year	Observed Dredge Hours	VTR Dredge Hours	% Coverage
2009	27,512	505,354	5.4
2010	23,765	594,416	4.0
2011	22,446	393,243	5.7
2012	22,693	323,177	7.0
2013	14,717	241,382	6.1
2014	23,101	313,561	7.4
Total	134,233	2,371,132	5.7

Table 2. Mortality rates applied to estimated interactions of loggerheads in Mid-Atlantic scallop dredge gear, 2009-2014

Dredge type	Observable mortality rate	Unobservable/quantifiable mortality rate
Standard	80%	N/A
Chain mat	80%	Unknown (applied 0% and 100% as a range)
Chain mat & TDD	28%	28%

Table 3. Observed loggerhead interactions in Mid-Atlantic scallop dredge gear, 2009-2014

Year	Month	Day	Depth (m)	SST (^{0}C)	Entanglement situation	Curved notch to tip length (cm)
2009	8	28	40	25.6	Turtle entangled in turtle chain, inside of dredge bag	74.0
2009	8	9	53	25.4	Turtle caught on top of dredge or dredge frame	78.0
2009	9	21	60	24.2	Turtle inside dredge chain bag at bottom of bag. Head caught where two rock chains weren't attached fully to rest of the gear	78.1
2011	12	8	51	12.7	Turtle caught in chains on outside of gear, hanging on top portion of dredge	61.5

Table 4. Model describing loggerhead interaction rates in Mid-Atlantic scallop dredge fishery from 2009-2014. Model #2 was used to model interactions from 2001-2008 (Murray 2011). Model #3 was selected to model interaction rates from 2001-2014. "Regulation period" refers to the time period before (2009 to 30 April 2013) and after (1 May 2013 to 2014) turtle deflector dredges were required in the fishery.

Model No.	Model structure	Degrees of freedom	Residual deviance	Cumulative % of deviance explained	AIC statistic	AIC - AIC_{min}
1	Null model	1	799.9	0	801.9	172.5
2	Null + s(SST) + s(depth) + chain mat	8	626.4	22	642.2	12.8
3	Null + s(SST) + s(depth) + chain mat + s(year)	12	605.9	24	629.4	0
4	Null + s(SST) + s(depth) + chain mat + (regulation period)	10	621.1	22	640.9	11.5

Table 5. Annual estimated interactions between loggerhead turtles and scallop dredge gear in the Mid-Atlantic region, 2009-2014. AEI = Adult equivalent interactions from combined observable and unobservable/quantifiable interactions; AEM= Adult equivalent mortality. Estimates of mortality are expressed as a range to reflect different assumptions about mortality rates for unobservable/quantifiable interactions in dredges with chain mats.

Year	Observable Interactions	CV (95% CI)	Observable and Unobservable/ Quantifiable Interactions	CV (95% CI)	Estimated Mortality	AEI	AEM
2009	27	0.46 (7-53)	51	0.84 (9-191)	22-46	4	2-4
2010	30	0.48 (6-58)	57	0.72 (10-175)	24-51	5	2-4
2011	5	0.66 (1-13)	10	0.74 (1-29)	4-9	1	0-1
2012	3	0.78 (0-8)	5	0.84 (0-17)	2-4	0	0
2013	2	0.82 (0-6)	4	0.94 (0-13)	1-1	0	0
2014	1	0.89 (0-3)	2	1.06 (0-8)	1-1	0	0
Average Annual	**11**	**0.46 (3-22)**	**22**	**0.73 (4-67)**	**9-19**	**2**	**1-2**

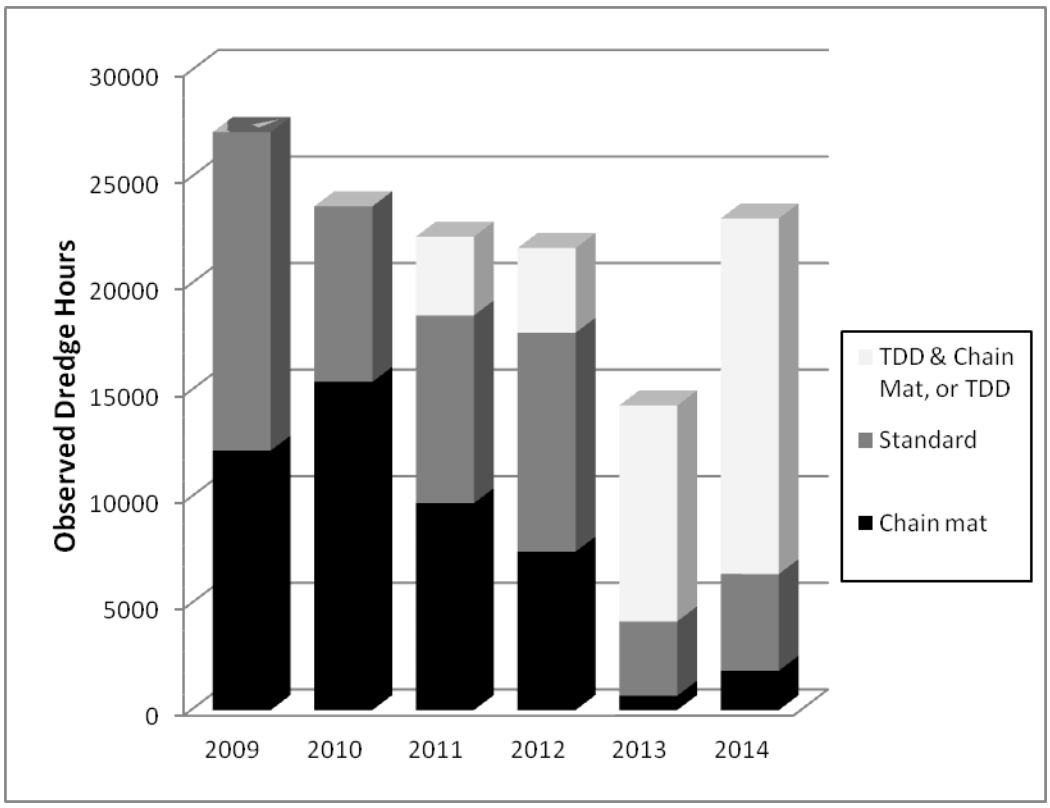

Figure 1. Observed dredge hours by dredge type in the Mid-Atlantic, 2009-2014. Dredge types include the standard dredge (without any turtle excluder devices), a dredge with only a chain mat, a dredge with only a turtle deflector dredge (TDD), and a dredge with both a TDD and a chain mat.

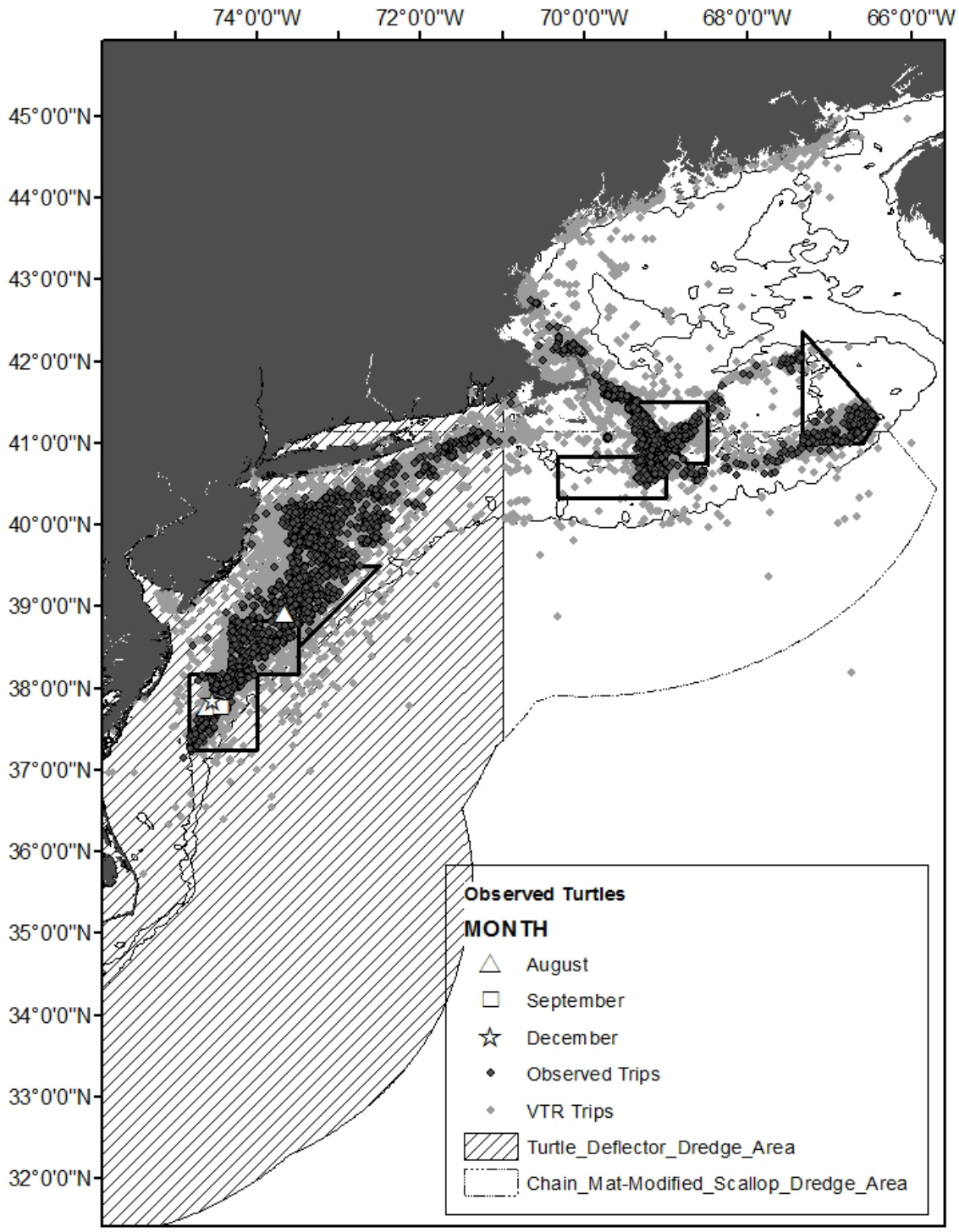

Figure 2. Observed and commercial scallop dredge trips (VTR) from 2009-2014, including observed loggerhead interactions. Scallop rotational management areas are shown in solid black lines, as well as boundaries of the turtle chain mat and turtle deflector dredge requirements. "Mid-Atlantic" as defined in this analysis includes waters west of 71°W and south of 42°N to the southern limit of the distribution of the sea scallop dredge fishery (~36°N).

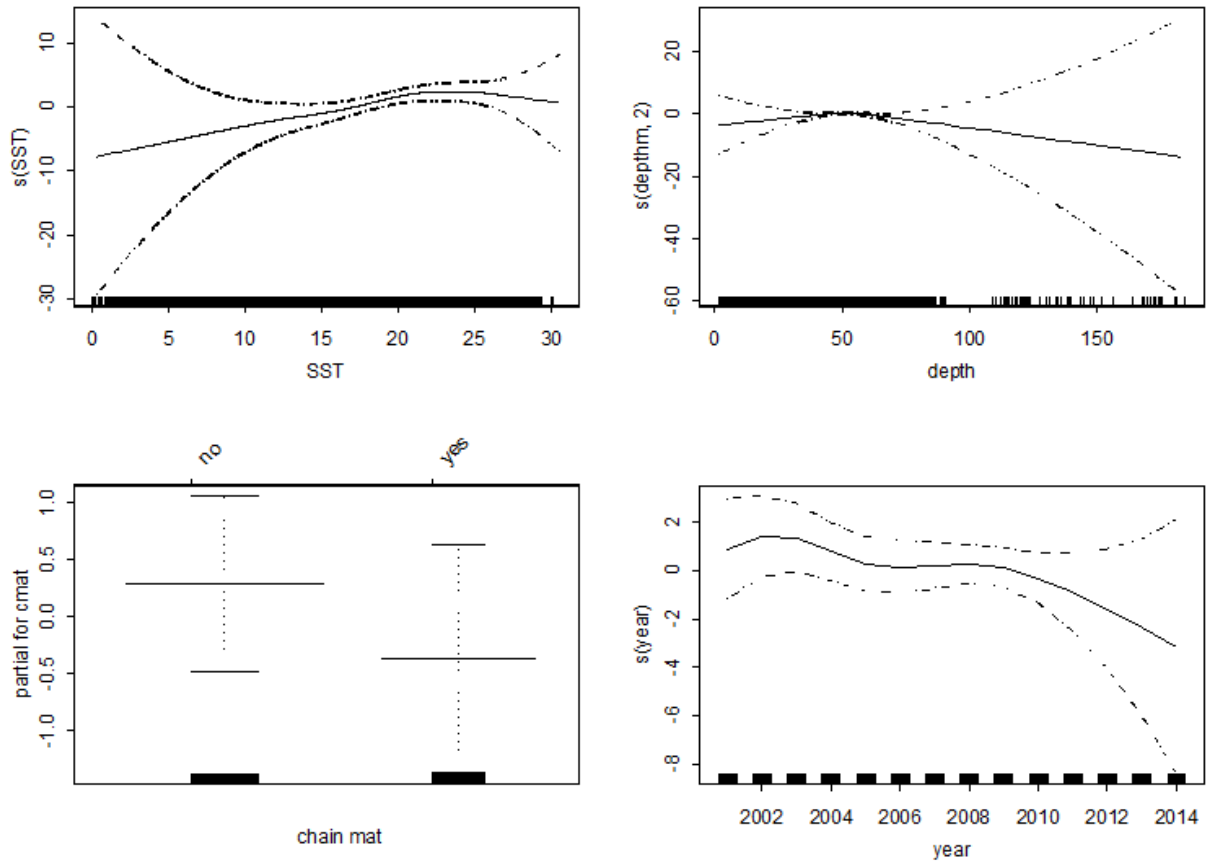

Figure 3. Generalized additive model smoothers depicting effect of sea surface temperature, depth, chain mats, and year on loggerhead interaction rates. Rugplot on x-axis shows the number of observations; dashed lines are 95% confidence intervals.

Procedures for Issuing Manuscripts in the *Northeast Fisheries Science Center Reference Document* (CRD) Series

Clearance

All manuscripts submitted for issuance as CRDs must have cleared the NEFSC's manuscript/abstract/webpage review process. If any author is not a federal employee, he/she will be required to sign an "NEFSC Release-of-Copyright Form." If your manuscript includes material from another work which has been copyrighted, then you will need to work with the NEFSC's Editorial Office to arrange for permission to use that material by securing release signatures on the "NEFSC Use-of-Copyrighted-Work Permission Form."

For more information, NEFSC authors should see the NEFSC's online publication policy manual, "Manuscript/abstract/webpage preparation, review, and dissemination: NEFSC author's guide to policy, process, and procedure," located in the Publications/Manuscript Review section of the NEFSC intranet page.

Organization

Manuscripts must have an abstract and table of contents, and (if applicable) lists of figures and tables. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area" and/or "Experimental Apparatus," "Methods," "Results," "Discussion," "Conclusions," "Acknowledgments," and "References Cited."

Style

The CRD series is obligated to conform with the style contained in the current edition of the United States Government Printing Office Style Manual. That style manual is silent on many aspects of scientific manuscripts. The CRD series relies more on the CSE Style Manual. Manuscripts should be prepared to conform with these style manuals.

The CRD series uses the American Fisheries Society's guides to names of fishes, mollusks, and decapod crustaceans, the Society for Marine Mammalogy's guide to names of marine mammals, the Biosciences Information Service's guide to serial title abbreviations, and the ISO's (International Standardization Organization) guide to statistical terms.

For in-text citation, use the name-date system. A special effort should be made to ensure that all necessary bibliographic information is included in the list of cited works. Personal communications must include date, full name, and full mailing address of the contact.

Preparation

Once your document has cleared the review process, the Editorial Office will contact you with publication needs – for example, revised text (if necessary) and separate digital figures and tables if they are embedded in the document. Materials may be submitted to the Editorial Office as files on zip disks or CDs, email attachments, or intranet downloads. Text files should be in Microsoft Word, tables may be in Word or Excel, and graphics files may be in a variety of formats (JPG, GIF, Excel, PowerPoint, etc.).

Production and Distribution

The Editorial Office will perform a copy-edit of the document and may request further revisions. The Editorial Office will develop the inside and outside front covers, the inside and outside back covers, and the title and bibliographic control pages of the document.

Once both the PDF (print) and Web versions of the CRD are ready, the Editorial Office will contact you to review both versions and submit corrections or changes before the document is posted online.

A number of organizations and individuals in the Northeast Region will be notified by e-mail of the availability of the document online.

Research Communications Branch
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

MEDIA MAIL

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review and most issues receive copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a regularly-issued, quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. This report undergoes internal review, but receives no technical or copy editing.

TO OBTAIN A COPY of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2350) or consult the NEFSC webpage on "Reports and Publications" (http://www.nefsc.noaa.gov/nefsc/publications/). To access *Resource Survey Report*, consult the Ecosystem Surveys Branch webpage (http://www.nefsc.noaa.gov/femad/ecosurvey/mainpage/).

ANY USE OF TRADE OR BRAND NAMES IN ANY NEFSC PUBLICATION OR REPORT DOES NOT IMPLY ENDORSEMENT.