Northeast Fisheries Science Center Reference Document 04-11

Bycatch of Sea Turtles in the Mid-Atlantic Sea Scallop (*Placopecten magellanicus*) Dredge Fishery during 2003

by

Kimberly T. Murray

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Table of Contents

Tables

Figures

PREFACE

The NEFSC has re-estimated takes of loggerhead sea turtles in the Mid-Atlantic sea scallop fishery during 1 June to 30 November 2003, first estimated in the Northeast Fisheries Science Center Reference Document 04-11, issued in August 2004. This revision of the document uses improved data about the location of trips used in the analysis.

The resulting estimate changed by 119 animals, from 630 to 749. The August bycatch analysis used actual location data from only those trip reports with recorded lat./long. locations, and prorated the remaining trips (about 32% of the trips used) to areas under analysis. The revised analysis uses trip reports with good trip location information entered either as lat./long. or as loran coordinates (only 1.5% of trips are prorated). Trips and takes that had been previously prorated to areas proved to be distributed differently than was assumed in the first analysis.

The analytical method used is unchanged, as are the resulting bycatch rates and the coefficient of variance (CV=0.28) for the estimates. The conclusions of the analysis, that sea surface temperature and tow duration/speed have more influence on the likelihood of loggerhead takes than gear configuration or other observed fishery practices, are also unchanged.

Abstract

During 2003, fisheries observers aboard commercial vessels in the U.S. sea scallop dredge fishery documented sea turtle bycatch in the Mid-Atlantic region, from Long Island, New York to Cape Hatteras, North Carolina. This study utilizes Generalized Linear Model and Generalized Additive Model fitting techniques to identify environmental factors and gear characteristics that influence bycatch rates of sea turtles in the 2003 Mid-Atlantic scallop dredge fishery, and predicts total bycatch in this area during June-November 2003. Significant factors affecting sea turtle bycatch were sea surface temperature and tow speed. In estimating total bycatch, rates were stratified based on sea surface temperature because tow speed was not available in fishing logbooks. Highest bycatch rates occurred in surface temperatures greater or equal to 22°C. Total estimated bycatch of sea turtles during 1 June to 30 November 2003 in the Mid-Atlantic scallop dredge fishery was 749 animals (C.V. = 0.28).

INTRODUCTION

During 2001 and 2002, fisheries observers aboard commercial vessels in the sea scallop dredge fishery documented sea turtle bycatch in two regions of the Mid-Atlantic (Murray 2004). These areas, termed the 'Hudson Canyon Controlled Access Area' and the 'Virginia Beach Controlled Access Area' were closed in April 1998 to allow juvenile scallops to recover and reopened in May 2001 on a conditional basis. Observers sampled approximately 11% of the commercial dredge effort in the Hudson Canyon Access Area during 2001 and 2002, and 16% of the effort in the Virginia Beach Access Area during 2001. No trips were observed in the Virginia Beach Access Area during 2002 due to low commercial fishing effort in the area. Outside of these two areas, observer coverage was less than 1%. Over both years, observers documented 27 sea turtle interactions in the Controlled Access Areas (CAAs). Estimated bycatch in the Hudson Canyon Area was 69 turtles in 2001, and 95 turtles in 2002. Estimated bycatch in the Virginia Beach Access Area was 5 turtles in 2001, and 0 turtles in 2002.

The spatial extent of observer coverage in the commercial scallop dredge fishery expanded in 2003. This increase in spatial coverage was needed to properly assess bycatch outside of the CAAs. Bycatch in these two areas was not estimated in 2001-2002 because of scientific concerns that bycatch rates differed throughout the broader Mid-Atlantic based on environmental factors, fishing practices, and dredge gear characteristics. Accounting for differences in bycatch rates based on these factors reduces bias in the total bycatch estimate.

The purpose of this paper is to identify factors that influenced the bycatch rate of turtles in the Mid-Atlantic sea scallop dredge fishery in 2003, and to provide a total bycatch estimate for this fishery. This bycatch assessment is based on new and expanded information about the fishery in the Mid-Atlantic, taking into consideration fishing practices, environmental variables, and gear characteristics both inside and outside of the Controlled Access Areas.

METHODS

Spatial and Temporal Boundaries used for Bycatch Rate Extrapolation

The 2003 fishing year for the U.S. commercial sea scallop fishery occurred from 1 March 2003 to 28 February 2004 (NEFMC 2002) in the Gulf of Maine, Georges Bank, and Mid-Atlantic regions. This analysis deals solely with trips operating in the Mid-Atlantic region from Long Island, NY to Cape Hatteras, NC (approximately 41°09'N/71°00'W to 35°15'N/71°00'W), from 1 June to 30 November 2003.

It is assumed here that there are no turtle interactions in the scallop fishery in the Georges Bank and Gulf of Maine regions; as such, commercial fishing effort north of Long Island, NY was excluded from the bycatch analysis. Compared to the Mid-Atlantic fishery, the Georges Bank and Gulf of Maine scallop fisheries operate in different ecological conditions. These fisheries operate north of the general range of loggerhead turtles (~ 41°N latitude as a northern limit; Shoop and Kenney 1992). There has never been an observed turtle interaction in the Georges Bank and Gulf of Maine areas; however, observer coverage (% trips observed) in these areas has been low (< 1.0% in 2001, 2002 and 2003).

A bycatch estimate is provided for the period June to November 2003, rather than throughout the entire fishing year, because outside of this time frame turtle interactions with the sea scallop dredge fishery are unlikely to occur. Loggerhead sea turtles inhabit northern temperate waters seasonally, appearing in early summer and remaining for several months until migrating south in the fall (Morreale 1999). By December, turtles are near or south of Cape Hatteras, NC (Shoop and Kenney 1992). Historically, turtle interactions have been observed in the scallop dredge fishery from late June to late October. The potential for interactions also exists during November due to the overlap of turtles and dredge fishing effort in the southern most area of the fishery.

Data Sources

Observer Coverage and Observed Turtle Interactions

From June - November 2003, observer coverage (percentage of dredge hours observed) in the entire Mid-Atlantic was 2.7%. Coverage was higher in the Hudson Canyon Controlled Access Area (9.7%) than outside this area (1.4%) (Figure 1).

Twenty-two turtle interactions were observed in the Mid-Atlantic region, of which 16 were in the Hudson Canyon Controlled Access Area, and 6 were outside this area (Table 1, Figure 2). Five turtles were released alive and uninjured, 1 was fresh dead, 12 were alive and injured, 1 was resuscitated, and 3 were alive yet whose condition was unknown. Four (18%) interactions occurred during July, 6 (27%) during August, 2 (9%) during September, and 10 (46%) during October.

Seventeen (77%) of the interactions were loggerheads (*Caretta caretta*), and 5 (23%) were not positively identified. Four of the 5 unidentified turtles occurred on trips that also interacted with a loggerhead. According to observer logs, instances where turtles could not be identified occurred when the turtle fell from the gear and the observer did not have enough time to positively identify the turtle. Since 2001, only loggerhead species have been positively identified in the Mid-Atlantic scallop dredge fishery. Because loggerheads have been the only species of sea turtles observed in the scallop dredge fishery since a dedicated observer program began in 2001, and 4 out of the 5 unidentified interactions took place in loggerhead territory, it is assumed that the 5 unidentified species were loggerheads. Therefore, the 2003 total bycatch estimate is considered to be for loggerhead turtles only.

In addition, two turtles, each on separate trips during October, were captured when an observer was off-watch (Table 2). One trip was inside the Hudson Canyon Controlled Access Area and the other was outside. These 2 interactions occurred when the observer was not collecting information on the haul. These turtles were not included in the count of turtles used to calculate bycatch rates, though they are subsumed in the extrapolated estimate. Furthermore, 6 severely decomposed turtles wrapped in gillnet gear were captured on a single trip during September. These interactions occurred in the Hudson Canyon Access Area. These turtles were also not included in the count of turtle interactions because the mortalities may have occurred from previous interactions with gillnet gear.

Commercial Fisheries Data

Any vessel issued a federal fishery permit with Vessel Trip Report (VTR) requirements must submit a report for each trip taken. In the report, vessel operators are required to provide information such as, date and time sailed, date and time catch landed, quantity and size of gear, average depth fished, statistical area fished, latitude and longitude, average tow time, species composition and catch weight, and total number of hauls.

Vessel Trip Reports from scallop dredge fishermen operating in Mid-Atlantic waters from Long Island, NY to Cape Hatteras, NC from June to November 2003 were used in this analysis. Number of dredge hours from trips without coordinate positions (1.5%) were prorated between the Mid-Atlantic and Hudson Canyon Controlled Access Area regions based on the percentage of dredge hours in these regions from trips with known coordinates.

The frequency of commercial and observed dredge hauls were compared for variables available in both the commercial and observer data to assess how representative the observer data were of the commercial fleet.

Temperature Data

It was necessary to acquire temperature values for each Observed and VTR fishing event in order to model and extrapolate bycatch rates for the total mortality estimate. Sea surface temperature at each position reported in the Observer and VTR databases was extracted from NOAA Advanced Very High Resolution Radiometer (AVHRR) Coastwatch Satellite Images. A Visual Basic routine was used to extract temperatures from 7-day composite images (3 days forward and backward of the haul date), using a 3x3 cell window at 1 km resolution. Therefore, a 9 km^2 area of coverage around each coordinate position was used to extract sea surface temperature. Within the 3x3 cell search radius, the pixel representing the warmest temperature was used to avoid temperatures affected by cloud coverage.

Sea surface temperature values could not be obtained for 4% of the VTR data due to missing coordinate positions on the VTR logs or to unclear satellite images. For these fishing events, sea surface temperature was predicted using a generalized additive model based on year, month, day, and statistical area in which the vessel fished.

Modeling Approach

Generalized Linear Model (GLM) and Generalized Additive Models (GAM) fitting techniques were used to understand and predict bycatch rates of sea turtles in relation to environmental variables, fishing practices, and gear characteristics in the U.S. commercial sea scallop dredge fishery in the Mid-Atlantic region.

Before a GLM was constructed, a GAM helped group continuous variables into categories (Figure 3). Fitting the GLM model with categorized variables was necessary to extrapolate bycatch rates to derive a total estimate of the bycatch of turtles in scallop dredges. All of the variables tested in the GLM model were first fitted to a GAM, in which the parameters of the continuous prediction variables were estimated by a smoothing spline. Variable values were grouped according to whether they had a positive or negative influence on the bycatch rate (i.e., the group explained more or less of the bycatch rate).

Development of a GLM Bycatch Model

The bycatch rate of turtles is defined as:

$$\frac{\text{Number of Observed Turtles}}{\text{Number of Observed Dredge Hours}}$$

where

Dredge Hour[1] = Number of Dredges*Dredge Haul Duration (Hrs)

[1]In previous years most hauls were 1 hour long with little variation around this time. With an increased sample size in 2003, there was more variation in haul durations, making it necessary to standardize for the amount of time each dredge was in the water.

Because bycatch events were counts ranging from zero to one, a logistic regression was used to model the probability of turtle bycatch per unit dredge hour, i.e., the bycatch rate (GLM function, SPLUS 6.2). The model can be written as:

$$\log(turtlebyc \,/\, dredgehr) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots \beta_i x_i$$

where β_i is a parameter coefficient, and x_i a predictor variable describing environmental, gear, or fishing characteristics.

In order to model the bycatch rate (i.e., adjusting for varying time spans), the logarithm of dredgehr becomes an offset variable with a coefficient set to 1.0 (Allison 1999; Palka and Rossman 2001). Thus the model can be rewritten as:

$$\log(turtlebyc) = \log(dredgehr) + \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots \beta_i x_i$$

A forward stepwise selection method was used to determine the best fitting model. Model parameters were estimated by maximizing the log-likelihood function. The null model was the first model in the stepwise process and was specified with the offset variable alone:

$$H_0 : \text{log(turtle bycatch)} = \text{log(dredgehr)}$$

At each step, a new variable was added to the null model (Table 3) and tested against the previous model formulation (ANOVA function, Chi-square test) to determine the better fitting model. Main effects of each variable were tested in the stepwise selection process. If a P-value was less than or equal to 0.05, then the additional variable was considered to explain more of the variability in bycatch than a model without that variable.

The order in which variables were tested in the forward stepwise model was determined by first ranking variables based on their Akaike Information Criterion (AIC) value relative to other variables in the model (StepAIC function, SPLUS 6.2). The AIC is defined as:

$$AIC = -2\log(L\theta|y)) + 2K$$

where $\log(L(\theta|y))$ is the numerical value of the log-likelihood at its maximum point and K is the number of estimable parameters (Burnham and Anderson, 2002). The AIC is a measure of the goodness of fit that includes the level of parsimony, defined as a model that fits the data well and includes as few parameters as necessary (Burnham and Anderson, 2002).

In the StepAIC process, a sequence of models is fitted to the null model in an automated process, where the first variable added has resulted in the greatest change in AIC relative to all other variables in the scope of the model. If the AIC value decreases, the new combination of variables in the model fit the data better. A 2nd variable is then fitted to the previous model based on the greatest change in AIC and so on, until the AIC value no longer reduces. Each variable in the final sequence was then tested individually in the forward stepwise selection process described above. A low AIC value relative to another model does not necessarily mean the additional variable is significant at α=0.05. P-values, therefore, were used for model selection.

Alias patterns in the full GLM model (i.e., a model with all categorical variables included) were examined to assess correlation among the explanatory variables. In addition, scatter plots and Pearson correlation coefficients between variables were examined before variables were grouped into the GAM categories to assess possible interactions.

Bycatch Rate Estimates

The spatial and temporal stratification of bycatch rates in the Mid-Atlantic was determined by the explanatory variables in the best-fitting GLM. Parameter estimates from the best-fitting model were used to predict the bycatch rate for each stratum.

The coefficient of variation (C.V.) for each bycatch rate was estimated by bootstrap resampling (Efron and Tibshirani, 1993). The resampling unit was a single trip. Replicate bycatch rates were generated based on the best-fitting GLM model, by sampling with replacement 1000 times from the original data set. The C.V. was defined as the standard deviation of the bootstrap replicate bycatch rate in a stratum divided by the bycatch rate for that stratum estimated from the original data.

An annual C.V. from stratified estimates was calculated by taking the square root of the sum of bycatch rate variances over all strata, and dividing by the sum of bycatch rates over all strata (Wade and Angliss, 1997):

$$\text{Annual CV} = \sqrt{\sum \text{var}(x_i)} \,/ \sum x_i$$

where x_i = the bootstrap replicate mean bycatch rate in each stratum.

Total Bycatch

The total estimated turtle bycatch in each stratum was calculated as the product of predicted bycatch per dredgehr (i.e., the predicted bycatch rate) for that stratum and the total number of dredge hours by the commercial fishery in that stratum:

$$\frac{\sum \text{Predicted Bycatch}_i}{\sum \text{Dredge Hour}_i} \quad \text{x} \quad (\text{Total Dredge Hours})_i$$

where i = stratum

Total bycatch was the sum of the stratified bycatch estimates.

RESULTS

Data Representativeness

Based on the spatial distribution of commercial dredge fishing effort in the Mid-Atlantic, the Hudson Canyon Controlled Access Area was over-sampled in 2003 (Table 4). Small vessels (from 42-77 ft) were under-sampled, as were small dredges (<=10 ft frame width). Fifteen percent of dredge hauls accomplished by commercial vessels in the Mid-Atlantic used dredges less than or equal to 10 feet, while only 2% of this size dredge was sampled by observers. Commercial effort in shallow depths (2-26 fm) was under-sampled, and over-sampled in mid-depth ranges (27-31 fm).

Some variables, such as tow speed, could not be used to estimate total bycatch because these data are not recorded on VTR records. Thus, for these variables, it is assumed that unobserved hauls have the same characteristics as the observed hauls used in the bycatch model.

Factors Influencing Bycatch

Significant factors affecting sea turtle bycatch were sea surface temperature and tow speed (Table 5). In estimating total bycatch, rates were stratified based on temperature because tow speed was not available from fishing logbooks. Highest probability of bycatch occurred in surface waters 22°C or warmer. Hence bycatch rates were stratified based on whether temperatures were higher or lower than 22°C.

Bycatch rates inside and outside the Hudson Canyon Controlled Access Area were identical. In addition, rates did not differ due to use and number of rock and tickler chains, vessel length, or frame width of the dredge.

Total Mortality Estimate

The total estimated bycatch of sea turtles from June to November, 2003 in the Mid-Atlantic sea scallop dredge fishery is 749 turtles (C.V.=0.28)(Table 6). Five of the 22 observed turtles were released alive and uninjured, implying a 22.7% survival rate and a 77.3%

mortality/injury rate. Hence, of the 749 interactions, an estimated 579 turtles are considered to have died or have injuries.

Out of the 749 interactions, 122 (16%) occurred in the Hudson Canyon Controlled Access Area, and 627 (84%) outside of this area (Table 6a). Interactions in the Virginia Beach Controlled Access Area are subsumed in the total estimate. However, because there was only 1 commercial trip in this Access Area between June and November 2003, the likelihood of a turtle interaction in this Access Area was very low.

DISCUSSION

Factors Influencing Bycatch

Stratifying bycatch rates by sea surface temperature accounts for much of the temporal and spatial variation in bycatch rates of turtles in the Mid-Atlantic. Observed hauls in waters 22°C or warmer occurred in offshore waters from New York harbor down to the mouth of the Chesapeake, with waters closer to shore (i.e. west of the 27fm isobath) warming sooner than offshore (Figure 4). In general, months for these warm waters, as indicated by the observed hauls, range from early July to end of October. The timing of surface temperature warming and cooling on shelf waters in the Mid-Atlantic depends on a variety of factors, including air temperatures, the position of the Gulf Stream, water transport from the north, and the timing of vernal warming or fall overturn (Jossi and Benway 2003).

Tow speed was also a significant factor affecting bycatch of turtles. Had bycatch rates been stratified by tow speed, highest rates would have occurred during hauls having tow speeds between 4.4 and 4.9 knots.

Tow speed should be investigated further as a factor influencing the bycatch of turtles. Tow speed may affect how dredges come in contact with the bottom, influencing the potential for a turtle encounter. According to James Kendall (1998), "with dredge gear, as well as with a lot of other towed gear including trawls, speed plays an important role.....the fact is that if fishermen tow too fast, they will actually fly the gear right up off the bottom much as with a kite, because the gear becomes functionally weightless." It is possible that there is an optimal speed to catch scallops that allows for the dredge to maintain contact with the bottom, leading to a higher probability of a turtle encounter if turtles are foraging or crouching on the bottom. Presence or absence of a pressure plate, which helps keep the dredge frame on the bottom, did not significantly affect turtle bycatch, though other related factors not considered in this analysis may play a role.

Bycatch Patterns

Over the last three years, sea surface temperature has been a significant predictor of sea turtle bycatch in both the Mid-Atlantic Controlled Access Areas [2001-2002], and over the broader Mid-Atlantic from New York to North Carolina [2003]. In 2001-2002, a higher probability of turtle bycatch occurred after waters warmed to 19°C, and in 2003, higher probabilities occurred after waters warmed to 22°C. These differences may reflect inter-annual variation in sea surface temperatures, turtle distributions, and shifting patterns in the fishery. Nevertheless, there may be a consistent minimal threshold temperature from year to year above which turtle bycatch is more likely to occur, though the minimal temperature threshold at which the observed interaction occurs is likely to fluctuate from year to year.

From 2001-2003, turtle bycatch occurred between depths of 25-35 fm. In general, the fishery operated in depths from 5-50 fm, with 40-50% operating in depths shallower than 25 fm over these three years. While depth was not a significant predictor of bycatch in this analysis, the area in which turtle bycatch occurred over the last three years is worth noting. Hot spots for turtle bycatch may consistently occur within certain depths that do not coincide with the entire range of the fishery. More sampling coverage should be accomplished in shallower depth ranges to further explore this idea.

Data Caveats

While the best-fitting GLM model for predicting turtle bycatch in the scallop dredge fishery included tow speed, this co-variate had to be removed from the final model because tow speed information is not available in VTR logbooks. Removing the effect of tow speed from the final model forces the assumption that bycatch rates are the same for vessels fishing at different speeds. This may cause the bycatch estimate to be biased in certain directions depending on the variability of tow speeds throughout the Mid-Atlantic.

The disproportionate amount of observer coverage in the area outside of the Hudson Canyon Access Area relative to total commercial effort may have obscured the ability to detect differences in bycatch rates among the variables examined. For example, there was very little coverage on boats using dredges 10 feet wide or smaller. The low sample size of small dredges may have prevented the detection of a difference in rates due to dredge size. This analysis assumes that bycatch rates are the same for all dredge sizes. If rates are higher or lower in small dredges the total estimated bycatch will likewise be biased high or low. Many vessels using small dredges are fishing under a General Category permit for scallops, where scallop catch is limited to 400 pounds shucked scallops outside the Controlled Access Areas and 100 pounds inside. More coverage is needed on boats using small dredges and/or of the General Category permit boats to ensure that fishing behavior on these boats does not increase the potential for turtle bycatch.

In this analysis, main effects of each categorical variable were considered in the bycatch model because there did not appear to be any interaction effects between variables. In other words, the effect of vessel length and depth on bycatch rates, for instance, are considered independently from one another in the GLM. The clustered nature of many of the parameter values, however, may have statistical consequences on the model results. For instance, the majority of smaller vessels may tow in shallower waters and at lower tow speeds. So, the range of parameter values is not represented equally across all variables. Further work needs to address whether this clustering influences the model's ability to detect significant effects of a single variable.

Further work should also investigate whether the behavior of particular vessels, other than what has been examined in this analysis, increase the likelihood of a turtle interaction. For example, 1 of the observed trips (Trip K, Table 1) took 4 turtles, 2 of the observed trips (I and L, Table 1) took 3 turtles, and 3 of the observed trips (A, C, and J, Table 1) took 2 turtles. Hence, 16 (73%) of the 22 observed interactions involved multiple interactions. These vessels may have been behaving in a manner that increased the likelihood of catching a turtle in the dredge. Identifying such possible behavioral patterns may facilitate mitigation options for reducing interactions. Furthermore, some of these options may need not apply to the entire commercial fleet.

Finally, given the association between sea surface temperature and turtle bycatch, further work should examine bycatch rates over a range of different temperature strata. Exploring changes in rates as a function of temperature may indicate whether predicted bycatch rates are sensitive to small changes in temperature. Furthermore, this research would help inform the design of possible time and area closures intended to reduce turtle bycatch, by examining the percentage of bycatch reduction achieved at various temperature ranges.

Other Fisheries

The bycatch of turtles in the Mid-Atlantic scallop dredge fishery represents only a portion of the total bycatch of sea turtles in Northwest Atlantic Ocean fisheries. For example, trawl fisheries targeting a variety of species also operate in the same area and months when turtles are present in the Mid-Atlantic. Trawls that target scallops may have a different bycatch rate of turtles than trawls that target fish because scallop trawl gear is of somewhat different design, is fished closer to the bottom, and is fished at different speeds than trawl gear for fish. However, there has been very little observer coverage with which to estimate bycatch in the scallop trawl fishery. Based on reported trips, coverage (% trips observed) from 2001-2003 was roughly 0.2%. There were 7 trips observed during 2001-2004 [4 in 2001; 1 in 2002; 0 in 2003; and 2 in 2004 through July] and no sea turtles were observed on any of these trips. Observer coverage is currently scheduled for late summer and fall of 2004. This coverage may start to shed light on the magnitude of turtle bycatch in the scallop trawl fishery.

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Table 1: Turtle Bycatch in 2003 Mid-Atlantic Scallop Dredge Fishery. 'CAS'=Controlled Access Area; 'Out'=Outside this Area; 'Unk'=Unknown. Trip letters signify a unique trip.

Event Number	Month	Trip	Depth (fm)	Towspeed (kn)	Dredge Frame Width (ft)	Pressure Plate Used	Rock Chains Used	Number of Rock Chains Used	Tickler Chains Used	Number of Tickler Chains Used	Area	Vessel Length (ft)	Latitude (N)	Species	SST (C)	Animal Condition
1	7	C	27	4.6	15	1	1	3	1	2	cas	81	39	Cc	23.2	Alive, Injured
2	7	C	30	4.8	15	1	1	3	1	2	cas	81	39	Cc	22.8	Alive, Injured
3	7	E	32	4.4	15	1	1	3	1	3	cas	84	39	Unk	23.1	Alive, Not Injured
4	7	F	25	4.5	13	1	1	3	1	3	cas	82	38	Cc	20.8	Alive, Condition unknown
5	8	B	28	4.0	15	1	0	0	0	0	out	85	37	Cc	23.8	Alive, Injured
6	8	G	30	4.4	13	1	0	0	1	1	cas	76	38	Cc	25.4	Alive, Injured
7	8	H	30	4.5	13	Unk	1	3	1	3	cas	91	38	Cc	25.5	Alive, Resuscitated
8	8	I	28	4.5	14	1	1	3	1	2	cas	87	38	Cc	25.4	Dead, Fresh
9	8	I	29	4.6	14	1	1	3	1	2	cas	87	39	Unk	25.3	Alive, Not Injured
10	8	I	32	4.5	14	1	1	3	1	2	cas	87	39	Unk	25.1	Alive, Not Injured
11	9	J	32	4.7	15	1	1	3	1	2	cas	85	38	Cc	24.0	Alive, Injured
12	9	J	32	4.6	15	1	1	3	1	2	cas	85	38	Cc	23.6	Alive, Not Injured
13	10	A	26	4.9	13	1	1	3	1	2	out	88	38	Cc	23.1	Alive, Injured
14	10	A	27	4.7	13	1	1	3	1	2	out	88	38	Unk	24.4	Alive, Injured
15	10	D	28	4.8	15	1	0	0	1	1	cas	83	39	Cc	22.1	Alive, Injured
16	10	K	29	4.9	13	1	1	3	1	3	cas	75	38	Cc	22.2	Alive, Injured
17	10	K	30	4.7	13	1	1	3	1	3	cas	75	38	Unk	22.7	Alive, Condition unknown
18	10	K	30	4.8	13	1	1	3	1	3	cas	75	38	Cc	22.4	Alive, Condition unknown
19	10	K	30	4.7	13	1	1	3	1	3	cas	75	38	Cc	22.4	Alive, Injured
20	10	L	26	4.0	13	0	0	0	1	1	out	85	38	Cc	21.9	Alive, Injured
21	10	L	28	4.0	13	0	0	0	1	1	out	85	38	Cc	22.7	Alive, Injured
22	10	L	28	4.1	13	0	0	0	1	1	out	85	38	Cc	24.9	Alive, Not Injured

Table 2. Turtles caught on off-watch hauls or which were severely decomposed in the 2003 scallop dredge fishery. These turtles were not included in the 2003 total bycatch estimate. Trip letters signify a unique trip.

Off-Watch Bycatch Events	Trip	Month	Species	Area	Comments
	A	October	Loggerhead	Outside	
	B	October	Loggerhead	Hudson Canyon CA	
Severely Decomposed Animals	C	September	Loggerhead (identified by skull)	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear
	C	September	Unknown	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear
	C	September	Unknown	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear
	C	September	Unknown	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear
	C	September	Unknown	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear
	C	September	Unknown	Hudson Canyon CA	Turtle brought on board entangled in gillnet gear

Table 3: Categorical Variables Examined in an Analysis of Factors Affecting Sea Turtle Bycatch in 2003 Mid-Atlantic Scallop Dredge Fishery. Percentage of Observed Hauls in each category is also shown.

Variable	**Definition** (%Hauls)
Sea Surface Temperature	Thi: 22°C - 26.5°C (43%) Tlo: 7.6°C - 21.9°C (57%)
Season	Spring: June (14%) Summer: July-Oct (68%) Fall: November (18%)
Depth	Shallow: 2-26 fm (25%) Mid-Depth: 27-31 fm (45%) Deep: 32-60fm (30%)
Latitude Zone	1: 37°N to 38.9°N (56%) 2: 39°N (39%) 3: 40°N (5%)
Inside/Outside Controlled Access Areas	Inside (56%) Outside (44%)
Vessel Length	Small: 42-77 ft (18%) Medium: 78-87 ft (45%) Large: 88-109 ft (37%)
Tow speed	Slow: 2.9-4.3 knots (34%) Medium: 4.4-4.9 knots (54%) Fast: 5.0-6.2 knots (12%)
Presence/Absence of Tickler Chains	0: No chains (17%) 1: Chains (83%)
Presence/Absence of Rock Chains	0: No chains (47%) 1: Chains (53%)
Number of Tickler Chains Used	1: 0 or 1 Chain (44%) 2: 2 or 3 Chains (51%) 3: 4 to 6 Chains (5%)
Number of Rock Chains Used	1: 0 Chains (47%) 2: 1-3 Chains (44%) 3: 4-11 Chains (9%)
Presence/Absence of a Pressure Plate	0: No pressure plate (11%) 1: Pressure plate (85)% 9: Unknown (4%)
Frame Width of Dredge	10 ft (2%) 11 ft (5%) 12 ft (1%) 13 ft (38%) 14 ft (16%) 15 ft (36%) 16 ft (2%)

Table 4. Frequency of observed versus commercial dredge hauls in the Mid-Atlantic scallop dredge fishery from June-November 2003.

Variable	Definition	Observed Hauls	VTR Hauls
Sea Surface Temperature	Thi: 22°C - 26.5°C Tlo: 7.6°C - 21.9°C	(43%) (57%)	(40%) (60%)
Season	Spring: June Summer: July-Oct Fall: November	(14%) (68%) (18%)	(19%) (65%) (16%)
Depth	Shallow: 2-26 fm Mid-Depth: 27-31 fm Deep: 32-60fm	(25%) (45%) (30%)	(45%) (29%) (26%)
Inside/Outside Controlled Access Areas	Inside=Hudson Canyon Controlled Access Area Outside=Mid-Atlantic excluding Hudson Canyon Access Area	(56%) (44%)	(15%) (85%)
Vessel Length	Small: 42-77 ft Medium: 78-87 ft Large: 88-109 ft	(18%) (45%) (37%)	(39%) (42%) (19%)
Frame Width of Dredge	<10 ft 10 ft 11 ft 12 ft 13 ft 14 ft 15 ft 16 ft	(0%) (2%) (5%) (1%) (38%) (16%) (36%) (2%)	(2%) (13%) (4%) (4%) (28%) (11%) (38%) (0%)
Length of Trip	Short: <3 days Long: >=3 days	(1%) (99%)	(5%) (95%)
Permit plan	SC: Limited Access Permit SCG: General Category Scallop permit	(99%) (1%)	(96%) (4%)
Quantity of Dredges per Haul	1 Dredge 2 Dredges	(3%) (97%)	(15%) (85%)

Table 5: Analysis of Deviance Table for Turtle Bycatch Model Selection. * indicates significant variables affecting turtle bycatch

Model	Df	Deviance	Residual Df	Residual Deviance	Pr(Chi)	AIC
null model only			4919	276.84		278.84
null + temp*	-1	-21.75	4918	255.08	0.000003	259.08
null + temp* + towspeed*	-2	-9.68	4916	245.40	0.008	253.40
null + temp + speed + season	-2	-4.27	4914	241.13	0.118	253.13
null + temp + speed + tickler chains used	-2	-2.83	4914	242.56	0.242	254.13
null + temp + speed + latitude zone	-2	-0.82	4914	244.06	0.514	254.29
null + temp + speed + pressure plate used	-2	-2.29	4914	243.11	0.317	254.88
null + temp + speed + inside/outside cas	-1	-0.22	4915	245.18	0.639	254.94
null + temp + speed + number of rock chains	-1	-0.03	4915	245.37	0.856	255.04
null + temp + speed + number of tickler chains	-1	-0.01	4915	245.39	0.942	255.08
null + temp + speed + frame width	-1	-0.04	4915	245.36	0.844	255.13
null + temp + speed + depth	-2	-2.17	4914	243.23	0.338	255.44
null + temp + speed + vessel length	-2	-1.44	4914	243.96	0.486	255.97
null + temp + speed + rock chains used	-2	-0.72	4914	244.67	0.696	256.43

Table 6: Total Bycatch Estimate of Turtles from June-November in the Mid-Atlantic Sea Scallop Dredge Fishery

Water Temp	Predicted bycatch rate	Total Observed Dredge Hours	Total VTR Dredge Hours	Total Observed Trips	Total VTR Trips	Total Bycatch	Observer Coverage (% Dredge hrs observed)	CV	95% CI
>=22˚C	0.004271	4709.7	156749.8	31	1102	670	3.0%	30.0%	305-1058
<22˚C	0.000335	5965.1	235699.6	40	1597	79	2.5%	66.8%	0-192
Totals		10674.8	392449.4	71	2699	749	2.7%	28.2%	

Table 6a: Total Bycatch Estimate of Turtles from June-November in the Hudson Canyon Controlled Access Area and Outside this area in the Mid-Atlantic Sea Scallop Dredge Fishery

Area	Water Temp	Predicted bycatch rate	Total Observed Dredge Hours	Total VTR Dredge Hours	Total Observed Trips	Total VTR Trips	Total Bycatch	Observer Coverage (% Dredge hrs observed)	CV	95% CI
Hudson Canyon										
	>=22°C	0.004271	3156.6	25725.8	17	112	110	12.3%	30.0%	50-174
	<22°C	0.000335	2796.4	35569.5	17	122	12	7.8 %	66.8%	0-29
Total			5953.0	61295.3	34	234	122	9.7 %	28.2%	
Outside										
	>=22°C	0.004271	1553.1	131024.0	14	990	560	1.2%	30.0%	255-884
	<22°C	0.000335	3168.7	200130.1	23	1475	67	1.5%	66.8%	0-163
Total			4721.8	331154.1	37	2465	627	1.4%	28.2%	
Grand Total			10674.8	392449.4	71	2699	749	2.7%		

Figure 1. Observed and Commercial Scallop Dredge Trips from June-November 2003 in the Mid-Atlantic Region.

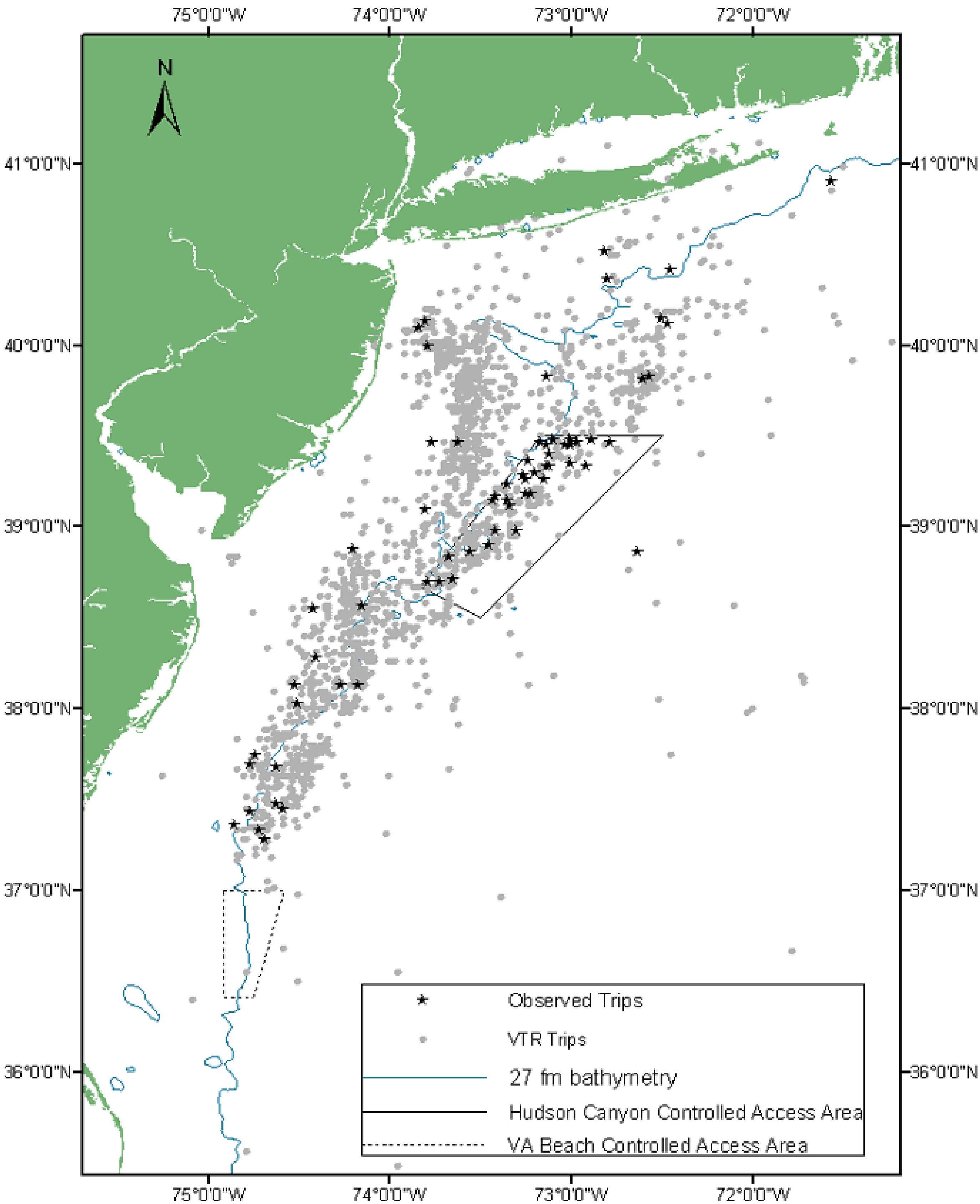


Figure 2. Turtle Bycatch in the 2003 Mid-Atlantic Scallop Dredge Fishery.

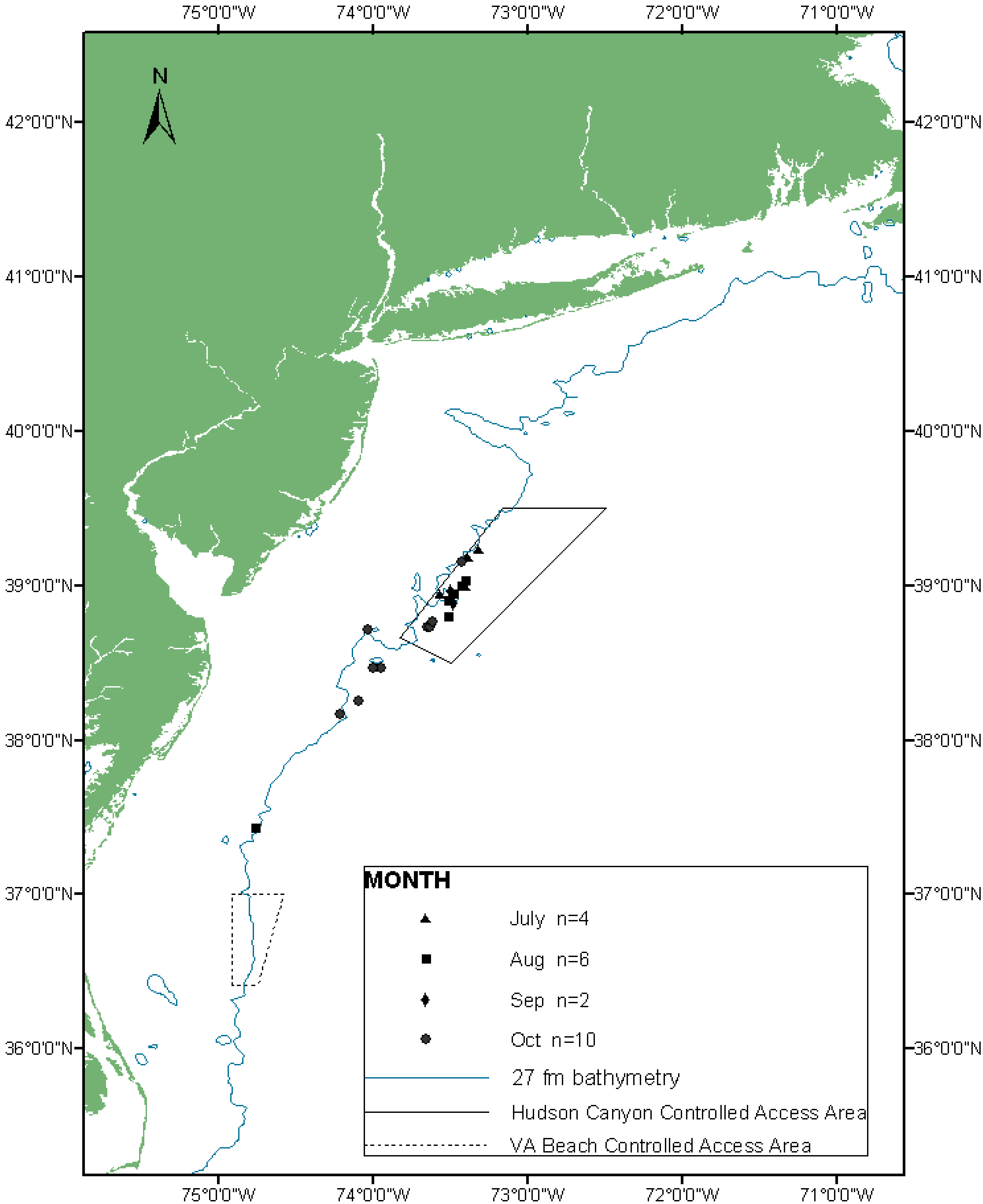


Figure 3. Partial fit for the General Additive Model (GAM) of sea turtle bycatch with temperature as a covariate, showing the relationship estimated by a smoothing spline. Temperatures above 22°C have a positive influence on the bycatch rate. 95% confidence bands are also shown. All continuous variables in the GAM were categorized in a similar manner.

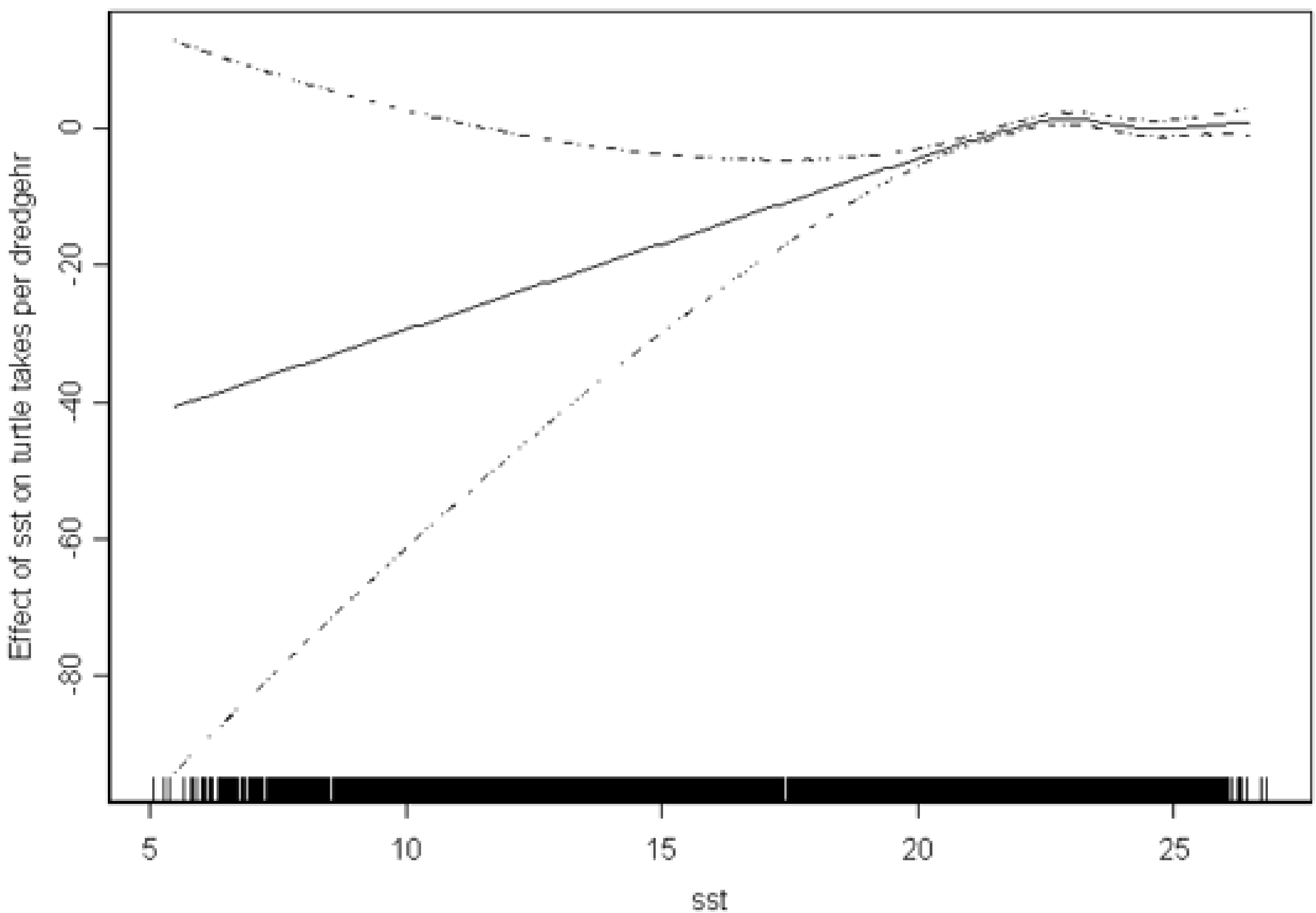
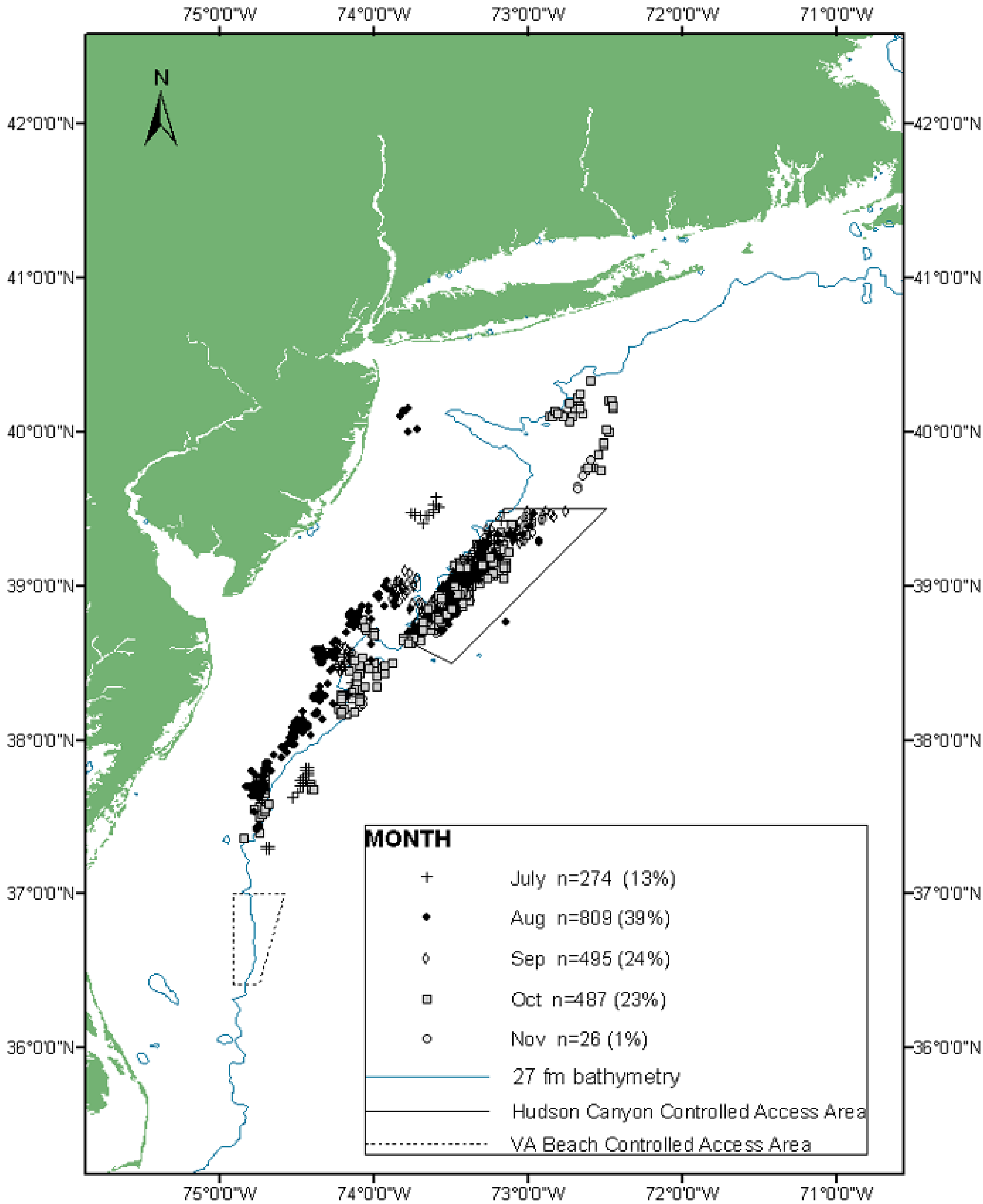


Figure 4. Observed Hauls where Sea Surface Temperature is greater or equal to 22°C in the 2003 Scallop Dredge Fishery.



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