Understanding Impacts of the Sea Scallop Fishery on Loggerhead Sea Turtles

Final Report

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Atlantic Sea Scallop Research Set Aside Program
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Submitted By

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Executive Summary:

Coonamessett Farm Foundation's (CFF) 2019/20 project "Understanding Impacts of the Sea Scallop Fishery on Loggerhead Sea Turtles" has continued to add invaluable data to our historical dataset on loggerhead sea turtles. The focus of this project is to monitor and evaluate changes in the distribution and behavior of loggerhead sea turtles to better understand their current interactions with the scallop fishery. This improved understanding will determine if ESA requirements for the Atlantic Sea Scallop fishery are being met and help reduce injury and mortality of turtle takes by scallop dredges.

We conducted one trip this summer. This trip occurred from June 4 – 9 on the F/V Kathy Ann. During this trip, we deployed 10 satellite tags within the southern Mid-Atlantic Bight (MAB) region (**Table 1; Figure 1**). Weather conditions were unfavorable, and we were limited to one full day and two half days of good weather. This forced us to end the trip a day early without completing an ROV deployment. We collected lavage samples from all caught turtles, and we did not identify the presence of nematodes in any of them.

Turtles behaved slightly differently than they did in previous years, with post-tagging migrations generally shorter in distance (**Figure 2**). This may be skewed due to the shorter transmission durations for most of the tags, as many of them stopped transmitting during periods when turtles may have continued migrating. The northern-most migrant was Turtle 2019.03, but this turtle did not cross 40°N latitude. This tag stopped transmitting on July 28, 2019, so it is possible that this turtle would have continued north during the remaining summer months before turning south in early fall, as is typical for loggerheads in the region. In the years prior to 2018, we typically documented several turtles, from the May and early June deployments in particular, travelling farther north, crossing the 40°N latitude line and reaching the New York Bight region. The 2019 turtles stayed more localized to their tagging locations, with some even travelling south after release. This more localized movement pattern is similar to observed turtle behavior in 2018, but is in conflict with established trends from 2009 - 2017. It is unclear why this shift has occurred, and more tagging is required to identify the cause of this change in behavior.

In FY19/20, in order to quantify the potential impact scallop fishing has on loggerheads, we developed a Turtle Impact Tool. This tool incorporates spatially and temporally specific data of monthly turtle densities, derived from loggerhead tagging efforts, and of scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data to calculate and quantify the potential impact allocation alternatives could have on loggerheads. In general, we found that more allocated days-at-sea (DAS) will likely yield higher turtle impact; however, the impact can be reduced when shifting where and when the DAS occur, even within the traditional peak season for loggerheads within the MAB (May – November). This tool can be continuously updated and improved; however, this requires continued loggerhead surveys and tagging along with the scallop surveys.

1. Purpose

The National Marine Fisheries Service (NMFS) expects scallop gear to catch an estimated average of 140 loggerhead sea turtles each year, with 47% incidental sea turtle mortality (NMFS 2012). Reasonable and Prudent Measures (RPMs) are deemed necessary to minimize estimated incidental turtle mortality in the scallop fishery (NMFS 2012). This research directly addresses RPMs #3, #4, #5, #6 and #7 (**Table 2**). There is a necessity to continually review available data to determine whether there are areas or conditions within the area where sea turtle interactions with scallop fishing gear are more likely to occur. For the scallop fishery to maintain an exemption from the prohibitions under Section 9 of the Endangered Species Act (ESA), these RPMs, which are non-discretionary, must be implemented for the scallop fishery to continue operation under current conditions. While this research is not one of the highest scallop RSA research priorities, it is required under the law. In the absence of NMFS Northeast Fisheries Science Center (NEFSC) funding, the scallop RSA is the only current source of funding available to allow the scallop fishery to continue meeting ESA requirements.

Table 1: Summary table for tags deployed during 2019.

Turtle ID	Date Deployed	Transmission Duration as of June 1, 2020 (Days)	Capture Lat	Capture Lon	Capture SST	Curved Carapce Length	Tag Type
2019.01	6/5/2019	107	38.15317	-74.2688	18.89	89.5	SMRU
2019.02	6/5/2019	362	38.01725	-74.5159	19.17	72	SMRU
2019.03	6/5/2019	53	38.04032	-74.5086	19.17	61.9	SMRU
2019.04	6/5/2019	65	38.04053	-74.5091	19.17	72.8	SMRU
2019.05	6/5/2019	73	38.04068	-74.5093	19.17	84.5	SMRU
2019.06	6/5/2019	173	38.04092	-74.5097	19.22	89	SMRU
2019.07	6/6/2019	82	37.46485	-74.7341	20.06	89.2	SMRU
2019.08	6/6/2019	196	37.54088	-74.8457	20.00	86.8	SMRU
2019.09	6/6/2019	75	37.74138	-74.7096	20.00	74.2	SMRU
2019.10	6/7/2019	53	38.02852	-74.4444	19.61	80.8	SMRU

This project continues over ten years of turtle research and has evolved from a multitude of studies conducted since 2004 under scallop RSA funding and NMFS contracts. These projects have led to the development of sea-turtle excluder gear (turtle chain mats and turtle deflector dredges) and their incorporation into accompanying regulations. Furthermore, they have advanced the ability to locate, track, and observe loggerhead sea turtles through innovative use of dredge and remotely operated vehicle (ROV) mounted video cameras, side-scan sonar, aerial surveys, and satellite tags. Over the duration of these past projects, this CFF/NMFS joint effort has resulted in the tagging of over 200 loggerheads, totaling ~66,500 days of tracking data. We have demonstrated exceptional success in tracking and observing sea turtles throughout the water column with an ROV and have obtained footage of sea turtles foraging on the sea floor and socializing at the surface. The data from these tags were critical for the first ever estimate of absolute abundance of loggerheads in the shelf waters of the east coast and have helped to define critical habitat for loggerheads (NMFS 2011). To maximize the value of the tagging efforts, additional sampling has been done after turtles are captured. In addition to morphometric

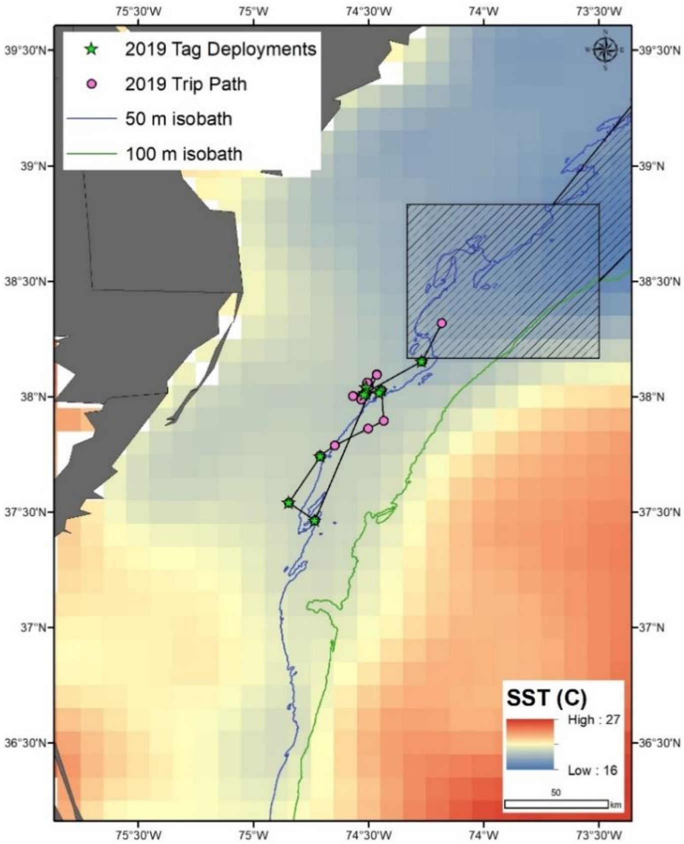

Figure 1: Trip path for the 2019 turtle tagging trip aboard F/V Kathy Ann with overlaid average SST for those days, June 5 – 8, 2019. Hashed boxes, in all maps, represent MAB scallop access areas.

measurements, blood, genetic, and fecal samples were taken from each tagged turtle to improve our understanding of the overall biology of this species and its interactions with the environment.

The Coonamessett Farm Foundation RSA-funded sea turtle research is a collaborative program, most notably with NEFSC, to help advance the goals of many entities. This collaborative effort was established due to the complicated nature and high costs of catching and tagging loggerhead turtles in the open ocean. As a result, we have developed a set of overarching programmatic goals that are expected to be resolved one piece at a time. To support these goals, CFF has continued, on a yearly basis, to catalog new data, update distribution maps, and assess new or modified methods while retaining the larger research goal of studying overlap with the sea scallop fishery (**Figure 3**). As such, the sea turtle research program is like most yearly fisheries surveys, which on an annual basis add important data points to update assessments but require several years of effort before yielding higher level products. Since 2014, this collaborative research program has led to six published peer-reviewed manuscripts, one in the final stages of peer review, and two more papers are in preparation (**Appendix 1**). Furthermore, the data from this program has been used in two fully funded Saltonstall-Kennedy (S-K) grants (FY18) focused on oceanography and climate change and a NMFS project (FY18-FY20), funded through the National Protected Species Toolbox program, to conduct a spatial and temporal overlap analysis of the sea scallop fishery and sea turtle densities in the Greater Atlantic Region.

The programmatic goals listed below determine if there are any factors that may be impacting anticipated turtle take rates, a key requirement for initiating an ESA Section 7 Consultation. Current take estimates are based on scallop-fishery dredge hours in the Mid-Atlantic from May through November (NMFS 2012), and continued use of the dredge-hour metric assumes turtle seasonal distributions, population size, and behavior have not changed since the 2007 fishing year. This indirect approach is required because scallop dredges rarely catch turtles and takes cannot be calculated from on-deck observations. The annual goals are objectives for the current funding year, while programmatic goals are those to be achieved across several years.

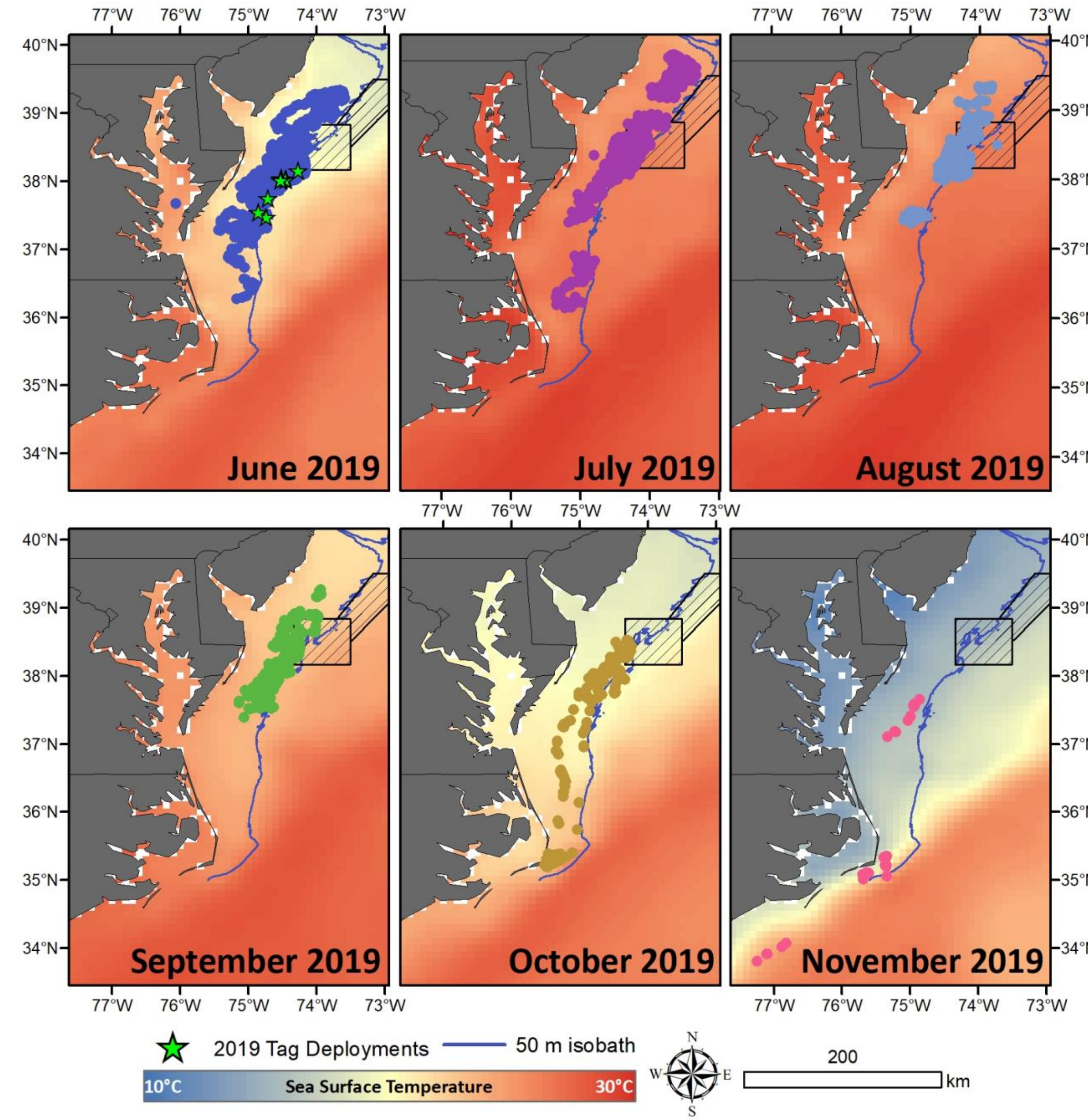

Figure 2: Turtle locations during the TDD required months for all tags deployed during the June 2019 trip overlaid with average monthly SST during that time.

Annual goals:

1. *Collect samples from a minimum of 10 loggerhead turtles caught at-sea.*
2. *Document seasonal distribution of loggerhead turtles within the MAB for transmitters functioning during the funding year.*
3. *Identify presence/absence of nematode parasite in lavage samples.*
4. *Present an updated analysis of the habitat range of loggerheads within the key areas overlapping the scallop fishery in both space and time.*

5. *Assess results of new or modified methods.*
6. *Expand database of loggerhead turtle biology and ecology to be used by management.*

Programmatic goals:

1. *How do latitudinal distributions change seasonally? Interannually?*
2. *How much time do turtles spend on bottom compared to time spent on the surface?*
3. *Is there a difference in spatiotemporal distributions based on demographics or morphometrics?*
4. *Do turtles display site fidelity to foraging areas?*
5. *How is behavior changed by water temperature?*
6. *What are the primary prey species and does this impact parasite load?*
7. *Do oceanographic features impact migratory patterns?*
8. *How will climate change alter the environmental parameters (temperature, chlorophyll concentration and oceanic currents) impacting loggerheads in this region?*
9. *What are the unique oceanographic characteristics of the MAB and how do they impact scallop abundance?*

Table 2: Samples taken per turtle and the relevant Reasonable and Prudent Measure (RPM) that each sample covers.

Samples Taken Per Turtle	Purpose	Relevance to Scallop Fishery
Morphometric Measurements (shell size and tail length)	To determine size and life stage of each turtle	TDD and turtle chains specifications - correct size for turtles within the region? (RPM #4) Demographic information for population estimates (RPM #3)
Blood Sample (12 ml)	Health status, hormone levels (gender), stable isotope values, genetics	Are turtles eating scallops? Population health and stress levels (RPM #3 and #6)
Skin Sample	Genetics, Stable Isotope values	Have turtles been eating scallops? Population health and structure (RPM #3)
Cloacal Lavage	Identify nematode presence	Nematodes
Physical Health Assessment	Checked for injuries, both new and healed.	Sources of injury, including from fisheries interactions (RPM #4, #7)
Passive tagging	For population estimates	Population size and distribution -> likelihood of interactions (RPM #3)
Body Temperature	Health Status	Baseline for healthy turtles to improve survival of incidentally taken turtles (RPM #6)

2. Methods

At-sea Operations

CFF provided at-sea scientists for the research trip, while Jim Gutowski at Viking Village Fisheries oversaw vessel coordination and operations of the F/V Kathy Ann.

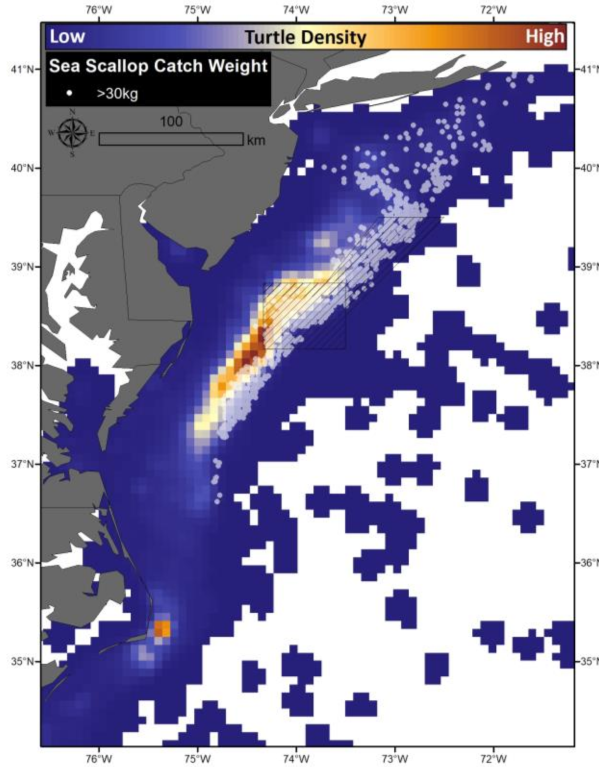

Figure 3: Density of sea turtle location data between May and November from 2009 – 2019 overlaid with scallop catch from the NMFS survey.

Turtle spotting efforts were restricted to daylight hours, between 0700 and 1800 hours. Once a turtle was spotted, the vessel maneuvered toward it and stopped when within 50 meters of the animal(s). Once the vessel was in the appropriate position, two crew members launched the collection boat, an open 14' Achilles soft bottom zodiac. When the zodiac approached within six feet of the turtle, a NMFS-approved ARC twelve-foot hoop net was used to capture it. The netted turtle was then carefully brought alongside the zodiac and lifted on board with the help of the crew member. The zodiac was brought alongside the larger vessel, and the turtle was transferred to a large rectangular net that is attached (as a brailer) to a specially rigged winch and boom to safely transfer the turtle aboard the F/V Kathy Ann.

After transfer, the turtle was positively photo-identified as a loggerhead sea turtle using the Sea Turtle Species Identification Key (NOAA Technical Memorandum NMFS-SEFSC-579). We then measured the carapace, taking the curved (CCL) and straight carapace lengths (SCL), and examined the animal to ensure it was in suitable condition for tagging. If the turtle was approved, epibionts were removed from the carapace at the intended bonding site of the tag. The transmitters were attached with a two-part cool setting epoxy with the antenna oriented backward, at the point where the first and second vertebral scutes meet (**Figure 4**). Biological samples were collected, including blood, tissue and lavage samples for on-shore analyses. Sea turtles were then lowered using the same large rectangular net over the side of the boat, with engine gears in a neutral position, in areas where they were unlikely to be recaptured or injured by vessels.

This year, two of the deployed tags were adopted by local high schools: Falmouth High School in Falmouth, MA and Jonathon Law High School in Milford, CT. We also deployed a drifter for Falmouth High School in the area where the turtles were tagged to compare passive movement by surface currents through the region with active movements of the turtles. The tag data were shared with the high schools during presentations by Samir Patel at the schools. This portion of the project was partially funded through a grant awarded by the Falmouth Fund and private donations.

Figure 4: Turtle safely being returned to the sea after sampling and satellite-tag attachment. The location and orientation of the tag on this turtle is representative of all tag placements.

Fecal Sample Analyses

In addition to samples taken at sea, seven fecal samples were taken from necropsied turtles in 2020. All fecal samples were analyzed at Roger Williams University in the Roxanna Smolowitz lab. Analysis protocols were developed by Dr. Smolowitz specifically for identifying the presence of eggs from the nematode species *Sulcaris sulcata*. First, each sample was strained through a fine-mesh tea strainer to remove large particulate matter. From each sample, a maximum of 50 ml was used. This 50-ml subsample was centrifuged to remove excess liquid. From the remaining particulate, 15 ml was taken and centrifuged again. Excess liquid was decanted, and a flotation solution was added. This mixture was centrifuged a third time with a cover slip placed as a lid on the sample tube. Due to the density of the flotation solution, centrifugation pushed the eggs to the surface in contact with the cover slip. This cover slip was placed on a microscope slide and thoroughly analyzed at 10x and 20x magnifications, and all noticeable findings were photographed.

Data Analysis

To complete the annual goals, we summarized telemetry data received from all 10 tags. We then identified the seasonal movement patterns of these tagged turtles to determine the localized hotspots for loggerheads depending on time of year. We overlaid these data with SST to provide context for how the temperature regimes in the region shift through the year. Then we compared the 2019 tag data to those from previous seasons. We also updated the full suite of data with the 2019 tags to improve mapping of turtle density during the months the turtle deflector dredge is required in the MAB (May – November, **Figure 5**) and overlaid these results with historical scallop sampling from the NMFS survey. Overlap between loggerhead seasonal distributions and scallop fishing effort was analyzed in more depth during the development of our new Turtle Impact Tool (**Appendix 2**).

We investigated diving behavior both throughout the duration of tag deployments and also specifically in the MAB during the TDD-required months. We compared the amount of the time at the surface as a proxy for the time spent diving (i.e. more time at the surface indicates less time diving and vice versa). Transmitted data were aggregated into percent of time spent at the surface over six-hour bins. We compared day versus night diving and diving based on demographics, specifically comparing Stage 3 (<82 cm CCL) and Stage 4 (>82 cm CCL) size classes (TEWG 2009). There were five turtles within each demographic stage; however, transmission durations varied substantially. Stage 3 turtles had generally shorter transmission durations, as a result, we compared dive behavior across the complete TDD-required months and also for the first 60 days of transmissions to ensure a more equal comparison of data.

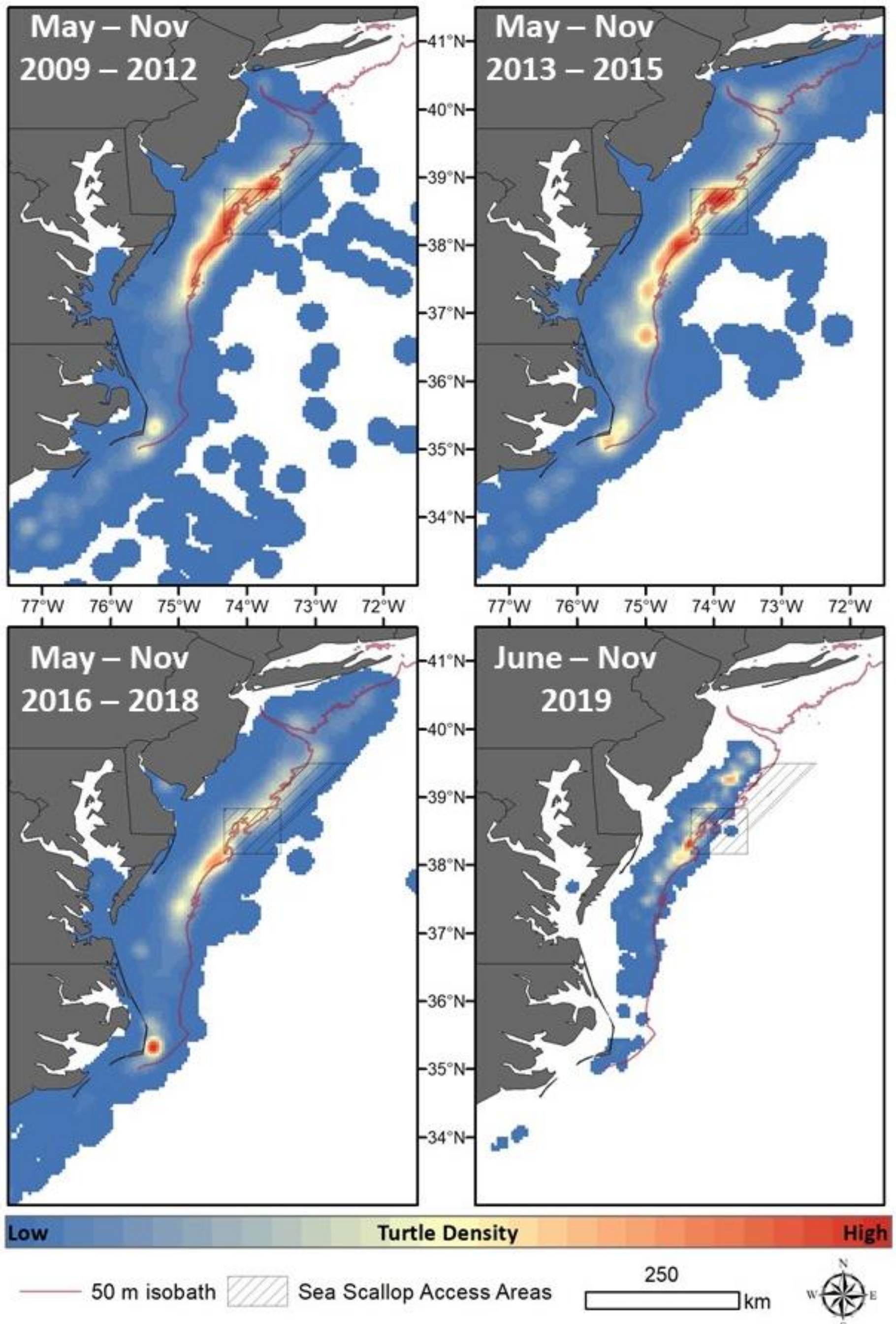

Figure 5: Comparison of turtle location data between the 2019 tags and previous years.

We compared SST with dive behavior using a regression model to determine if there was a linear relationship between these variables. To continue investigation of the Cold Pool, started in Patel et al. (2018), we plotted the temperatures recorded by the tags during surface and deepest dives within the MAB.

Because all 2019 sampled turtles were negative for nematodes, nematode analysis included data from 2016-2018. We aggregated the location data for the turtles that were positive for nematodes to determine a geographic range for turtles more likely to have the parasite.

3. Results and Discussion

Annual Goal #1: *Collect samples from a minimum of 10 loggerhead turtles caught at-sea.*

During the 2019 season we deployed 10 SMRU SRDL tags. In total, we encountered 29 turtles. SST ranged between 19° - 20° C throughout the trip. All turtles were caught in shelf waters and mean (± SD) CCL (notch to tip) was 80.1 ± 9.4 cm. Compared to 2018, we encountered turtles that were slightly smaller on average (2018 CCL mean ± SD = 81.4 ± 8.6 cm, n = 35); however slightly larger than 2017 turtles (2017 CCL = 78.4 ± 12.1 cm; n = 22). In addition to tag deployments, we accrued a range of biological and morphometric samples to improve understanding of the health and demographics of this population. As of June 1, 2020, one tag was still transmitting on Turtle 2019.02. When combined across all years, we have now accrued ~66,500 transmission days with 211 satellite tag deployments.

The satellite tags had been sitting in standby mode for over a year, resulting in potentially lower battery life at deployment. Overall, tag duration this year averaged 124 days as of June 1, 2020. This is substantially lower than previous years (average duration for all previous years combined

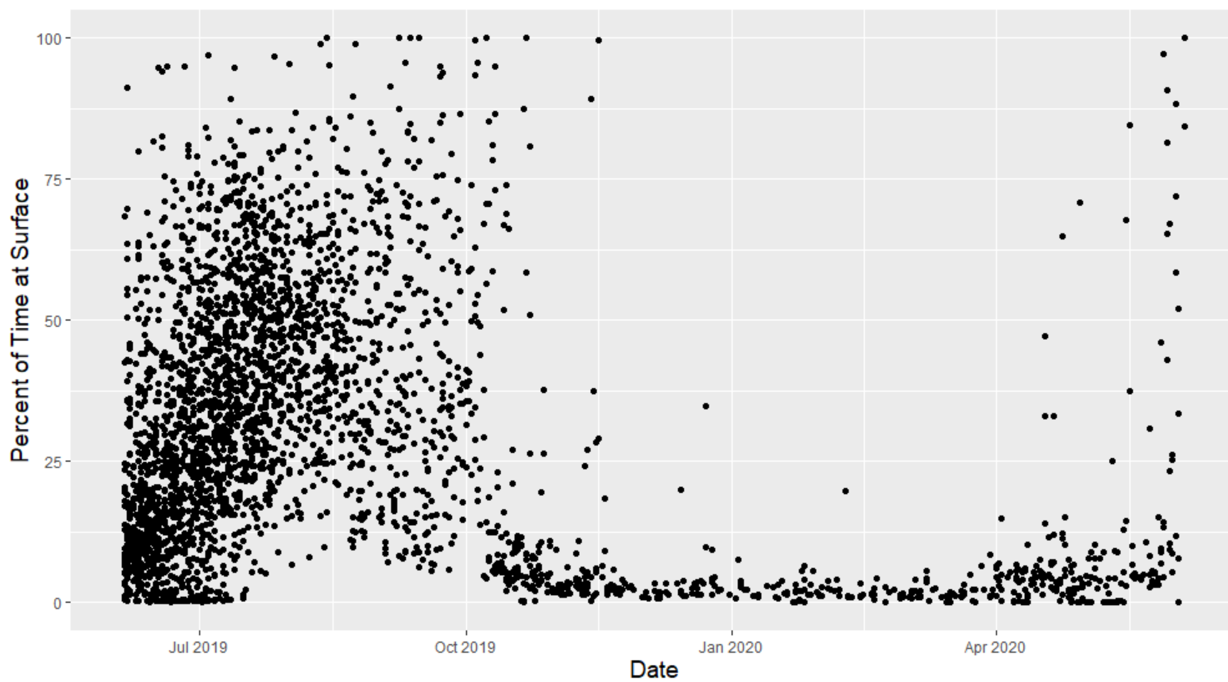

Figure 6: Percent of time at the surface for all 2019 tags from date of deployment till June 5, 2020.

= 315.1 days), and we suspect this is due to the tags remaining in storage for such an extended period of time. In our proposal we requested purchase of 20 new tags, which are typically parametrized to last 13 months, but our budget was reduced and we were only able to deploy these ten older tags. To adequately monitor loggerheads and allow the scallop fishery to continue meeting its ESA obligations, we must continue to tag and sample from at least 20 turtles per season (see report conclusions for more detail). Tagging efforts for 2019 did not meet this threshold, and as a result, our conclusions on the collected data do not necessarily represent population scale trends.

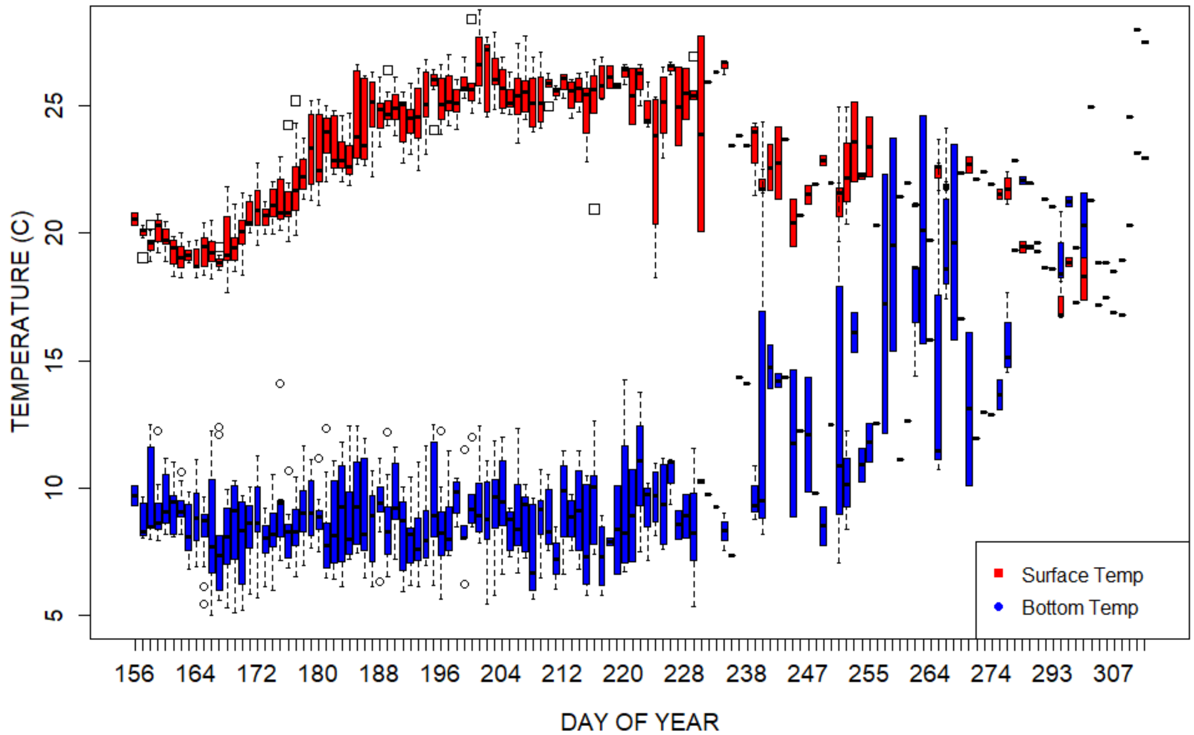

Figure 7: Surface and bottom temperatures from satellite tags deployed in 2019. Due to low tag durations and in turn fewer transmissions, large data gaps started occurring after day ~230.

Annual Goal #2: *Document seasonal distribution of loggerhead turtles within the MAB for transmitters functioning during the funding year.*

Turtles tagged in 2019 exhibited a similar pattern to previous years of foraging in the MAB throughout the summer and early fall months before retreating south in mid to late fall. Similar to the 2018 cohort of tagged turtles, the 2019 turtles remained farther south during their time in the MAB, with no turtle migrating north of latitude 40°N. The 2019 turtles had a particularly small distribution range within the MAB, and this was likely due to the combination of few tag deployments and shorter transmission durations not capturing the full extent of turtle movements within the region. The 2018 set of tags also had short tag durations; however, by deploying 35 tag this countered the limitations in the data associated with such short deployments.

Dive patterns were analyzed to determine if turtles adjust their habitat usage depending on time of day, demographics and SST while in the MAB. It's important to understand the drivers of dive behavior to determine what conditions cause loggerheads to be more susceptible to being directly impacted by a dredge (Hawkes et al. 2006). Dive behavior varied based on season, region, time of day and size of turtle. For season and region, time at surface dropped to nearly zero after turtles left the MAB and settled along the coastal North Carolina waters (**Figure 6**). Time at surface began to increase again in April as turtles initiated their return migration to the MAB. In 2019, due to poor tag durations, we only received data from three tags after Dec 1. Within the MAB and TDD-required months, dive behavior transitioned from less than 25% of time at the surface to closer to 50% of time at the surface. This contrasts established trends of dive behavior associated with migration and foraging behavior (Patel et al. 2015), but due to the unique temperature profiles of the MAB, this behavior aligns well with the increased SST for the region (**Figures 7 and 8**). Previous research has found that during migratory behavior on route to a foraging ground, loggerheads typically spend more time closer to the surface and then transition to less time at the surface due to the increase in diving to the bottom to forage on benthic prey (Patel et al. 2015). However, in the MAB, turtles seemed to spend less time near surface during their migration through the region, with an increasing trend in time spent at the surface as SST rose in the region. This relationship was significant (glm, $p < 0.0001$) with SST explaining 42.8% of the deviance in percent time at the surface. Surfacing time and SST reached a peak in late July, and plateaued for ~2 - 3 months, before returning to less time at the surface as the thermocline broke down.

Dive behavior was significantly different (t-Test, df = 2911, $p < 0.001$) between day and night in the MAB (**Figure 9**). Due to the programming of the tag, day was considered 0700 – 1900 and night was considered 1900 – 0700. During the day turtles averaged (±SD) 31.7 ± 20.4 percent of their time at the surface per six-hour period, while during the night turtles averaged 35.0 ± 24.1 percent of their time at the surface.

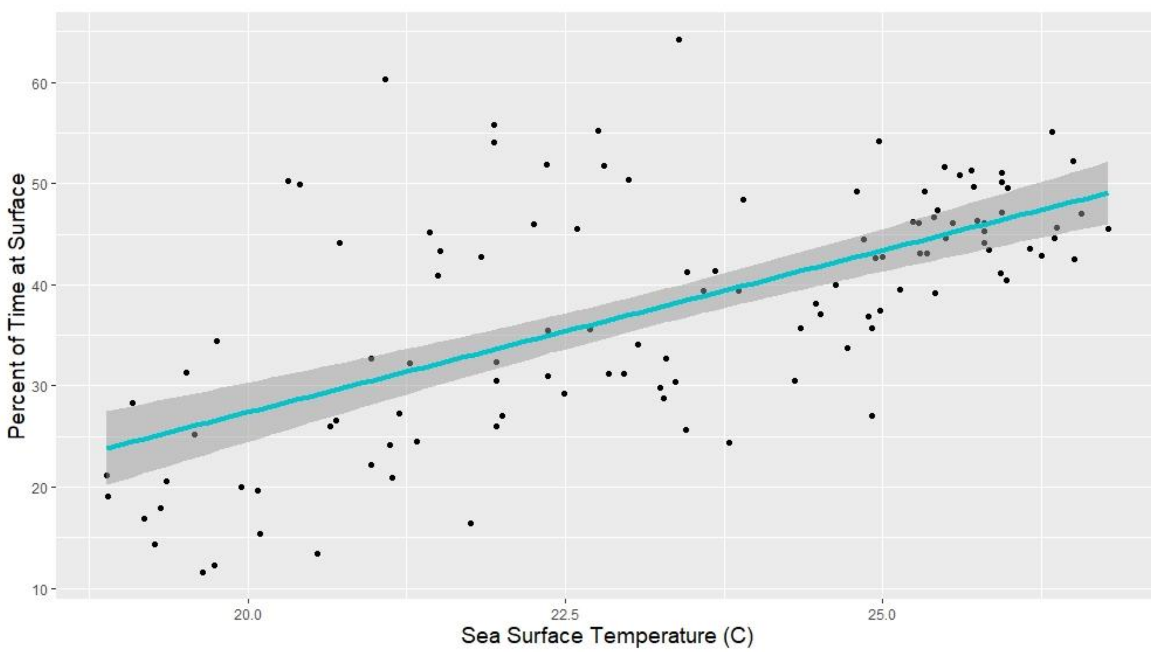

Figure 8: Relationship between percent of turtle dive time at the surface and SST from June - Sept 2019. Shaded area around fitted line is the 95% confidence interval.

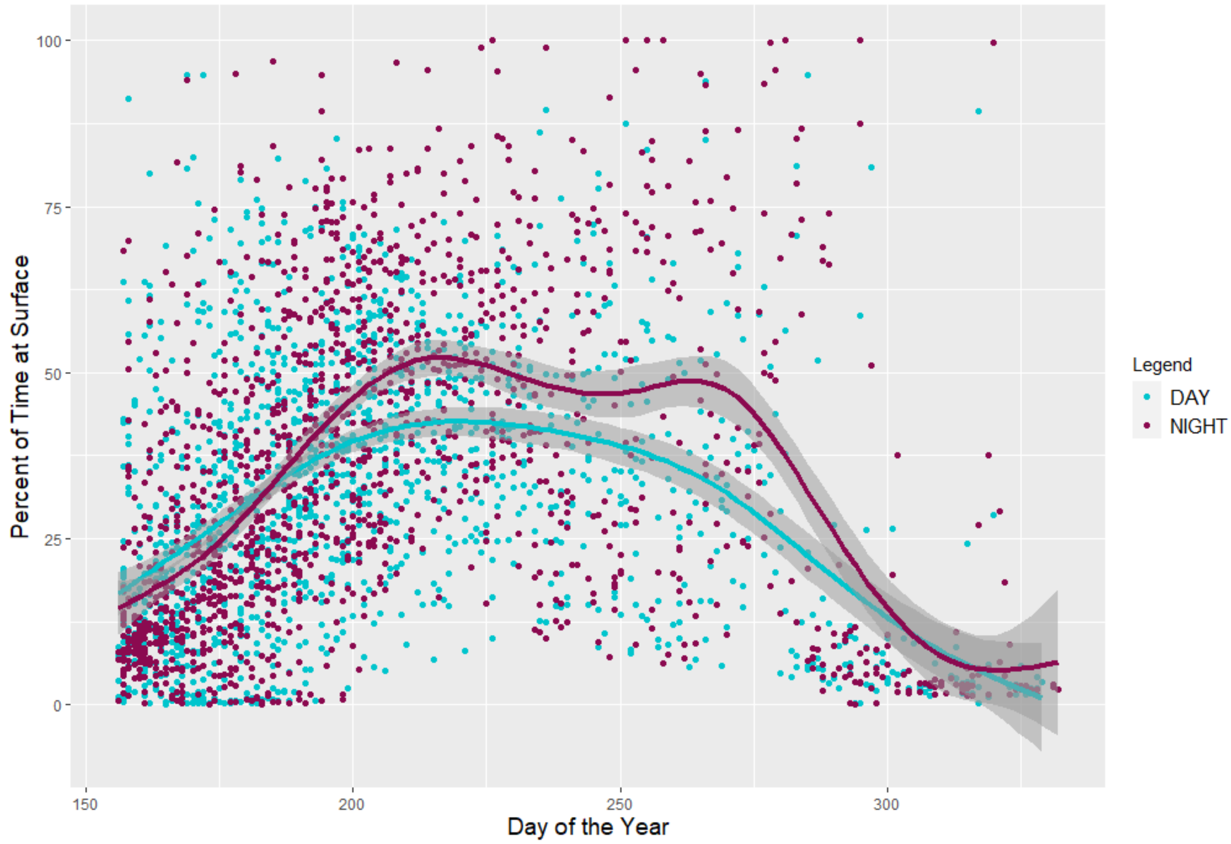

Figure 9: Percent of time at the surface between day and night during the TDD-required months. Trend lines calculated using a GAM. Shaded areas around fitted curves are the 95% confidence intervals

There was also a significant difference between surfacing time based on demographics throughout all TDD-required months (t-Test, df = 2911, $p < 0.05$) and during the first 60 days of tag transmissions (t-Test, df = 2009, $p < 0.001$). Over the course of all TDD-required months, turtles >82 cm CCL averaged 32.3 ± 21.4 percent of time at the surface per six-hour period and those <82cm averaged 34.2 ± 23.1 percent of time at the surface (**Figure 10**). During the first 60 days of transmission, larger turtles averaged 29.9 ± 19.5 percent of time at the surface and smaller turtles averaged 33.9 ± 21.9 percent of time at the surface. Larger turtles may require less time at the surface, as they may recover more quickly from the energetic costs of foraging and may be buffered from the lower temperatures of deeper waters thus not needing to bask for as long before returning to a preferred body temperature. This difference in foraging behavior may also be associated with a difference in prey preferences. Pelagic foraging turtles tend to be smaller, but also tend to spend more time at or near the surface, while benthic foraging turtles spend more time at-depth (Hawkes et al. 2006). In the MAB, we have recorded both pelagic and benthic foraging; however, we have yet to distinguish a size class most associated with each type of behavior due to the inability to measure turtles using the ROV (Smolowitz et al. 2015). Dive behavior from the satellite tags may provide the first clues of the prey preferences of turtles based on size.

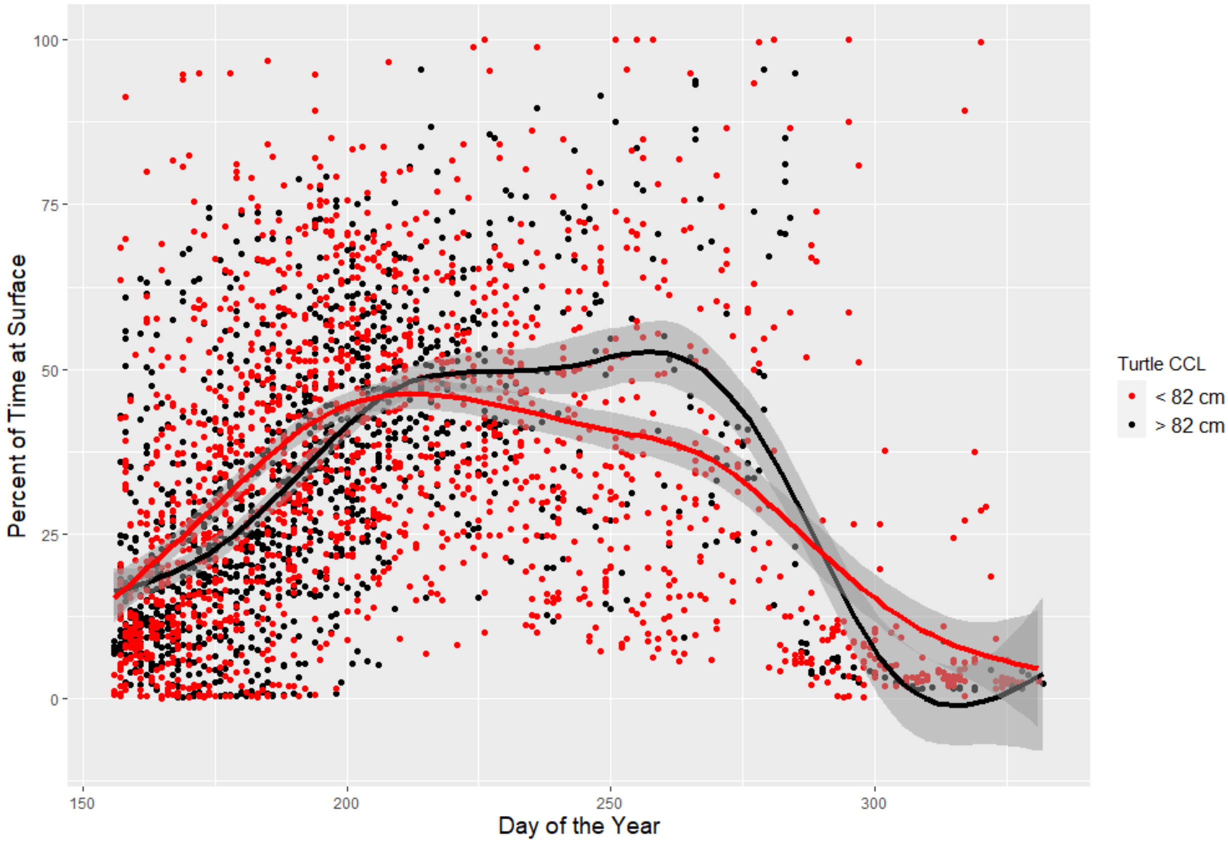

Figure 10: Percent of time at the surface during the TDD-required months based on size of the turtles. Trend lines calculated using a GAM. Shaded areas around fitted curves are the 95% confidence intervals

In October 2019, a scalloper, fishing in the MAB, recovered satellite tag #172190 that was deployed on Turtle 2018.19 (**Figure 11**). This turtle was negative for nematodes and measured 81.4 cm CCL notch to tip. The tag lasted only 82 days and showed signs of damage at the base of the antenna. It is unclear how this damage occurred or if it is correlated to the tag halting transmissions. This turtle travelled south and closer to shore after release, then spent a considerable amount of time foraging close to the deployment site. Eventually this turtle continued north and seemed to be maintaining that trajectory when the tag stopped functioning. Return of this tag allows for a larger portion of the data to be recovered in a time-series format and gives far more detail into the behavior of the turtle beyond the typically compressed data that are transmitted through the satellites. For example, the recovery of this tag allows for the downloading of all stored GPS data. The tag only transmitted 494 GPS locations; however, it had stored 3,332 GPS locations. This increased resolution helps fill in the gaps on the movement patterns of this turtle, particularly when it was traveling.

Annual Goal #3: *Identify presence/absence of nematode parasite in lavage samples.*

None of the turtles tagged in 2019 were positive for nematodes. The samples from turtles necropsied in 2020 have not been analyzed yet because Roger Williams University closed for COVID-19. From turtles tagged between 2016 through 2018 (n = 92), we have found 18 samples that were positive for nematode eggs, and for all necropsied turtles sampled from 2016 - 2019 (n

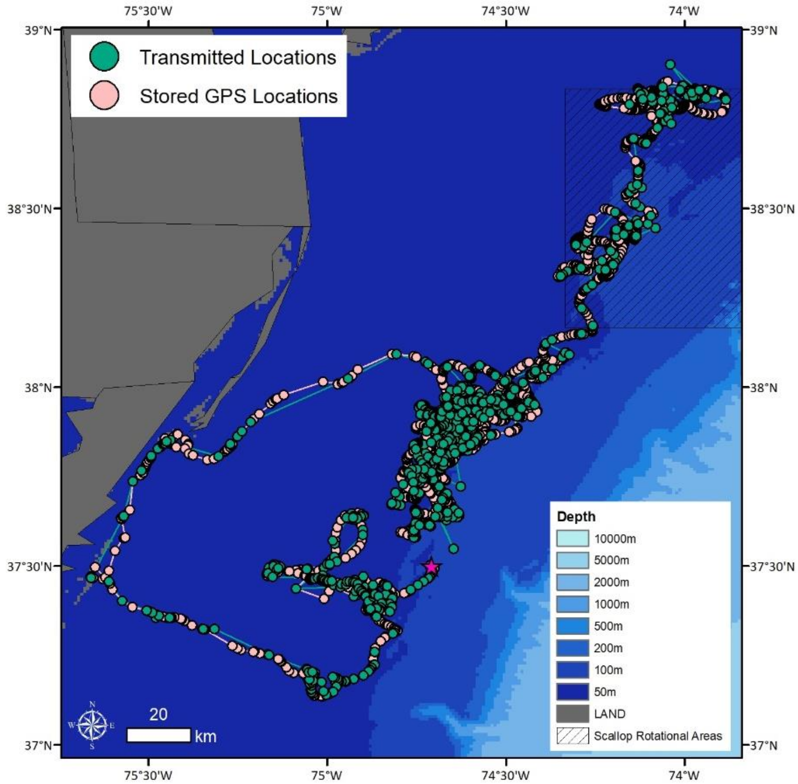

Figure 11: Locations for recovered tag deployed on Turtle 2018.19. Purple star is deployment location.

= 166), we have found 9 samples that were positive for nematodes, including samples from Kemp's ridley and green sea turtles. For the tagged turtles, those that have been positive tend to be slightly larger turtles with a mean (± SD) CCL notch to tip of 81.4 ± 9.3 cm, while those that are negative for nematodes measure 79.3 ± 9.7 cm. The positive turtles had a limited range and foraged primarily in the northwestern portion of the MAB Access Areas (**Figure 12**).

Annual Goal #4: *Present an updated analysis of the habitat range of loggerheads within the key areas overlapping the scallop fishery in both space and time.*

The Turtle Impact Tool was created to provide estimates for the impact of different scallop fishery management alternatives on loggerhead sea turtles, and it incorporates spatially and temporally specific data for monthly turtle densities, derived from loggerhead tagging programs, and for scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data (**Figure 13**). The tool was developed with input from sea turtle and scallop biologists and statisticians at NEFSC and the Greater Atlantic Regional Fisheries Office (GARFO). Currently, the tool is built as an R Shiny app or an R script that can be edited and run from the R command line. The guide for Version 1.0 of the tool is included as **Appendix 2**.

Tool components include monthly loggerhead densities derived from a geostatistical model that was developed using 2004-2016 tagging data (Winton et al. 2018) and filtered monthly tagging data from 67 tags deployed by CFF and NEFSC during the 2017 and 2018 field seasons (**Figures A2.2-A2.3**). It also includes a shapefile for the most recent MAB Scallop Area Management Simulator (SAMS) estimation areas (**Figure A2.1**) and estimated scallop biomass (meat weight in MT) for each MAB SAMS area for 2019 and the mean for 2016-2019. Users can input details about different scallop management alternatives, including open area days-at-sea (DAS) and the number of trips allocated to MAB rotational access areas. The tool outputs include a total impact map for each alternative and impact ratios comparing the two management alternatives by month, for the TDD-months of May-November, and for the full year (**Figures A2.6-A2.7**). The units of turtle impacts are scallop fleet DAS x number of sea turtles in all of the MAB SAMS areas.

The current version of the tool provides defaults for key parameters based on a limited set of data (**Appendix 3**). Future versions will incorporate more extensive data sets from turtle tagging efforts, VMS, and VTR. Because impact estimates from the first version of the tool track current estimates of scallop dredge hours used for estimating turtle takes by the scallop fishery (**Table A2-2**), further analysis will be undertaken to determine if output from the tool could provide an improved metric that incorporates seasonal and spatial distributions of both loggerheads and scallop fishing effort.

Annual Goal #5: *Assess results of new or modified methods.*

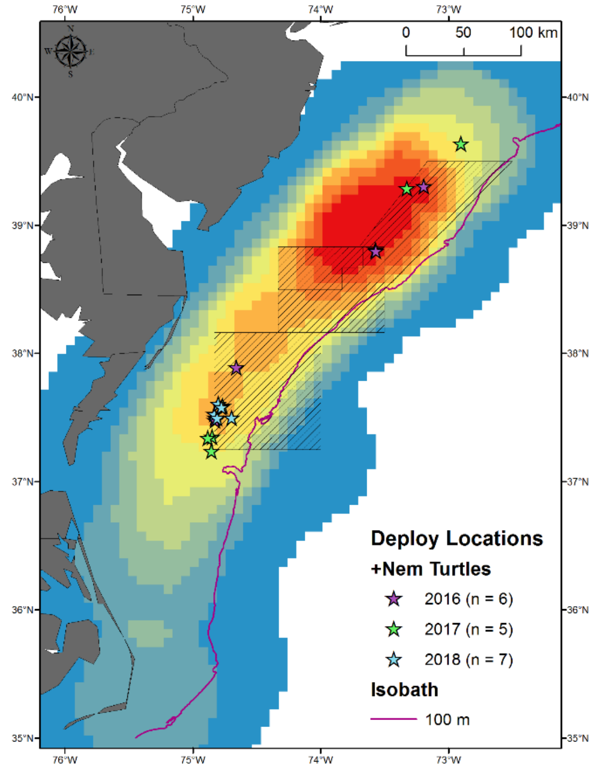

Figure 12: Heat map for turtles positive for nematodes. Red indicates the highest concentration of turtles, orange and yellow are intermediate concentrations and blue is the lowest.

Due to the partial funding of the FY 19/20 project, the modified methods this year were primarily associated with the inability to purchase new tags and the required use of surplus tags bought in previous years through NEFSC Atlantic Marine Assessment Program for Protected Species (AMAPPS) funding. Surplus tags are those that were left over from previous years due to an inability to deploy them on their originally planned trips, with this inability caused by a combination of poor weather, bad spotting conditions and difficulties in catching turtles due to seasonal variation in turtle behavior. From the decade of deployments, we have determined that spotting and capturing is generally most successful on sunny days with little to no wind in late-May in the Delmarva region of the MAB.

Over the last few years, CFF and NEFSC have accrued several surplus tags; however, we have also noticed a decreasing trend in tag durations associated with these leftover tags. In 2014, tags were purchased for a late season trip; however, none were deployed. In 2015, our order of new tags was delayed, and it did not arrive until after the tagging trip was complete. As a result, for the 2015 RSA cruise, surplus tags were deployed. Later in 2015, tags were bought through AMAPPS funding for an NEFSC white boat cruise, and only two tags were deployed on that trip. Tag durations in 2015 averaged 252 days, nearly 150 days shorter than the average duration for all tags (n = 109) prior to that. Then in 2016 and 2017, although we deployed over twenty tags each year, we had saved tags for late season trips (August/September) that yielded few deployments. Finally, in 2018, we deployed 35 tags, and were able to reduce the stock of tags back down to only ten AMAPPS-funded tags. These ten tags, which were donated to the RSA program, were then deployed in 2019.

As a result of only using surplus tags, the FY19/20 project has been rendered nearly incompatible with previous years' data. The low tag durations have resulted in essentially anecdotal data on the habitat use of loggerheads in the MAB for 2019. Previous years' use of surplus tags were in conjunction with new tags and a larger number of deployments. This provided a broader range of tag durations yielding an adequate assessment of the loggerheads for those years despite the use of surplus tags. Overall, successful years with a robust collection of data required at least 20 deployments of new tags.

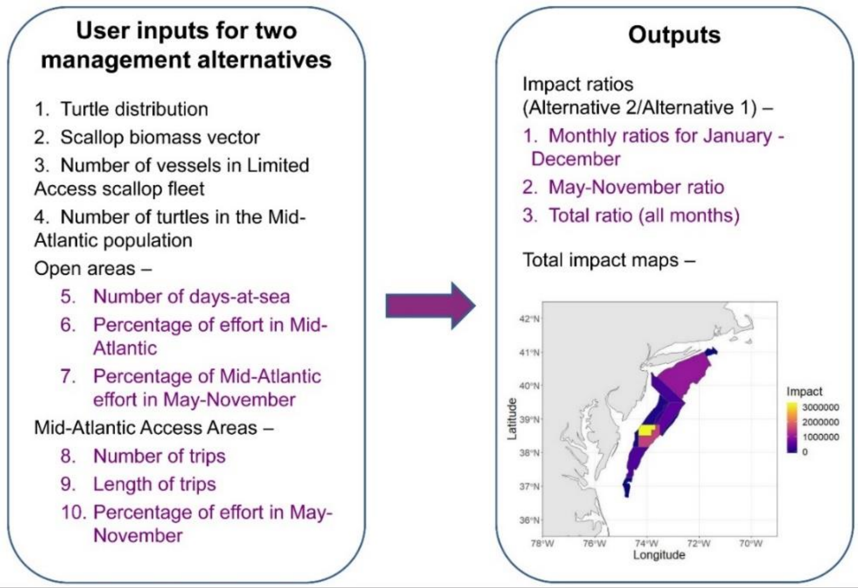

Figure 13: Schematic for user inputs and Turtle Impact Tool outputs. Full description of the tool can be found in Appendix 2.

Annual Goal #6: *Expand database of loggerhead turtle biology and ecology to be used by management.*

The FY19/20 turtle program added ~1,250 days of data to the loggerhead data set, along with 10 sets of demographic, biological and morphometric data, which is substantially lower than previous years. Although we have tagged over 210 turtles, we still have not reencountered a turtle tagged through the combined RSA and NEFSC funded loggerhead tagging, indicating that this population is very large and needs continued monitoring before nuanced population-level trends can be identified. In general, we have consistently observed that loggerheads primarily forage in benthic environments overlapping with high densities of scallops in the MAB. In the Pacific, sea turtle takes regularly cause closures and force management to adopt regulations for fisheries to avoid these animals, resulting in the creation of seasonal and area closures (for a recent example see https://www.govinfo.gov/content/pkg/FR-2019-03-28/pdf/2019-05939.pdf). Currently, the Atlantic sea scallop industry has remained ahead of these particularly consequential management strategies; however, without continuous monitoring and understanding of loggerhead ecology and overlap with the industry, closures of productive scallop grounds could be implemented as part of a strategy to minimize bycatch (e.g. closure of newly created Closed Area II Southwest on Georges Bank to reduce yellowtail flounder bycatch). The peak concentration of loggerheads in the MAB is from June – Sept each year (Winton et al. 2018). A closure during these months would force the fishery out of the MAB during a period when Limited Access vessels over the past three years have captured 25 – 30% of the total catch resource wide within the access areas in the region. Closures of this region would impose substantial strain to the fishing vessels docked in the Mid-Atlantic, due to increased travel distances to other areas, and the habitats of Southern New England and Georges Bank, due to shifted fishing efforts. Currently, without observed captures of sea turtles, alternative strategies are required to ensure the industry is not exceeding their take quota, as a direct capture is not the only form of a take. This direct loggerhead research currently provides the only alternative platform to ensure the industry remains compliant with the ESA requirements by monitoring the health and status of the population. Through this project, not only are we encountering a large cohort of loggerheads, but also a healthy population (Yang et al. 2019), clearly indicating the success of the scallop industry at reducing sea turtle interactions. Without this project, the scallop industry would have no certainty in ensuring their continued compliance with ESA requirements and avoiding the adoption of more severe regulations to protect sea turtles.

In 2020, an ESA Consultation of the sea scallop industry was triggered due to the fishery exceeding the dredge hour surrogate in the MAB from May – November in 2016. This requires the ESA to review the industry to determine if they have exceeded their allowable takes of loggerheads and also results in a new Biological Opinion and associated RPMs. The dredge hour surrogate is a very conservative tool used to determine if the fishery has exceeded its allowable take as it doesn't consider where in the MAB fishing has occurred during the TDD-required months. This understanding is a critical component of understanding scallop fishery bycatch because sea turtles are not evenly distributed throughout the region during that time. Furthermore, when fishing allocations are determined for the year, potential dredge hours in the MAB from May – Nov are not explicitly calculated, creating situations when the allowable allocations themselves can put the industry in jeopardy of exceeding the dredge hour surrogate. With additional improvements, our Turtle Impact Tool may offer a solution to remedy the shortcomings of the dredge hour surrogate by providing a metric that explicitly includes both spatial and temporal information about loggerhead and fishing effort overlap.

Programmatic Goals

During FY2019/20, we completed each of the annual goals and made progress at completing some of the programmatic goals. Below we have included status reports for each Programmatic Goal. In general, the annual goals are meant to identify specific aspects of the loggerhead ecology project that are achievable with one year's worth of data, funding and time, while the programmatic goals identify topics that need several years of data, funding and time to achieve.

1. *How do latitudinal distributions change seasonally? Interannually?*

Winton et al. (2018) partially addressed this goal when they developed a model, based on tag data from the entire region, to predict the seasonal shift in loggerhead density within the US Atlantic shelf waters. For the 2018 tagged turtles, we did notice a slight change in regional distribution, which continued for the 2019 tagged turtles. It is unclear if this change in regional distribution is naturally occurring or based on the low tag durations in those year. With the shorter tag lifespans, we may not have captured the full seasonal movements, resulting in location data being biased by deployment location. For the 2020 season, we did not receive funding to continue this research, so it will be difficult to determine is this shift in habitat usage is becoming a trend or if simply based on the limitations of the satellite telemetry devices used in 2018 and 2019.

2. *How much time do turtles spend on bottom compared to time spent on the surface?*

Patel et al. (2018) partially addressed this goal by discussing and presenting the suite of data collected by loggerheads that overlap with the MAB Cold Pool water mass (CPW) – a benthic water mass at between 30-70 m of depth that remains cold during the summer months. We currently have a manuscript in review discussing the movement patterns, including dive behavior, of loggerheads as they reacted to the passing of Hurricane Irene in August 2011. Above we have presented the dive behavior of the 2019 tagged turtles. This goal will continue to be updated as more data are accrued.

3. *Is there a difference in spatiotemporal distributions based on demographics or morphometrics?*

This goal has been partially addressed by two collaborators. Ceriani et al. (2014) used stable isotopes from tissue samples to identify foraging preferences of loggerheads based on region and demographic. Yang et al. (2019) have established baseline blood characteristics for these turtles to improve understanding of this cohort. This is our most recent publication and specifically discusses the health of the sampled loggerheads. Excerpts from this publication were presented in previous final reports. Furthermore, as part of Annual Goal # 2, we have presented dive behavior differences based on demographics for the 2019 tagged turtles.

4. *Do turtles display site fidelity to foraging areas?*

This goal is being addressed through the use of long-term tags. The first attempt with these types of tags from Wildlife Computers is fully discussed in the FY2018/19 final report. We have not been able to continue this goal, as we did not receive funding for FY20/21.

5. *How is behavior changed by water temperature?*

Patel et al. (2018) partially addressed this goal by discussing and presenting the suite of data collected by loggerheads that overlap with the MAB Cold Pool. Again, we have a manuscript in review (Crowe et al. *in review*) discussing dive behavior associated with a passing hurricane and the oceanographic changes imposed by this weather system, specifically a substantial drop in SST. Furthermore, we have discussed above how dive behavior and water temperature may be linked.

6. *What are the primary prey species and does this impact parasite load?*

Smolowitz et al. (2015) and Patel et al. (2016) have both reported on the results from the extensive ROV research and presented information on prey preferences. Ceriani et al. (2014) also took steps to determine broader foraging preferences of loggerheads in the region through isotope analyses. Since 2016, we have been taking lavage samples to identify the presence of nematodes in the loggerheads and more data are needed before appropriate conclusions can be made.

7. *Do oceanographic features impact migratory patterns?*

We recently completed an S-K funded project investigating the role SST plays in loggerhead distribution based on tag data collected from RSA-funded research. We determined that the habitat envelope for loggerheads in the MAB consists of SST ranging from ~15° - 27° C and depths ranging from 0 – 110 m. Then based on a climate change model we projected that this habitat envelope will shift farther north well into Georges Bank. The final report for this project has been submitted and a manuscript is in preparation (Patel et al. *in prep*).

8. *How will climate change alter the environmental parameters (temperature, chlorophyll concentration and oceanic currents) impacting loggerheads in this region?*

This goal is also being addressed by same S-K project mentioned above and manuscript in preparation. Overall, we identified that loggerhead marine habitats will likely expand to more northern regions and increase in seasonal duration from earlier in the spring to later into the fall.

9. *What are the unique oceanographic characteristics of the MAB and how do they impact scallop abundance?*

Patel et al. (2018) partially addressed this goal by presenting data on the regionally unique MAB CPW. The goal is also being partially addressed through an additional S-K grant to calibrate sea turtle-derived ocean temperature data for infusion into oceanographic models for forecasting temperature by depth within the region. We expect the turtle-derived data to greatly improve the oceanographic models and particularly the forecasting of bottom temperatures, which are most relevant for scallops.

Conclusions

During FY19/20, CFF collected samples on 10 loggerheads, specifically documenting their seasonal locations in the MAB, morphometrics, health statuses, nematode presence, genetics and stable isotope values. Due to the required use of satellite tags that were surplus from previous years, the movement data fell short of expectations and the sample size in general (n = 10) limited our understanding of the overall biology and ecology loggerheads for the 2019 season. In previous reports and proposals, we have reiterated the value of higher sample sizes and longer duration satellite tags. We have suggested that 20 new satellite tags, resulting in the complete sampling of 20 turtles each year, provides the best balance between costs and at-sea effort to yield an effective annual survey dataset. Since 2009, CFF has contributed to the sampling of over 200 loggerheads. Many research goals have been met through this sampling (see list of publications in **Appendix 1**); however, the primary goal of determining the impacts of fisheries on these species requires a particularly large sample size and continued monitoring (Sequeira et al. 2019). For example, observed loggerhead bycatch in the scallop fishery is extremely rare due to the implementation of turtle-specific gear modifications (NMFS 2015). As a result, being able to document these rare interactions between this fishery and loggerheads requires a high level of monitoring both from fisheries observer coverage and direct loggerhead sampling (Murray 2012, Sequeira et al. 2019). This holds true for the other turtle species as well, and in particular for turtle-fisheries interactions with an unknown level of occurrence (Hamelin et al. 2017).

Unfortunately, the scallop industry cannot depend on NMFS to conduct this directed research on loggerheads specifically in regard to interactions with the fishery. Similarly, the industry cannot depend on NMFS to provide a comprehensive survey of the scallop biomass. As a result, just as the industry has designated funding for additional scallop biomass surveys, the scallop industry must take the initiative to ensure their interactions with protected species do not jeopardize their ability to continue fishing. With the recent triggering of an ESA consultation of the industry, the data acquired through the RSA-funded research, which demonstrates that the loggerhead population in the MAB is healthy, provides the best defense that the fishery is not causing additional harm to turtles despite having exceeded the dredge hour surrogate. The only alternative research path is to conduct an aerial survey multiple times a year to ensure that the loggerhead population is not shrinking or shifting habitats. However, this is far costlier than annual tagging studies and does not provide a direct assessment of the health status of the population. Furthermore, aerial surveys depend on satellite telemetry data to calculate the population estimates and cannot be conducted effectively without adequate co-located tagging research to estimate how much time turtles spend near the surface in view of an aerial observer (NMFS 2011).

As a way to preempt further consultations and reduce the chances of exceeding the dredge hour surrogate in the future, CFF has also developed a tool specifically to be used by scallop managers to interpret how allocations of DAS and access area trips will impact loggerheads. This tool could only be developed because of the long-standing annual survey of loggerheads funded by the RSA and the close collaboration with the NEFSC, and the tool can only be useful with continued sea-turtle tagging and monitoring.

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Appendix 2

Turtle Impact Tool 1.0

The Turtle Impact Tool was created to provide estimates of the relative impact of different scallop fishery management alternatives on loggerhead sea turtles. This tool incorporates spatially and temporally specific data for monthly turtle densities, derived from loggerhead tagging programs, and for scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data.

Tool components

Loggerhead sea turtle normalized monthly density

The tool includes two options for monthly turtle density shapefiles:

1. Monthly densities derived from a geostatistical model that was developed using 2004-2016 tagging data from 271 tags deployed by six tagging programs in the western North Atlantic (Winton et. al. 2018): Densities were modelled for 40x40km grid cells from Florida through southern Georges Bank (**Figure 1**) and normalized to range from 0-1 for each month. Therefore, use of these monthly density shapefiles assumes that the total number of loggerheads in the modelled area does not change month to month (i.e no significant immigration or emigration of turtles). Shapefiles of log(density) are available through the Northeast Fisheries Science Center (NEFSC) Sea Turtle Ecology and Population Dynamics webpage at https://inport.nmfs.noaa.gov/inport/item/27337. Log(density) values were converted to density for use in the tool (**Figure 2**). Units for turtle shapefiles are percentage of turtles in each grid square for each month.

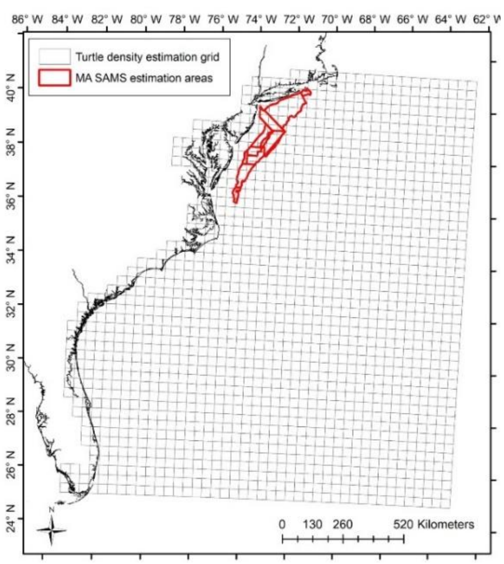

Figure 1: Map showing the grid used for estimating turtle densities and the location of the Mid-Atlantic SAMS areas

2. Monthly densities derived from 67 tags deployed by Coonamessett Farm Foundation (CFF) and NEFSC during the 2017 and 2018 field seasons. Tagging data was filtered to give daily position estimates for each turtle using a custom script written by Joshua Hatch (NEFSC contractor with the sea turtle group). A zonal statistics tool was used to bin the simplified tag data into grid cells that matched those from the Winton et. al. model, and the resulting grid counts were converted into normalized densities for each month (**Figure 3**). As with the model

data, use of these density shapefiles also assumes that the total number of loggerheads in the modelled area does not change month to month, with shapefile units equal to percentage of turtles in each grid square for each month.

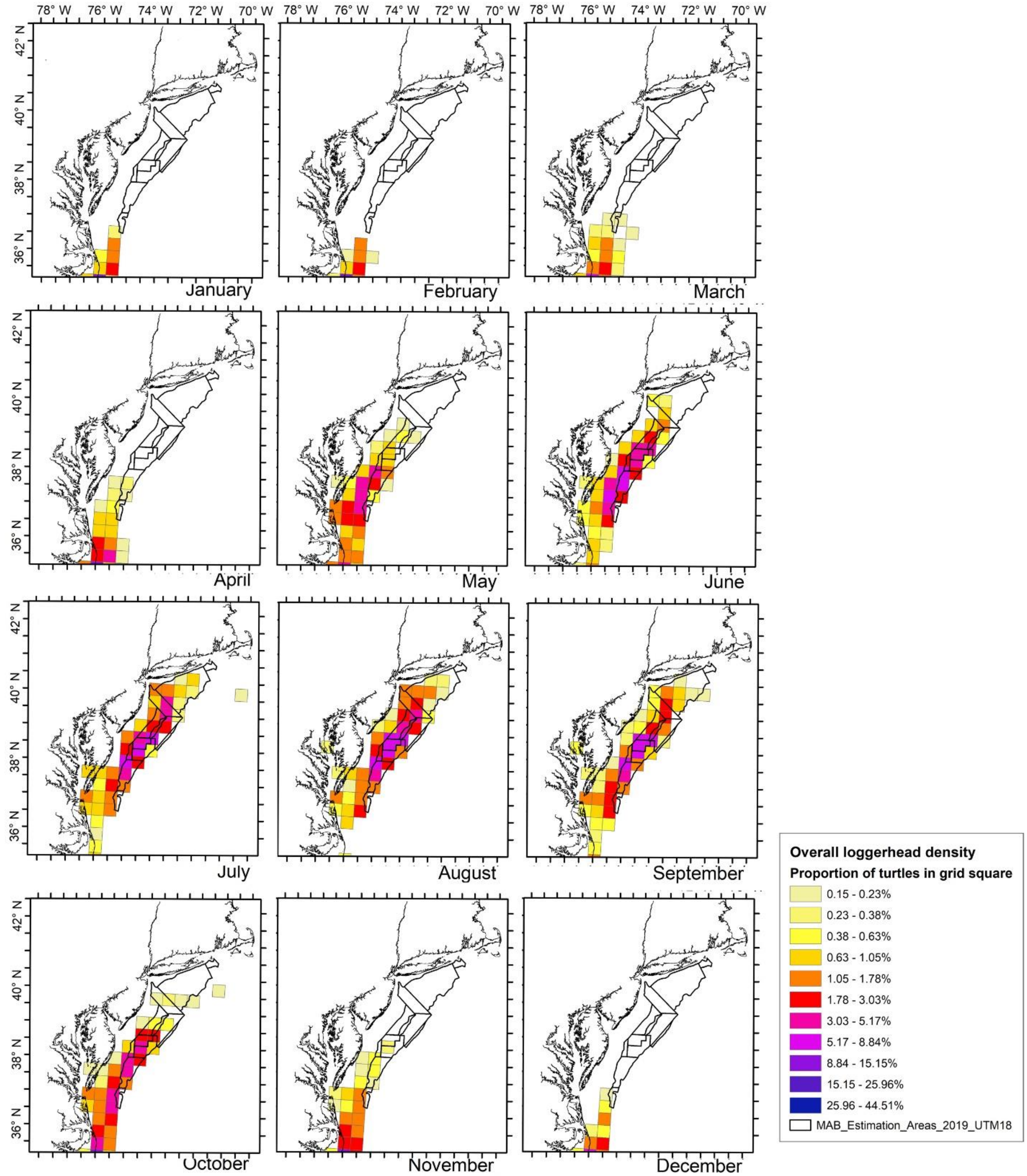

Figure 2: Monthly normalized turtle density maps from the Winton et. al. 2018 model. Grid cells with turtle density estimates under 0.15% are not shown.

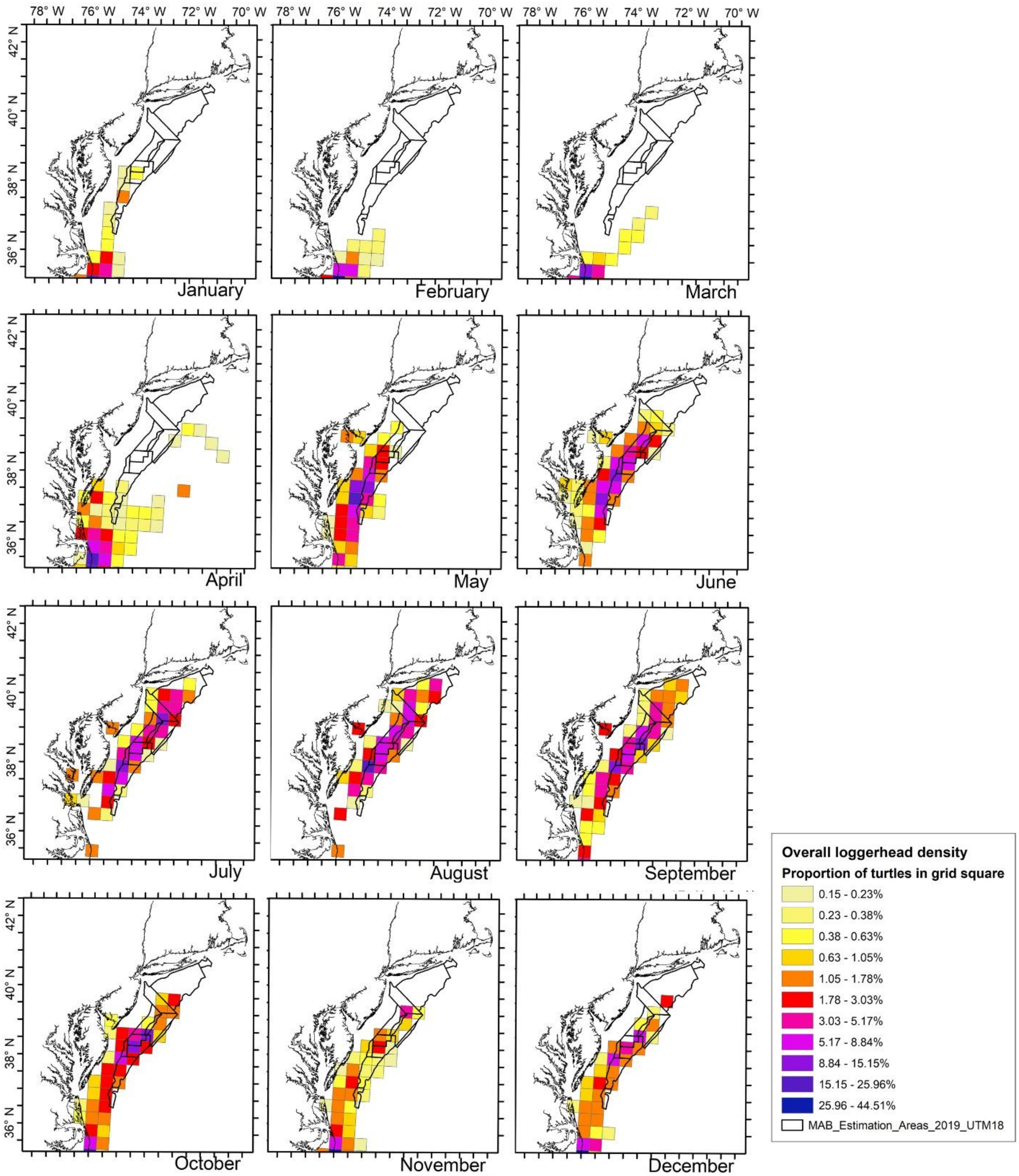

Figure 3: Monthly normalized turtle density maps from filtered 2017-2018 tag data. All grid cells with tagged turtles present within the map area are shown.

Mid-Atlantic Bight (MAB) Scallop Area Management Simulator (SAMS) areas

The tool includes a shapefile for the most recent Mid-Atlantic Bight (MAB) Scallop Area Management Simulator (SAMS) estimation areas, including the area (km^2) of each region (**Figure 1**).

Estimated scallop biomass for each SAMS area

The tool includes a data table with the estimated scallop biomass (meat weight in MT) for each MAB SAMS area for 2019 and the mean for 2016-2019 (NEFMC 2017, 2018, 2019, 2020). This data table also includes the status for each SAMS area (open, closed, access area) for the 2018-2020 fishing years.

Relationships between scallop biomass and fishing effort

Estimated scallop biomass and yearly effort data by SAMS area for 2015-2018 was used to derive best-fitting linear relationships between scallop biomass and fishing effort for open and access areas. Yearly effort statistics by SAMS area, based on VTR data, were provided by Benjamin Galuardi at the Greater Atlantic Regional Fisheries Office (GARFO) Analysis and Program Support Division. To allow inclusion of data from multiple years, biomass and effort data were normalized by year (mean = 1). For open areas, effort had a linear relationship with scallop biomass (R^2 = 0.97, **Figure 4A**). For access areas, effort had a linear relationship with scallop density (R^2 = 0.91, **Figure 4B**). Based on these relationships, fishing effort was allocated to the open SAMS areas based on the proportion of scallop biomass in each area. Similarly, fishing effort was allocated to access areas based on the proportional density in each area.

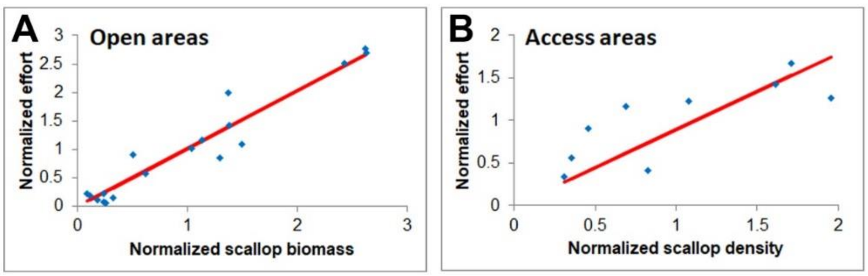

Figure 4: (A) Open area scallop biomass vs fishing effort. (B) Access area scallop density vs fishing effort. Scallop biomass is based on the combined estimates from multiple scallop surveys, with scallop density calculated using the area of each SAMS area in square km. Fishing effort is estimated from VTR data. All estimated are normalized per year with the mean value = 1.

<u>User inputs</u>

To run the tool, users input the following parameters for two management alternatives (**Figure 5**):

1) Turtle distribution (density shapefiles)

2) Vector of scallop biomass by SAMS area

3) Number of vessels in the Limited Access (LA) scallop fleet – the tool provides a default of 340 vessels based on the number of active LA vessels in 2018, reported in Scallop Framework 32, rounded to the nearest 10 (see Table 48 in NEFMC 2020).

4) Number of loggerhead sea turtles in the Mid-Atlantic – the tool provides a default of 48,700 turtles based on the most recent estimates for the Mid-Atlantic loggerhead population (Table 9 in NEFSC 2011), rounded to the nearest 100.

Open areas

5) Number of open area days-at-sea (DAS)

6) Percentage of open area effort in the MAB – the tool provides a default value of 65%, which is an estimate based on yearly effort by SAMS area estimates from VTR data provided by GARFO, rounded to the nearest 5% (**Table A1**).

7) Percentage of MAB open-area effort in May-November – the tool provides a default value of 65%, which is an estimate based on zonal statistics of monthly filtered VMS rasters for 2018-2019 provided by GARFO, rounded to the nearest 5% (**Table A2**).

Mid-Atlantic Access Areas (MAAA)

8) Number of trips in the Mid-Atlantic Access Areas (MAAA) – this currently includes the Elephant Trunk Open and Flex areas and the Hudson Canyon Access Area.

9) Length of MAAA trips in DAS – the tool provides a default of 6.5 days based on yearly total DAS and number of trips per SAMS area provided by GARFO (**Table A3**).

10) Percentage of MAAA effort in May-November – the tool provides a default value of 65%, which is an estimate based on zonal statistics of monthly filtered VMS rasters for 2018-2019 provided by GARFO, rounded to the nearest 5% (**Table A2**).

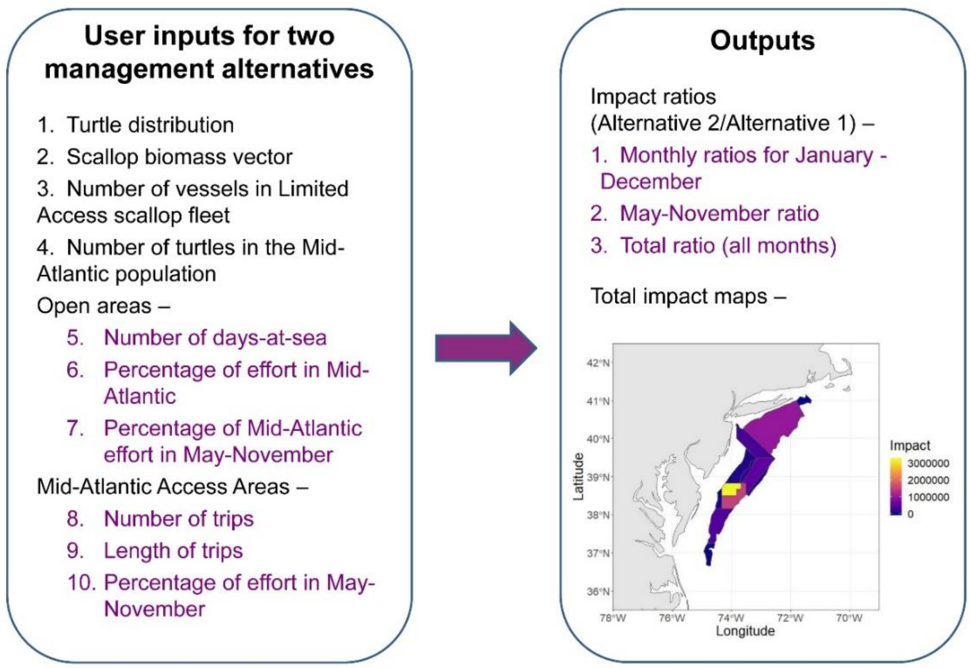

Figure 5: Schematic showing Turtle Impact Tool inputs and outputs.

__Output__

The tool outputs the following information (**Figure 5**):

1) Table with impact ratios (for each month, for May-November, and total for all months combined). The Impact Ratio = Alternative 2/Alternative 1 impact. Therefore, if the ratio is less than one, the scallop fishery will impact sea turtles more under Management Alternative 1. If the ratio is greater than one, the scallop fishery will impact sea turtles more under Management Alternative 2.

2) Total turtle impact map for each alternative. Units for the impact values in the maps are scallop fleet DAS x number of sea turtles per SAMS area.

The R Shiny script and app

The Turtle Impact Tool runs as an R script or as an R Shiny app. On the app User Interface (UI), inputs are entered for two management alternatives (**Figure 6**). The outputs include maps showing total impact (full year as all months combined) by SAMS area and an impact ratio table with values for each month, for May-November, the months currently used for estimating loggerhead sea turtle takes by the scallop fishery (NMFS 2012), and for all months combined. The R-script does identical calculations and creates the same maps and ratio table, but changes to management alternatives are made by editing the script.

When the app UI first opens, the two management alternatives are identical, with inputs set to defaults or the first choice on the drop-down list (**Figure 6**). Users can change as many inputs as they choose. When the "Run tool" button is clicked, the tool recalculates impacts for the new entries. Three examples with different user inputs are shown in **Figure 7**. An example of a workup based on Framework 32 alternatives, comparing tool outputs to qualitative language in the framework document, is shown in **Table 1 and Figure 8**.

Additional output data for each alternative is available if the R script is used. Impact values for each month, for May-November, and for a full year can be displayed. These impact values summarize overlap between scallop fishing effort and sea turtle presence, with units of scallop fleet DAS x number of sea turtles in all of the MAB SAMS areas. Impact maps for each month could also be generated with small changes to the code. An example of a workup comparing impact values from the tool to scallop dredge hours used as a proxy for incidental take of sea turtles is shown in **Table 2 and Figure 9**.

Literature cited

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Northeast Fisheries Science Center (NEFSC). 2011. Preliminary Summer 2010 Regional Abundance Estimate of Loggerhead Turtles (*Caretta caretta*) in Northwestern Atlantic Ocean Continental Shelf Waters. NEFSC Reference Document 11-03. 39 pp.

Figure 6: The Turtle Impact Tool User Interface (UI). This shows the appearance of the UI at start-up when the management alternatives are the same. The drop-down choices for turtle distributions and scallop biomass by SAMS area are shown above the UI.

Figure 7: Three examples of Turtle Impact Tool outputs with A) the turtle distribution changed, B) the open area allocation reduced from 24 to 18 DAS, and C) the MAAA allocation reduced from 3 to 2 trips. Changes are highlighted with boxes. In Example A, additional yellow boxes highlight alternative table entries that appear if no turtles are found during some months and a very high estimate for increased impact in the month of December, caused by higher turtle densities during this month when the more recent 2017-2018 tagging data is used (see Figures 2 and 3).

Table 1: Impact ratios for the Framework 32 alternatives described in Figure 8. Quoted text for each comparison can be found in Framework 32 in Section 6.4.3 Action 3 – Fishery Specifications & Trip Exchanges (NEFMC 2020).

	Preferred / Status quo	**No action / Status quo**	**Preferred / No action**
Text from Framework 32	"the reduced projected area swept relative to the Status Quo … means the overall duration of time gear is deployed in the water would be similar or reduced, thereby having similar or reduced potential for interactions with sea turtles"	"No Action will result in less effort and lower projected area swept relative to Status Quo, as well as less overall effort allocations in the [MAAA] … the number of potential interactions with sea turtles is likely to be lower"	"additional effort in the MAAA under [preferred] Alternative 2 options could result in somewhat elevated potential for interactions with protected species, particularly ESA-listed species of sea turtles"
May – Nov impact ratio	0.789	0.486	1.623
Total impact ratio	0.787	0.484	1.627

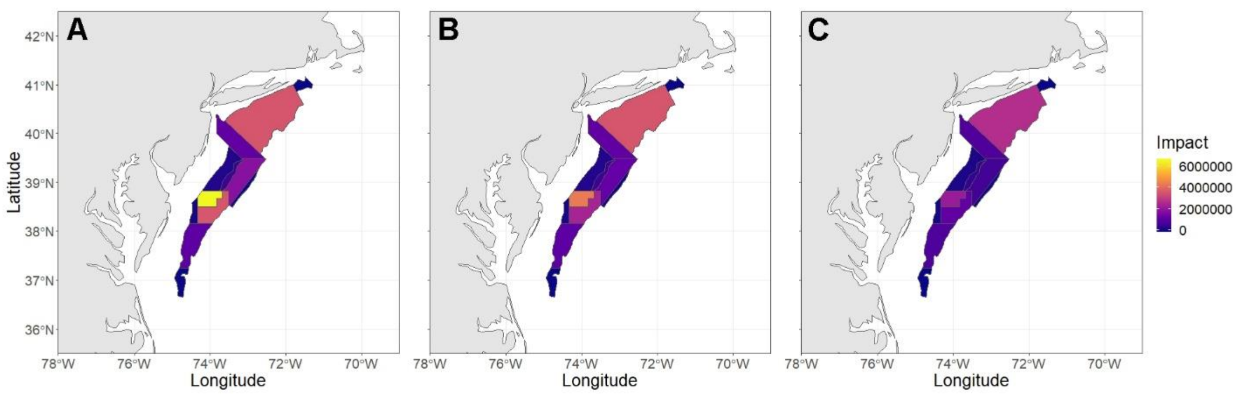

Figure 8: Total impact maps from Scallop Framework 32 analysis. Alternatives considered under the framework included A) Status quo: 3 MAAA trips, 24 open-area DAS, B) Preferred alternative: 2 MAAA trips, 24 open-area DAS, and C) No action: 1 MAAA trip, 18 open-area DAS (NEFMC 2020). The analysis used the 2017-2018 turtle tagging data, mean 2016-2019 scallop biomass by SAMS area, and default values for all inputs not specified in the descriptions of the three alternatives that were analyzed.

Table 2: Impact values estimated by the Turtle Impact Tool for 2015-2018 and scallop dredge hours for 2015-2017. The analysis used the modeled monthly turtle distributions and the scallop biomass by SAMS area estimates for each year. Parameters shown in regular text are specific for each year and based on values obtained from VTR data (length of MAAA trips) and scallop frameworks (summarized in NEFMC 2020). Parameters shown in italics are tool default values. Note the changes in access areas - access area trips were allocated to the Hudson Canyon Scallop (HCS) and Elephant Trunk (ET) open areas during all four years. The ET-Flex area was closed in 2015 and 2016. The Delmarva (DMV) access area reverted to open bottom in 2018. Units for impact values are scallop fleet DAS x number of sea turtles in all of the MAB SAMS areas.

	2015	**2016**	**2017**	**2018**
Number of vessels in the Limited Access (LA) scallop fleet	346	347	348	343
Number of loggerhead sea turtles in the Mid-Atlantic	*48,700*	*48,700*	*48,700*	*48,700*
Number of open area days-at-sea (DAS)	30.86	34.55	30.41	24
Percentage of open area effort in the MAB	0.54	0.64	0.82	0.52
Percentage of MAB open-area effort in May-November	*0.65*	*0.65*	*0.65*	*0.65*
Number of trips in the Mid-Atlantic Access Areas (MAAA)	3	3	2	2
Length of MAAA trips in DAS	5.8	7.3	6.6	6.0
Percentage of MAAA effort in May-November	*0.65*	*0.65*	*0.65*	*0.65*
MA Access Areas	HCS, ET-Open, DMV	HCS, ET-Open, DMV	HCS, ET-Open, ET-Flex, DMV	HCS, ET-Open, ET-Flex
Total impact	10,519,319	13,373,443	10,381,371	7,598,172
May-November impact	10,485,231	13,333,295	10,366,670	7,584,847
Dredge hours reported by NMFS	279,258	451,741	301,692	??

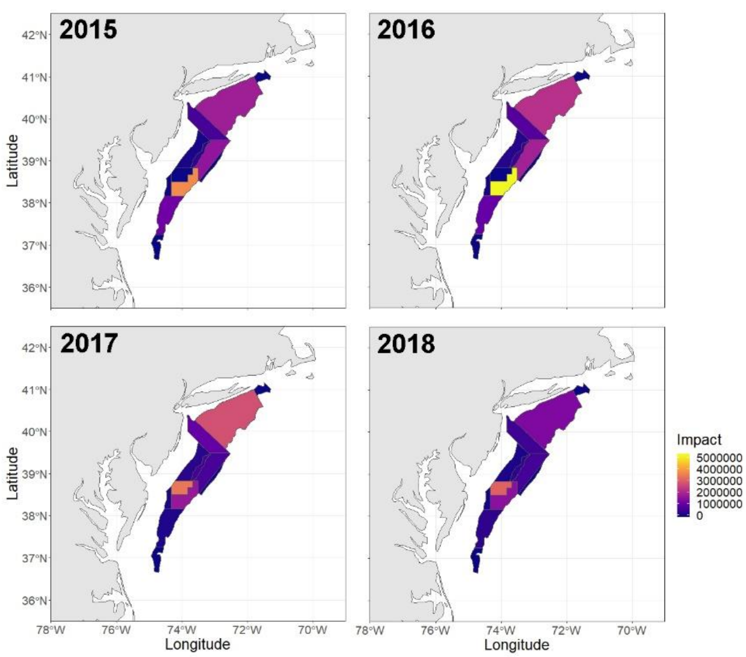

Figure 9: Total impact maps for 2015-2018 using the modeled monthly turtle distributions and the parameter values shown in Table 2.

Data used for estimating defaults values

Table A1: Percentage of open area effort in the MAB based on estimates of DAS derived from yearly VMS effort rasters for 2015-2018. Effort estimates by grid square were summed by SAMS area using zonal statistics.

Year	GB open DAS	MAB open DAS	MAB/(MAB+GB)
2015	57386.494	66302.065	0.536
2016	86294.757	152223.685	0.638
2017	27383.199	122575.874	0.817
2018	29292.747	31600.220	0.519
		Mean	**0.628**

Table A2: Percentage of MAB open- and access-area effort in May-November based on monthly estimates of DAS derived from monthly VMS effort rasters for April 2018-March 2019. Effort estimates by grid square were summed by SAMS area using zonal statistics.

Month	MAB open DAS	MAB access DAS
May 2018	2311.594	6706.353
June 2018	2347.923	3192.531
July 2018	1555.361	1263.338
August 2018	3903.146	2054.021
September 2018	3105.116	4121.649
October 2018	3257.593	2743.552
November 2018	1270.087	1820.227
sum	17750.820	21901.671
April 2018	7724.538	10526.015
December 2018	500.383	1254.516
January 2019	272.413	426.450
February 2019	541.071	99.550
March 2019	1188.646	74.683
sum	10227.051	12381.214
May-Nov/(full year)	**0.634**	**0.639**

Table A3: Length of MAAA trips by SAMS area based on VTR data for FY 2016-2018

Fishing year	SAMS area	Days/trip
2016	DMV	7.456
2016	ET-Open	6.892
2016	HCS	7.448
2017	ET-Close	6.778
2017	ET-Open	6.200
2017	HCS	6.707
2018	ET-Close	5.442
2018	ET-Open	5.818
2018	HCS	6.651
	Mean	**6.599**

Appendix 3: Data currently used and data needs to improve the Turtle Impact Tool

Tool parameter inputs	Current data	Data needed for maintaining or improving tool	Difficulty (Low, Medium, High)	Added cost (Low, Medium, High)	Previous funding sources
1) Turtle distributions	turtle-density distributions including a model-based set of monthly shapefiles from Winton et al. 2018 and filtered 2017-2018 tagging data	Updated turtle distributions - there is evidence that turtle distributions are shifting so use of old data is not appropriate	**Medium** - Mid-Atlantic loggerheads have been routinely tagged by expert groups like NEFSC/CFF	**Medium** - turtle projects are a high priority for the 2021 RSA	Scallop RSA, Atlantic Marine Assessmen Program for Protected Species (AMAPPS), and NEFSC Protected Species Branch
2) Vectors of scallop biomass by SAMS area	scallop biomass estimates from 2015 - 2019 scallop surveys	Updated scallop biomass estimates by SAMS area	**Low** - scallop biomass estimates are updated based on surveys conducted each year	**Low** - urveys are funded as highest priorities by the Scallop RSA	Scallop RSA and NEFSC Population Dynamics Branch
3) Number of vessels in the Limited Access (LA) scallop fleet	default - based on number of active LA vessels reported in Scallop Framework 32	Updated numbers of active vessels	**Low** - numbers of active scallop vessels are known and reported in scallop frameworks	**Low** - these numbers are routinely reported	GARFO
4) Number of loggerhead sea turtles in the Mid-Atlantic	default - based on best estimate for the size of the Mid-Atlantic sea turtle population from 2010 data	Updated estimate of the Mid-Atlantic loggerhead population size - current best estimate is from 2010	**High** - requires satellite-tag and aerial-survey data and complex data analysis	**High** - satellite tags cost $1500-$5000 each, depending on tags used, and research trips of 6-10 days are needed to deploy the tags. Aerial survey costs ???	Scallop RSA, AMAPPS, and NEFSC Protected Species Branch
5) Number of open area days-at-sea (DAS)	NA - this parameter is tested as part of the management alternatives				

6) Percentage of open area effort in the MAB	default - average of percentages from 2015-2018, with effort based on VMS data rasters	Updated percentage - should include most recent data available	**Low -** current data was obtained from GARFO upon request. CFF does not have access to VMS data.	**Low -** yearly effort rasters are routinely generated but not publicly available	GARFO
7) Percentage of MAB open-area effort in May-November	default - based on monthly VMS data from April 2018-March 2019	Updated percentage - should be based on data from more than one year and include most recent data available	**Medium** - monthly effort rasters are not routinely generated and are not publically available. Current data was obtained from GARFO upon request. CFF does not have access to VMS data.	**Medium** - will require additional work by NOAA or CFF staff (if acccess to VMS data permitted)	GARFO
8) Number of trips in the Mid-Atlantic Access Areas (MAAA)	NA - this parameter is tested as part of the management alternatives				
9) Length of MAAA trips in DAS	default - average of length of trips in MAAA access areas for FY2016-2018 from VTR data	Updated trip lengths by SAMS area - should include most recent data available	**Medium** - trip length data by SAMS area is not routinely generated and is not publically available. Current data was obtained from GARFO upon request. CFF does not have access to VTR data.	**Medium** - will require additional work by NOAA or CFF staff (if acccess to VTR data permitted)	GARFO
10) Percentage of MAAA effort in May-November	default - based on monthly VMS data from April 2018-March 2019	Updated percentage - should be based on data from more than one year and include most recent data available	**Medium** - monthly effort rasters are not routinely generated and are not publically available. Current data was obtained from GARFO upon request. CFF does not have access to VMS data.	**Medium** - will require additional work by NOAA or CFF staff (if acccess to VMS data permitted)	GARFO