Understanding Impacts of the Sea Scallop Fishery on Loggerhead Sea Turtles

Final Report

Prepared for the 2018
Atlantic Sea Scallop Research Set Aside Program
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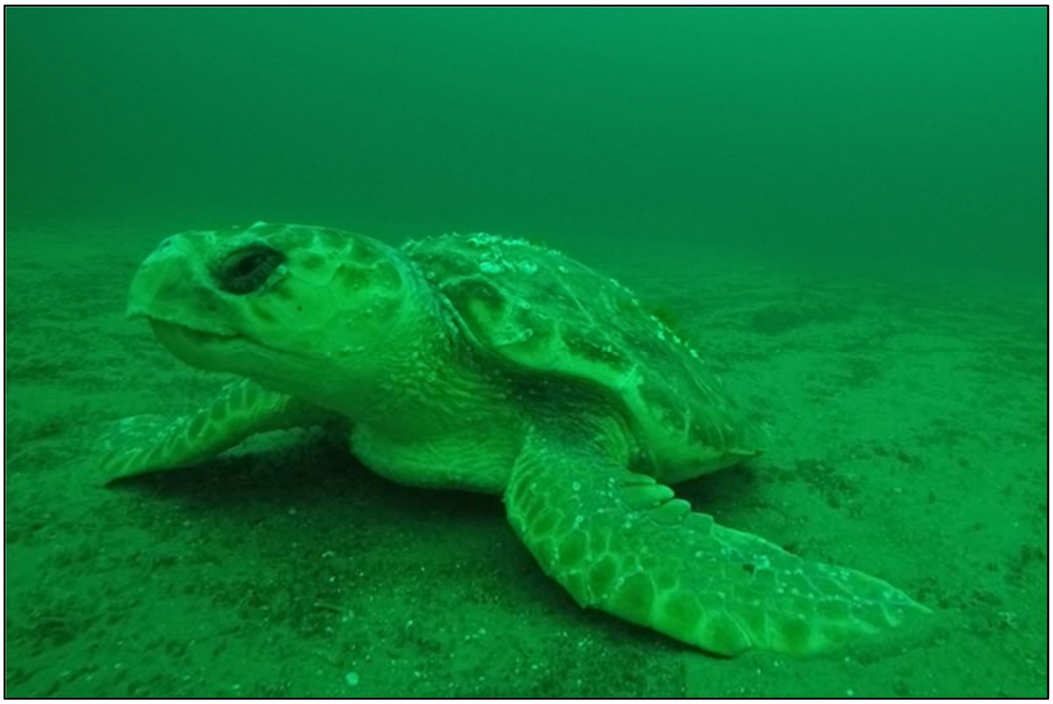

Submitted By
Samir H. Patel
Coonamessett Farm Foundation, Inc. (CFF)

In Collaboration with
Ronald Smolowitz
Coonamessett Farm, Inc.
Heather Haas
Northeast Fisheries Science Center
Jim Gutowski
Viking Village Fisheries
Roxanna Smolowitz
Roger Williams University

Coonamessett Farm Foundation, Inc

277 Hatchville Road
East Falmouth, MA
02536

508-356-3601 FAX
508-356-3603
contact@cfarm.org

www.cfarm.org

Project Summary:

Coonamessett Farm Foundation's (CFF) 2018 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 are being met as well as help reduce injury and mortality of turtle takes by scallop dredges.

Table 1: Summary table for tags deployed during 2018. Green indicates turtles that tested positive for nematodes.

Turtle ID	Date Deployed	Transmission Duration as of June 18, 2019 (Days)	Capture Lat	Capture Lon	Capture SST	Curved Carapace Length	Tag Type
2018.01	5/21/2018	112	38.037	-74.520	15.9	95.0	SMRU
2018.02	5/21/2018	393	37.927	-74.674	16.1	86.0	SPOT375B
2018.03	5/21/2018	97	37.876	-74.682	16.6	75.0	SPOT375B
2018.04	5/22/2018	115	37.589	-74.767	16.7	86.5	SMRU
2018.05	5/22/2018	202	37.584	-74.775	16.8	59.5	SPOT375B
2018.06	5/22/2018	275	37.487	-74.825	17.5	85.7	SPOT375B
2018.07	5/22/2018	85	37.467	-74.817	17.7	84.0	SMRU
2018.08	5/22/2018	116	37.433	-74.833	18.5	79.1	SPOT375B
2018.09	5/22/2018	116	37.441	-74.850	18.8	75.6	SPOT375B
2018.10	5/23/3018	154	37.465	-74.853	18.9	79.9	SMRU
2018.11	5/23/2018	73	37.465	-74.853	18.9	87.5	SPOT375B
2018.12	5/23/2018	107	37.496	-74.843	19.2	79.5	SPOT375B
2018.13	5/23/2018	170	37.529	-74.832	19.7	90.0	SPOT375B
2018.14	5/23/2018	125	37.529	-74.824	19.7	100.1	SMRU
2018.15	5/23/2018	230	37.538	-74.823	19.7	76.5	SMRU
2018.16	5/23/2018	121	37.543	-74.814	19.7	78.3	SMRU
2018.17	5/23/2018	14	37.500	-74.769	18.7	79.0	SMRU
2018.18	5/23/2018	172	37.500	-74.752	18.7	82.5	SMRU
2018.19	5/23/2018	82	37.501	-74.714	18.7	80.1	SMRU
2018.20	5/23/2018	87	37.500	-74.698	18.7	69.4	SMRU
2018.21	5/23/2018	5	37.502	-74.698	18.7	98.9	SMRU
2018.22	5/25/2018	50	37.454	-74.818	18.9	71.5	SMRU
2018.23	5/25/2018	88	37.453	-74.817	18.9	82.3	SMRU
2018.24	5/25/2018	127	37.482	-74.817	18.8	77.8	SMRU
2018.25	5/25/2018	360	37.497	-74.827	19.0	82.0	SMRU
2018.26	5/25/2018	134	37.498	-74.824	19.0	79.2	SMRU
2018.27	5/25/2018	56	37.497	-74.810	19.2	94.7	SMRU
2018.28	5/25/2018	261	37.497	-74.810	19.2	79.1	SMRU
2018.29	5/25/2018	64	37.608	-74.802	19.2	74.5	SMRU
2018.30	5/25/2018	110	37.608	-74.802	19.2	73.2	SMRU
2018.31	5/25/2018	385	37.608	-74.802	19.2	80.5	SMRU
2018.32	5/25/2018	92	37.581	-74.776	19.2	94.0	SMRU
2018.33	5/25/2018	89	37.589	-74.777	19.2	71.5	SMRU
2018.34	5/25/2018	114	37.638	-74.765	19.2	87.0	SMRU
2018.35	5/25/2018	210	37.638	-74.765	19.2	74.0	SMRU

We completed one early summer trip during 2018. This trip occurred from May 20 – 26 on the F/V Kathy Ann. We did not conduct a second late-season trip due to their generally lower success rates in past years. During the May research trip, we focused efforts in the southern Mid-Atlantic region. We tagged 35 turtles and spotted an additional 22 (**Table 1**). We also spent a day within Gulf Stream waters at approximately 36.5° latitude, -73.5° longitude (**Figure 1**). Sea surface temperature (SST) reached ~25°C in these offshore waters. Closer inshore, temperatures ranged between ~15°- 20°C. All turtles were caught in the western portion of the former Delmarva Access Area. We collected lavage samples from all caught turtles, and identified the presence of nematodes in seven turtles.

Tagged turtles behaved similarly to those tracked during previous years in that they continued to meander north through the summer, reaching their northernmost foraging grounds in August and September (**Figure 2**). Turtles foraged within all Mid-Atlantic Bight (MAB) scallop access areas

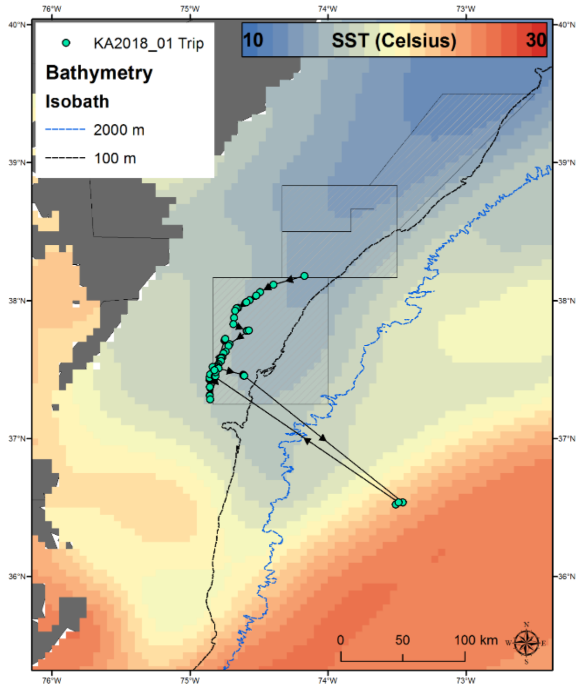

Figure 1: Trip path for the May 2018 turtle tagging trip aboard F/V Kathy Ann with overlaid average SST for those days, May 21 – 25, 2018. Hashed boxes, in all maps, represent current and former MAB scallop access areas.

throughout the entire summer. Turtles diagnosed as positive for the nematode *Sulcascaris sulcata* did not move as far north beyond the range of the Access Areas as those without the parasite, with concentrations of nematode-positive turtles found in the Elephant Trunk and to the south in the former Delmarva Access Area (**Figure 3**). This is similar to distributions of nematodes found in scallops as presented by Rudders et al. (2018) at the 2018 Atlantic Sea Scallop Plan Development Team meeting.

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 action 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. 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.

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 remote 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 ~65,000 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 was critical for the first ever estimate of absolute abundance of loggerheads in the shelf waters of the east coast and has 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 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 impact to the environment.

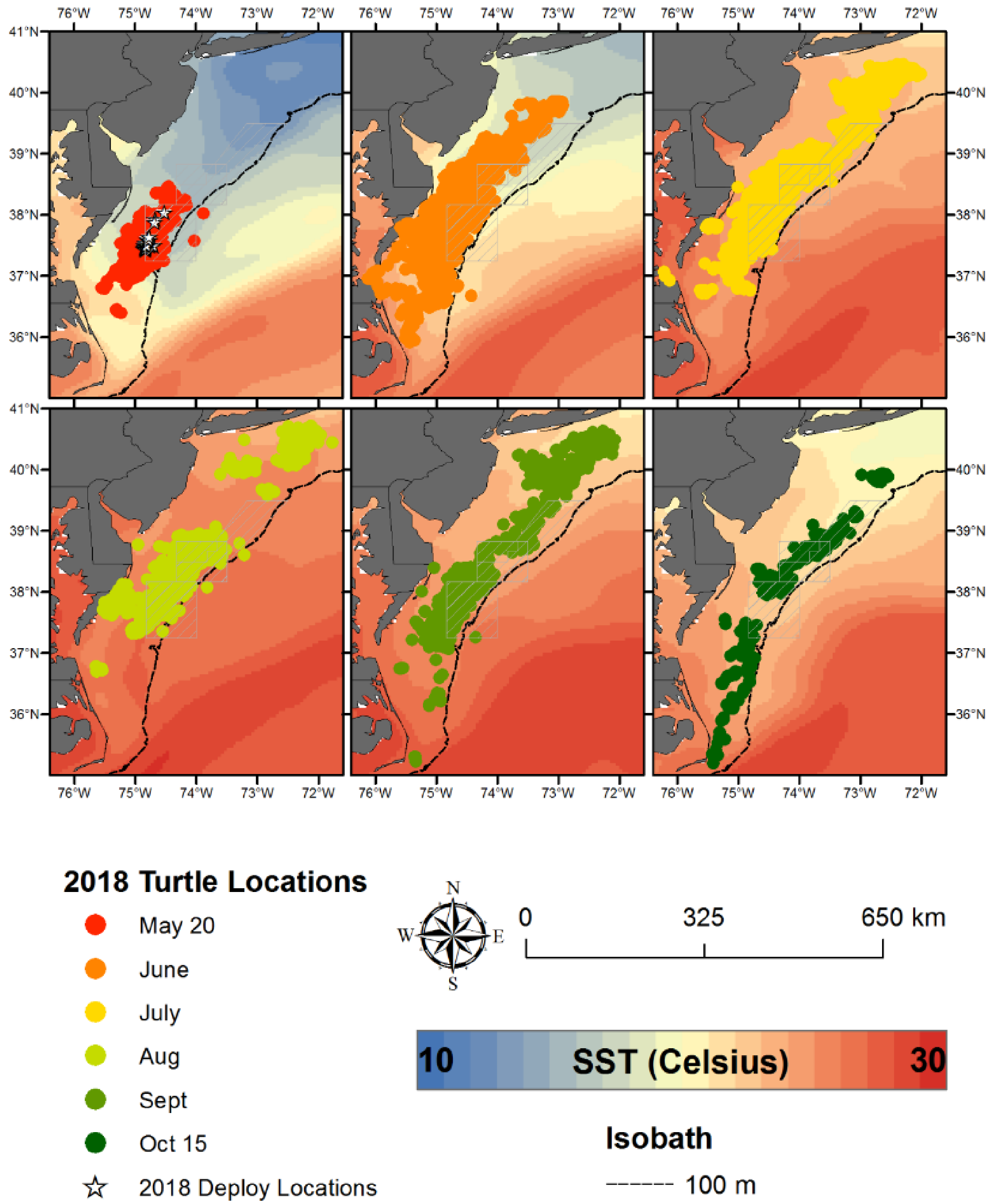

Figure 2: Turtle locations during the summer months for all tags deployed during the May 2018 trip overlaid with average SST during that time.

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)

The Coonamessett Farm Foundation RSA-funded sea turtle research is a collaborative program 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 will continue on a yearly basis to catalog new data, update distribution maps and assess new or modified methods while retaining the larger context of overlap with the sea scallop fishery (**Figure 4**). The sea turtle research program is similar to a yearly survey, which on an annual basis adds important data points to update assessments but requires several years of effort before yielding higher level products. Since 2014, this collaborative research program has led to six published peer-reviewed manuscripts, and two more papers are in preparation (**Appendix 1**). Furthermore, the data from this program is currently being used in two fully funded Saltonstall-Kennedy 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 commercial fisheries and sea turtle densities in the Greater Atlantic Region (GAR).

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. This indirect approach is required because scallop dredges no longer catch turtles and takes cannot be calculated from on-deck observations. The annual goals are objectives for the current funding year.

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?*

Annual goals:

1. *Collect samples from a minimum of 20 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. *Assess results of new or modified methods.*
5. *Expand database of loggerhead turtle biology and ecology to be used by management.*

2. Methods

At-sea Operations

CFF and NEFSC 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.

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

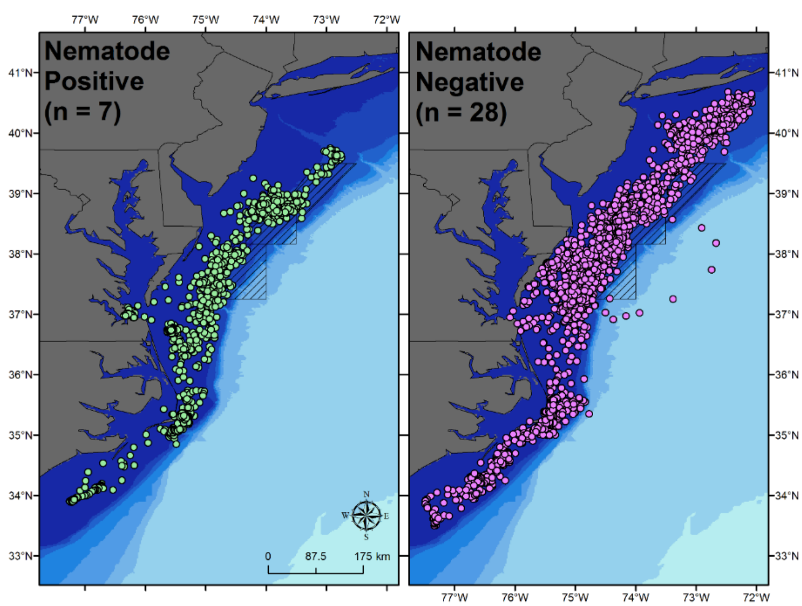

Figure 3: Comparison of all locations between tagged turtles that tested positive and negative for nematode eggs.

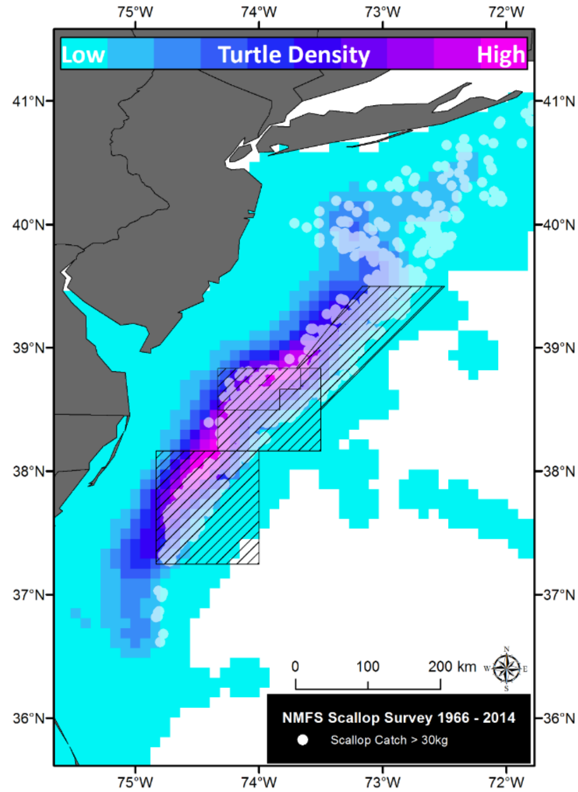

Figure 4: Density of sea turtle location data between June and September from 2009 – 2018 overlaid with scallop catch from the NMFS survey.

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 and straight carapace lengths, 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 5**). In addition to the SMRU SRDL tags, we deployed nine satellite tags from Wildlife Computers (WC) as a low cost, high output option to improve understanding of foraging fidelity. This tag does not transmit dive data, but provides location and temperature data and has a battery meant to last three years. Currently, the SMRU tags we have used since 2009 are programmed to last 13 months. In terms of biological sampling, blood, tissue and lavage samples are retrieved 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.

Fecal Sample Analyses

All fecal samples were analyzed at Roger Williams University in the Roxanne 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 then a flotation solution was added. This was then centrifuged a third time with a cover slip placed as a lid on the sample tube. Due to the density of the flotation solution, the centrifuging 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. All noticeable findings from the microscope were photographed. Currently, in collaboration with David Rudders at VIMS, we are working on developing a method to test for the presence of nematode eggs using genetic markers. This will allow for quicker and more accurate processing of the samples.

Data Analysis

Figure 5: Turtle safely being returned to the sea after sampling and satellite tag attachment.

To complete the annual goals, we summarized telemetry data received from all 35 tags. All location data were first filtered using methods developed by Winton et al. 2018 using an R Shiny app developed in collaboration with the NEFSC using National Protected Species Toolbox funding from the Office of Science and Technology, NMFS, NOAA. 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 2018 tag data to those from previous seasons. First, we compared the 2018 cohort with the 2017 tags, and then with the full suite of tag data from 2009. We also updated the full suite of data with the 2018 tags to improve mapping of turtle density during the peak foraging season in the MAB (June – September) and overlaid these results with historic scallop sampling from the NMFS survey.

After deploying all of the new WC SPOT375B tags, we assessed their value compared to the traditional satellite tags we have deployed since 2009 (SMRU SRDL). We compared tag duration and examined the data output from the WC tags. We also took a closer examination of the WC tag deployed in 2017 (Turtle 2017.25), as this tag lasted over a year and provided important information on foraging site fidelity.

During FY18/19, two SMRU SRDL tags were recovered by scallopers fishing in the MAB. This 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 each turtle beyond the typically compressed data that is transmitted through the satellites. We summarized the data from each recovered tag.

Regarding nematodes, we plotted the differences in foraging habitats for those turtles that tested positive and negative for the eggs. We also assessed demographic differences and compared results from offshore tagging with those from nearshore stranded turtles.

3. Results

During the 2018 season we deployed 35 tags. This is the most tags deployed during a single trip since the tagging program started. In total we encountered 57 turtles. All turtles were caught in shelf waters, and although we had ideal weather during our excursion to the Gulf Stream we did not spot a single turtle. All turtles were caught in temperatures below 20°C, while Gulf Stream waters were ~25°C. As of June 18, 2019, one tag was still transmitting. When combined across all years, we have now accrued ~65,000 transmission days with 201 satellite tag deployments.

We deployed nine WC SPOT375B tags and 26 SMRU SRDL tags. Both sets of 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 142 days as of June 18, 2019. This is substantially lower than previous years (average duration for all previous years combined = 363.1 days), and we suspect this is due to the tags remaining in storage for such an extended period of time. We had accrued a large number of tags due to a lack of deployments during the 2017 late-season trips. Trips 2 and 3 from 2017 yielded only 6 deployments.

Over the past two seasons, we deployed ten WC SPOT375B tags as a lower cost, longer term tag. We deployed one tag in August 2017 and nine tags in 2018. Overall performance was inconsistent, with a mean (±SD) duration of 203.5 ± 139.4 days. We expected these tags to last closer to 700 – 1000 days, as they are marketed as longer term tags with fewer sensors. These tags transmitted location, temperature and percent of time tag was dry, which translates into time spent at surface. The tags have metal contact points that emit and receive low levels of current.

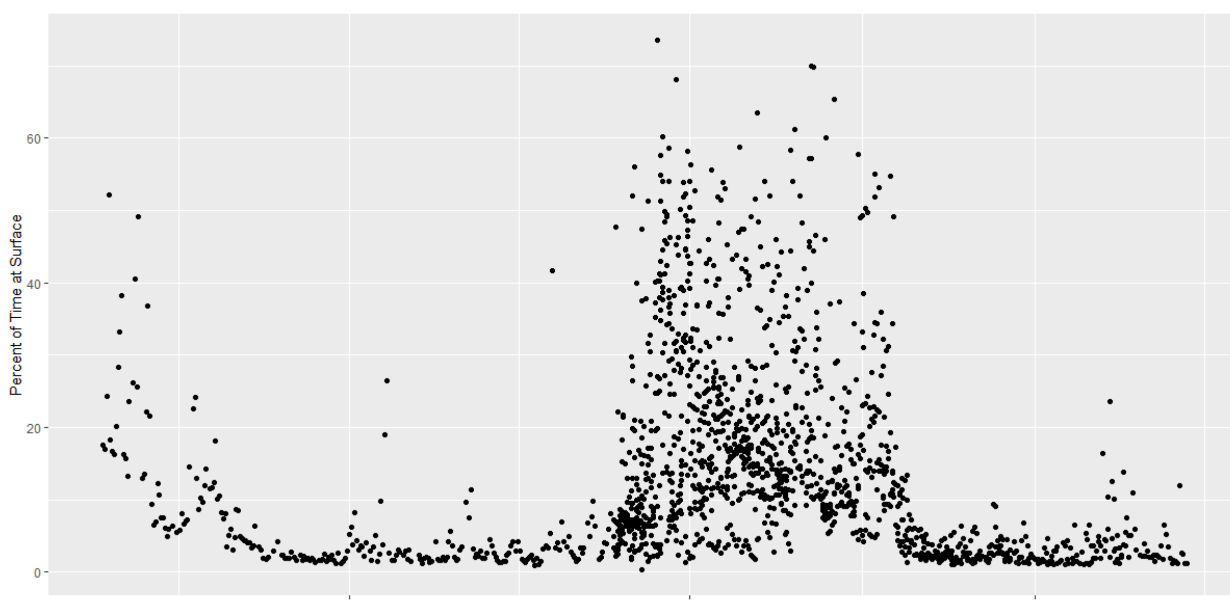

Figure 6: Percent of time at the surface for all ten turtles with Wildlife Computers tags.

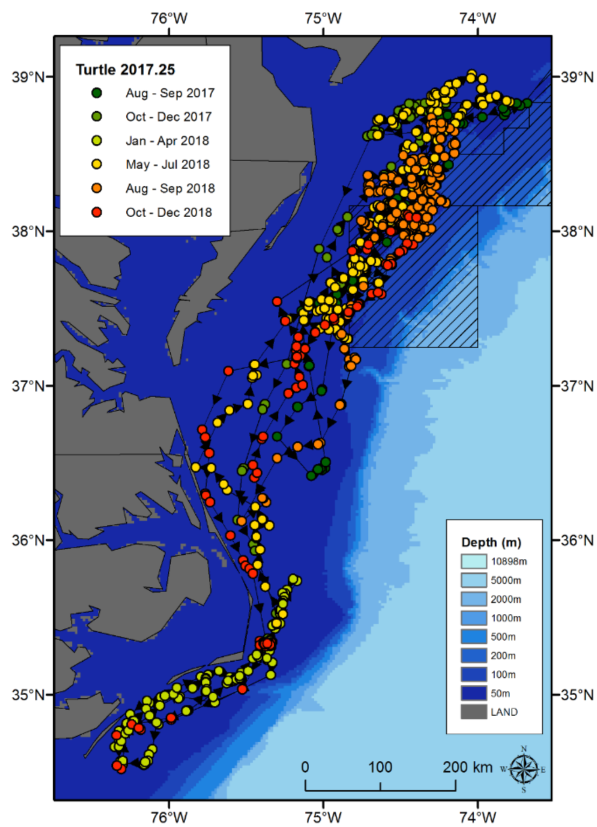

Figure 7: Location data for Turtle 2017.25.

When the tag is submerged in salt water, the water acts as a conductor and the current is able to flow between the contact points indicating to the tag that it is 'wet'. When the tag breaks the surface, the current cannot flow between the contact points and the tag registers as 'dry'. As a result, there is a fairly immediate indication to the tag when it has breached the surface and when it has become submerged. The occasional splash on the tag while the tag is above water in the 'dry' state will not register to the tag as 'wet'. Overall these turtles spent the majority of time in temperatures between 19° – 23° C. Regarding time at surface, there was a clear seasonal trend in the amount of time turtles spent at the surface (**Figure 6**). During the summer months, turtles spent substantially more time at the surface, while during the winter months, they spent nearly no time at the surface.

Turtle 2017.25 was tagged in August of 2017 with a WC SPOT375B that was more recently purchased, and this tagged lasted a total of 486 days and yielded 3,286 locations (**Figure 7**), 2470 time-at-temperature histograms (4 hr periods) and 147 histograms of the percent of time tag was dry (24 hr periods). Overall, this turtle seemed to show a high level of foraging site fidelity, returning to the same region in subsequent foraging seasons. Additionally, surface time was very similar between foraging seasons indicating a clear behavioral shift from foraging to overwintering. This turtle spent the majority of its deployment time in water temperatures between 17.5° – 20° C, and this is likely due to the majority of data coming from Oct – April, while the turtle was migrating south and overwintering. From May – Oct, this turtle spent the majority of its time in water temperatures between 20° – 22.5° C.

Two satellite tags were recovered within the past year (**Figures 8 and 9**). One tag was deployed on Turtle 2016.08 and the other was deployed on Turtle 2017.12. Turtle 2016.08 was tagged May 19, 2016, first travelled south, then returned back north and foraged just east of the Hudson Canyon Access Area. The tag stopped transmitting on October 9, 2016 and was recovered by a scalloper in August 2018. We were able to recover nearly all of the data from this tag starting on June 1, 2016 and ending on Jan 18, 2017. Data from June 1 to Oct 9 indicates consistent dive behavior, with ~40% of time above 5 m depth and ~24% of time below 30 m (likely on bottom). This turtle likely spent time in the Cold Pool water mass, with ~30% of dive time spent in temperatures below 10°C (Patel et al. 2018). However, from Oct 9 to Nov 8, the tag was continuously recording from the sea floor, before it then seemed to surface and remain at the surface till Jan 18. As a result, we suspect the tag was still on the turtle that had died in Oct, then sank and remained on bottom for a month, before becoming bloated due to decomposition and then resurfacing and floating till the tag stop functioning. Eventually, the tag fell off and returned to the sea floor.

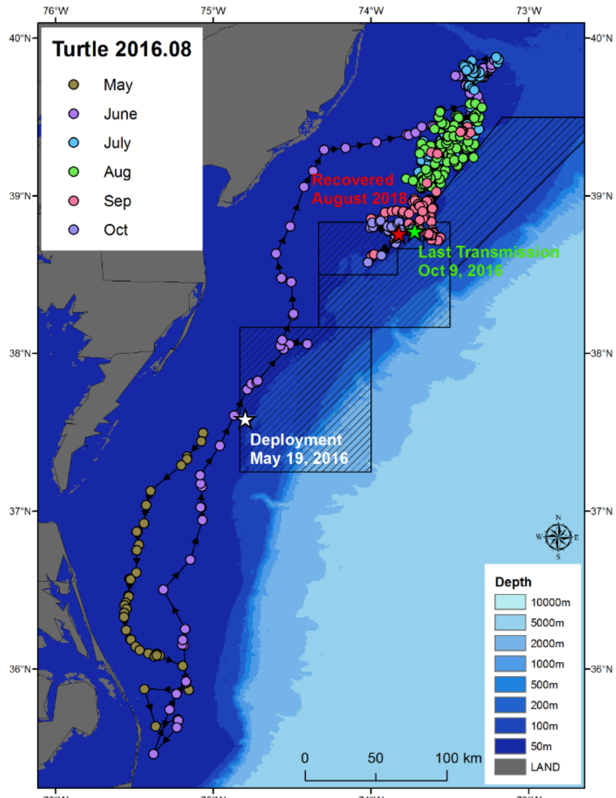

Figure 8: Location data from Turtle 2016.08. The tag from this turtle was recovered at the red star symbol in August 2018.

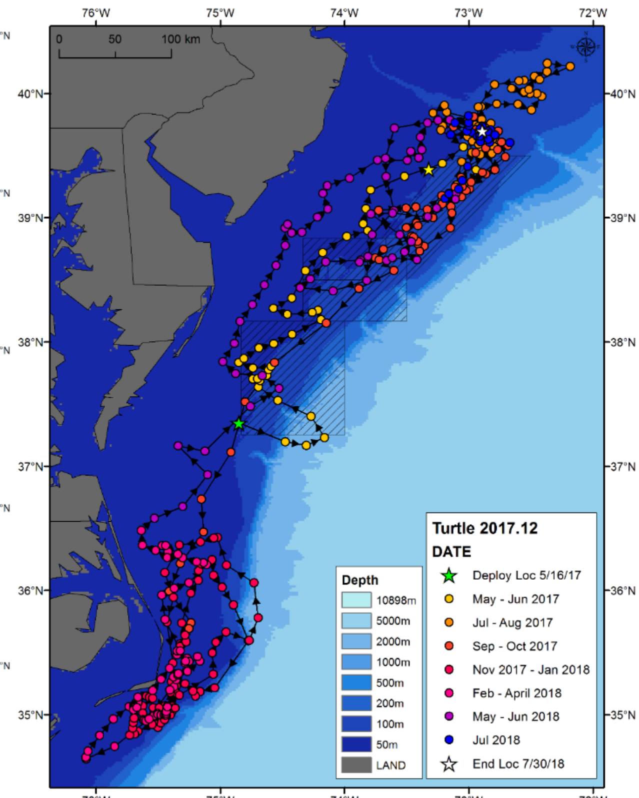

Figure 9: Location data for Turtle 2017.12. The tag from this turtle was recovered at the yellow star symbol in March 2019.

Turtle 2017.12 was tagged on May 16, 2017. This turtle travelled north through the Hudson Canyon Access Area and spent most of its time on the southern edge of Hudson Canyon during the summer of 2017. Then this turtle spent its winter adjacent to Cape Hatteras before then returning to the Hudson Canyon area during the summer of 2018 to nearly the same foraging location as the previous year. The tag stopped transmitting on July 30, 2018 and was recovered in March 2019 by another scalloper. From this tag we recovered a continuous time series of temperature/depth readings from June 22, 2017 to July 28, 2018. During the summer months this turtle spent ~64% of dive time above 5 m of depth and only ~16% of dive time below 30 m. However, during the winter months adjacent to Cape Hatteras the dive behavior was nearly reversed, with only ~7% of dive time above 5 m and ~77% of dive time below 20 m (shelf near Cape Hatteras is slightly shallower than summer foraging spot) (**Figure 10**). This turtle seemed to spend less time in colder waters during summer foraging than turtle 2016.08, with only ~9% of dive time in temperatures below 10°C.

From turtles tagged during 2018, we found 7 positive for nematode eggs. These turtles foraged within the MAB scallop access areas, and remained slightly more south than the remaining tagged turtles. Overall, there were no clear demographic differences between those positive and

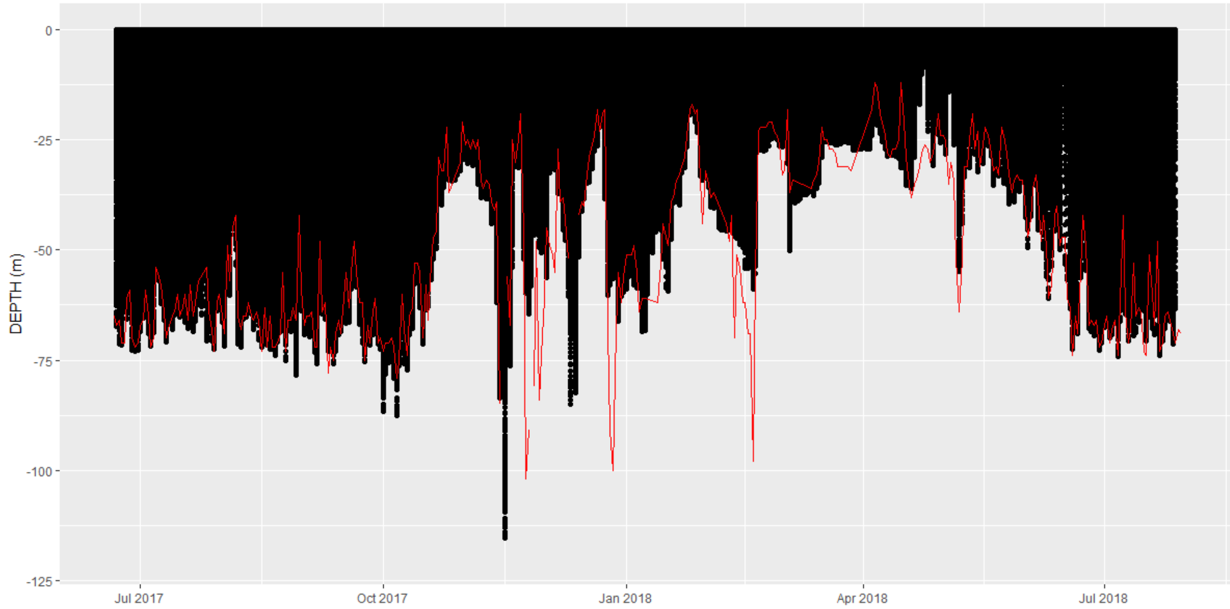

Figure 10: Dive data from recovered tag (Turtle 2017.12). The red line represents the actual bottom depth from the ETOPO1 model. When this turtle dove, it generally dove to the bottom.

negative for nematodes. We also sampled from 96 necropsied turtles during the 2018 cold stunned turtles that stranded on Cape Cod. From these samples, three turtles were positive for nematodes, including one Kemp's ridley turtle.

4. Discussion

During FY2018/19, 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 and a 'PG#' is also placed next to each statement within the discussion of the annual goals regarding work that directly contributes to the completion of a programmatic goal. 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.

Programmatic goals:

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

Winton et al. (2018) partially addressed this goal. Winton et al. (2018) 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. This goal will continue to be updated as more data is accrued.

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 that remains between 30 – 70 m during the summer months. This goal will continue to be updated as more data is 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. And 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.

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 final report. For the 2020/21 RSA proposal, we are requesting long-term tags from a new manufacturer, Kiwisat, in order to continue efforts in resolving this goal.

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. We are also taking steps to understand the impact of water temperature on sea turtle distribution through a project funded by the S/K program. The results from that project are the first steps in gaining a better understanding on how behavior also is impacted by temperature.

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?*

This goal is being partially addressed through an S/K funded project of determining how loggerhead distribution will shift as a result of climate change. Dy determining how the distribution will shift, we can start identifying how migratory pathways might also change. The S/K project ended Aug 31, 2019, and a final report will be available by Nov 30, 2019.

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. Through this project, we will be presenting how the sea surface temperature is projected to rise as a result of climate change.

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 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 to be infused into oceanographic models for forecasting temperature through depth within the region. We expect the turtle-derived data to greatly improve the ocean models and particularly the forecasting of bottom temperatures, which are most relevant for scallops.

<u>Annual goals:</u>

1. *Collect samples from a minimum of 20 loggerhead turtles caught at-sea.*

This year we caught and tagged 35 loggerhead turtles. CFF, through RSA funding, provided 19 tags, while NEFSC contributed an additional 16. We had a large stock of tags due to low deployment numbers during the final two trips of the 2017 tagging season. As a result, we had the opportunity to deploy more than 20 tags, and due to ideal weather conditions during the 2018 cruise, we also achieved our most successful tagging trip. 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. In 2018 we encountered turtles that were slightly larger on average (curved carapace length (CCL) mean ± SD = 81.4 ± 8.6 cm, n = 35) than 2017 (CCL = 78.4 ± 12.1 cm; n = 22); however there was not a significant difference in sizes (PG#3). It is imperative that we continue to tag and

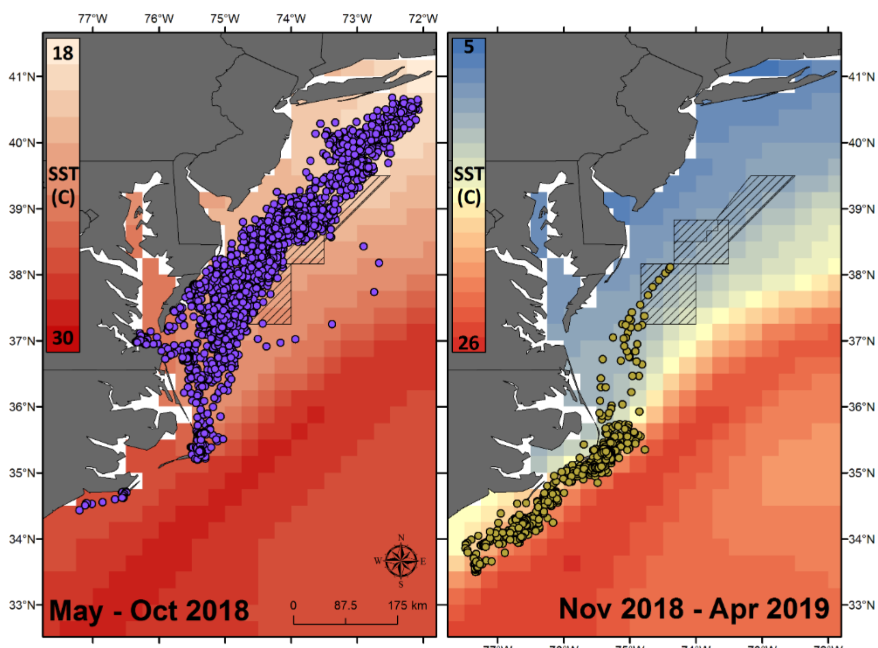

Figure 11: Seasonal distribution of loggerheads tagged in 2018, with SST overlay. Notice the SST colors and scale bars for each map are slightly different.

sample from at least 20 turtles per season. Currently, at this sample rate, we have not recaptured a single turtle we have tagged. As a result, our conclusions on the collected data do not necessarily represent population scale trends. The cohort of 2018 tagged turtles represents a clear shift from the previous years' trends on loggerhead distribution in the MAB (**Figures 11 and 12**), validating the need for more data before establishing accurate generalities for this population.

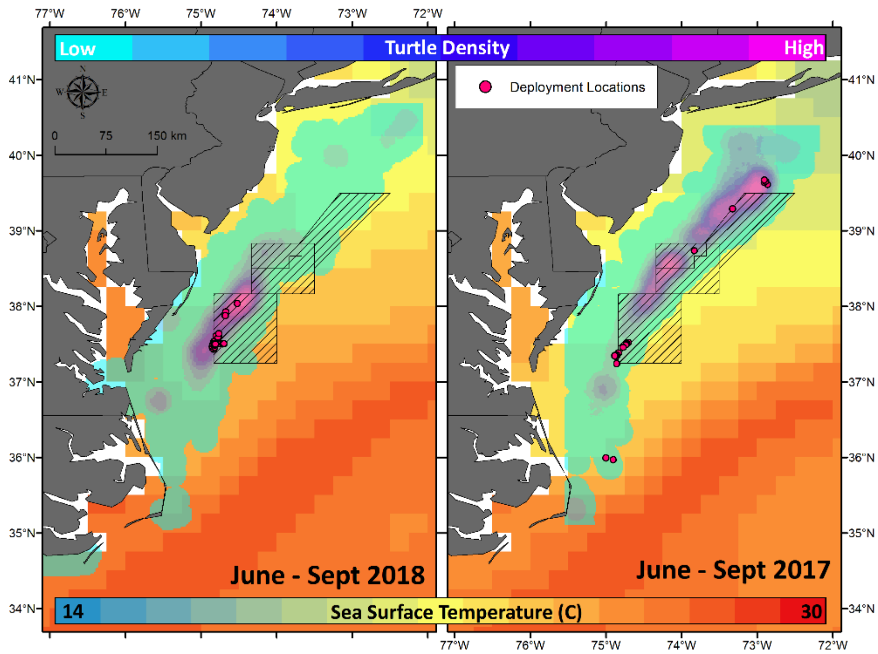

Figure 12: Concentrations of turtles tagged during the offshore loggerhead tagging trips in the MAB in 2018 (left) and 2017 (right) overlaid with mean SST from June – September.

2. Document seasonal distribution of loggerhead turtles within the MAB for transmitters functioning during the funding year.

In 2018, the majority turtles maintained the typical seasonal distribution of remaining in the MAB from May through Oct, before returning south to coastal North Carolina waters during the winter months (**Figure 13**; PG#1). However, across all years, we have started to notice a trend of turtles spending more time in the MAB beyond the date range (May – Oct) required for the Turtle Deflector Dredge (TDD; **Figures 14 – 16**; PG#1). This needs further investigation with a longer time series of data.

During the summer months, turtles tagged in 2018 did not migrate as far north as in previous years, concentrating within the southwestern portion of the former Delmarva Access Area. Typically, tagged turtles tend to concentrate in the Elephant Trunk. Although, tagging occurred at nearly the same time and location as previous years, the cohort of turtles that were captured and tagged seemed to exhibit a slightly different migratory strategy. This makes it abundantly clear that a yearly survey of loggerheads within the MAB is required to accurately determine where they are likely to concentrate during the time period required for the TDD.

Based on previous years' data, there had been a noticeable trend of more and more tagged loggerheads reaching Hudson Canyon and beyond. However, in 2018, fewer turtles migrated so far north even though summer SST was generally warmer than 2017, when there was a particularly high density of loggerheads near Hudson Canyon. In 2018, turtles spent 30% of their time in areas with SST between 25° – 27° C; however in 2017 turtles primarily resided in waters with SST between 22° – 25° C (PG#5, 7, 8). As a result, it seems that summer SST in the MAB is not a limiting factor for loggerhead dispersal.

3. *Identify presence/absence of nematode parasite in lavage samples.*

Overall we identified 10 turtles positive for nematodes from all sampling (PG#6). Seven turtles from the offshore cohort were positive for nematode, and these turtles exhibited a lower dispersal range than those negative for the nematode. The offshore loggerheads that were positive averaged approximately the same size as those that were negative (~82 cm CCL); however they remained resident in more southern waters overlapping with the MAB scallop access areas. Over the three years of nematode sampling, those positive for nematodes tend to stay further south, overlapping with the MAB scallop access areas, while those that are negative for nematodes show a higher level of dispersal. As a result, it does seem clear that turtles foraging in the MAB with the higher level of overlap with scallop abundance have a higher likelihood of being positive for the nematode. Although it is still uncertain when and how loggerheads obtain the nematode, by foraging within the Mid-Atlantic scallop grounds south of Hudson Canyon, it is apparent that they are not dispersing the parasite further north.

To gain a better understanding of the connection between foraging behavior and nematode presence, we have started developing a loggerhead camera tag to deploy on offshore turtles for 4-6 hrs at a time. These tags could help us identify exactly what these animals are eating by providing footage from the perspective of the turtle. These types of tags have been successfully deployed on hard-shelled turtles around the world and have not shown to noticeably impact natural behavior. With our 45 hours of ROV footage, we have a clear comparison for the on-animal footage to determine its impact. We expect this camera tag to be an important component in collecting direct data of loggerhead prey preferences to determine the foraging ecology of sea turtles in relation to sea scallops.

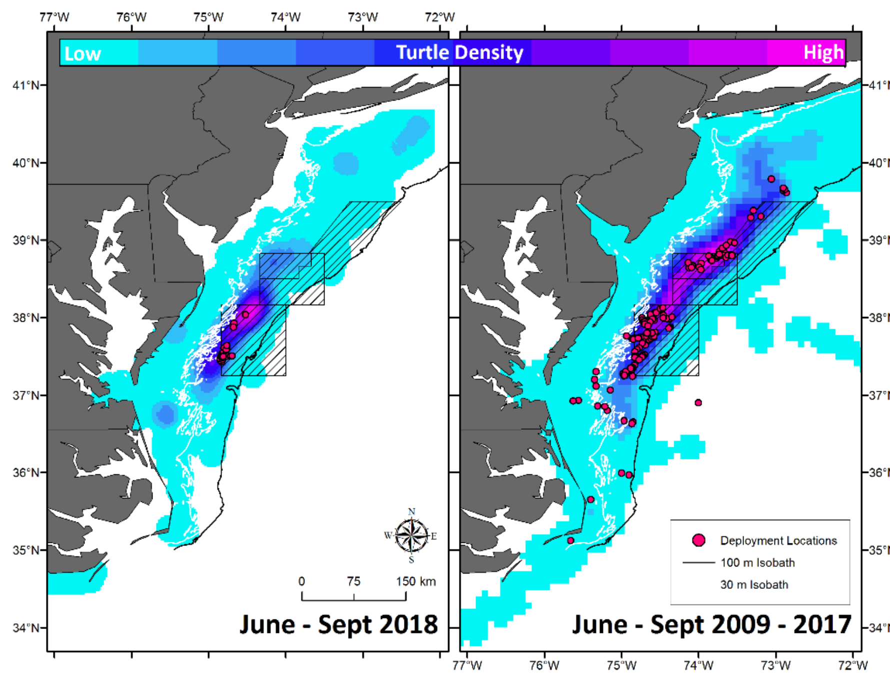

Figure 13: Concentration of turtles tagged in 2018 (left) and all previous year (right) from June – September.

One of the stranded turtles that tested positive for nematode eggs was a Kemp's ridley turtle. Typically, Kemp's ridleys of the demographics that strand in Cape Cod (10 – 30 cm CCL) are

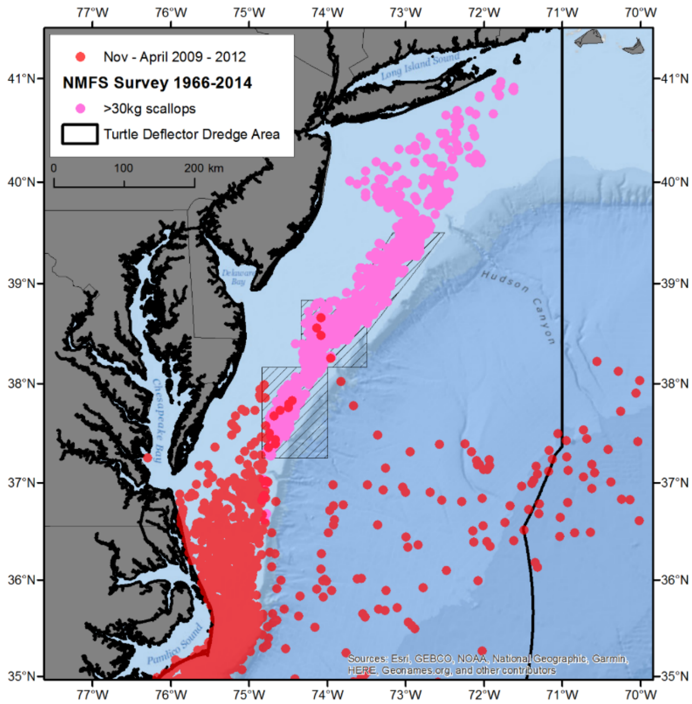

Figure 14: Turtle locations from November through April 2009 – 2012.

considered pelagic foragers unlikely to feed on benthic species. Although it is unknown how or when this turtle obtained the parasite, the conservative assumption is that this turtle obtained it through benthic foraging on or near scallop grounds. Currently, there are no gear modifications specifically designed to account for the potential bycatch of smaller sea turtles. Turtle chain mats in MAB have 14 inch windows to reduce the bycatch of juvenile and adult loggerheads; however are too large for the smaller turtles (<50 cm) that inhabit the region. Fishermen are already using chain mats when fishing in rocky habitats with 6 – 8 inch windows; however the efficiency of this gear modification hasn't been formally tested to determine its feasibility in regions with a higher potential for sea turtle bycatch.

4. *Assess results of new or modified methods.*

In combination with the third trip from FY17/18, we tested a new satellite tag, WC SPOT375B. We decided on this tag due to its low cost ($1500/tag) and advertised long battery life (25 – 36 months). Currently, the SMRU SRDL tags, which we have used since 2009, cost ~$5500/tag and last typically 11 – 13 months. These tags have been very effective, providing high data output and consistent results. However, to improve understanding on foraging site fidelity, we need to track turtles for 18 – 24 months to get a more complete sense of their summer foraging strategy from year to year. As a result, we purchased 10 WC tags as a pilot study to determine if we could achieve an 18 – 24 month deployment. The drawback to the WC tags was that they only record and transmit temperature, percent of time dry (equivalent to time at surface), and location. As a result, these tags have potentially very long battery lives but less data output. Overall, the results from the 10 deployments have been disappointing. These tags did not last nearly as long as projected; however, they did last longer than the SMRU tags deployed at the same time (SMRU mean ± SD = 132.4 ± 92 days).

In terms of overall data output, the WC tags did provide quality location, temperature and surface duration data. These data were useful in determining a strong seasonal difference in dive behavior (PG#2, 5). This makes it clear that while turtles are in the MAB during the summer and fall, they are inhabiting the entire water column, spending considerable time transiting from surface to bottom and back. In the winter months, turtles tend to spend the majority of time submerged and likely on the bottom. As a result, scallop dredges in the MAB could interact with a turtle on the bottom during dredge tows or throughout the water column during the deployment and return of the dredge.

Overall, we do not expect to deploy more WC tags; however, we will continue to pursue research into foraging fidelity through the use of more long term satellite tags (PG#4). While loggerheads seem to inhabit the entire MAB during the summer months, by determining the level of fidelity for specific foraging sites we can establish more specific habitat ranges for turtles within the region. There are other tags available from other companies that advertise the same battery life as the WC tags. For example, Kiwisat K2G 376D tags advertise 3 - 4 years of battery life along with full dive data and Argos locations. These tags are only $1600. If these tags work as advertised, they could be a full replacement for the SMRU SRDL tags because the data outputs are nearly identical. As a result, purchasing ten Kiwisat tags would cost only $15,000, rather than the current cost of $55,000 for ten SMRU SRDLs. However, before this full switch is implemented, we need at least 2 years of testing to determine feasibility of making this change.

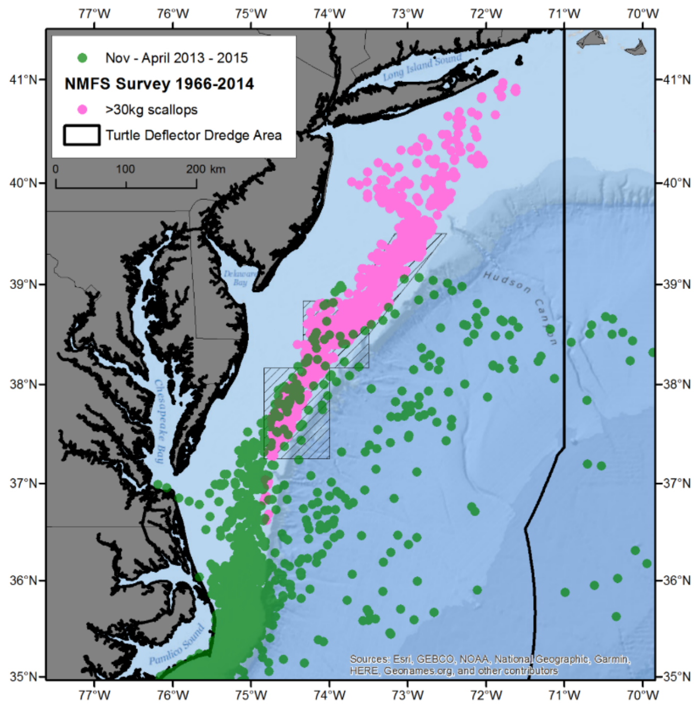

Figure 15: Turtle locations from November through April 2013 – 2015.

5. *Expand database of loggerhead turtle biology and ecology to be used by management.*

The FY18/19 turtle program added 5,000 days of data to the ever-expanding loggerhead data set, along with 35 sets of demographic, biological and morphometric data. Although we have tagged over 200 turtles, we still have not reencountered a turtle tagged through the RSA program, indicating that this population is very large and needs continued monitoring before population-level trends can be identified. As is clear from this season, more research is needed; although this was a particularly large cohort of tagged turtles, they exhibited unexpected behavior contradicting previous years' trends of distribution within the MAB.

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 (most recently: https://www.govinfo.gov/content/pkg/FR-2019-03-28/pdf/2019-05939.pdf). Currently, the 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 could quickly become implemented, as have occurred with the periodic closures of Closed Area II due to yellowtail flounder bycatch. Loggerheads concentrate in the MAB from June – Sept each year. A closure during these months would force the fishery out of the MAB during a period when Limited Access vessels have previously captured ~40% of the total catch within the access areas in the region (https://www.greateratlantic.fisheries.noaa.gov/ro/fso/Reports/ScallopProgram/FY2016/la_sub_acl_2017-03-16.pdf). Closures of this region would impose substantial strain to the fishing vessels and habitats of Southern New England and Georges Bank. Currently, without observed captures, 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 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.

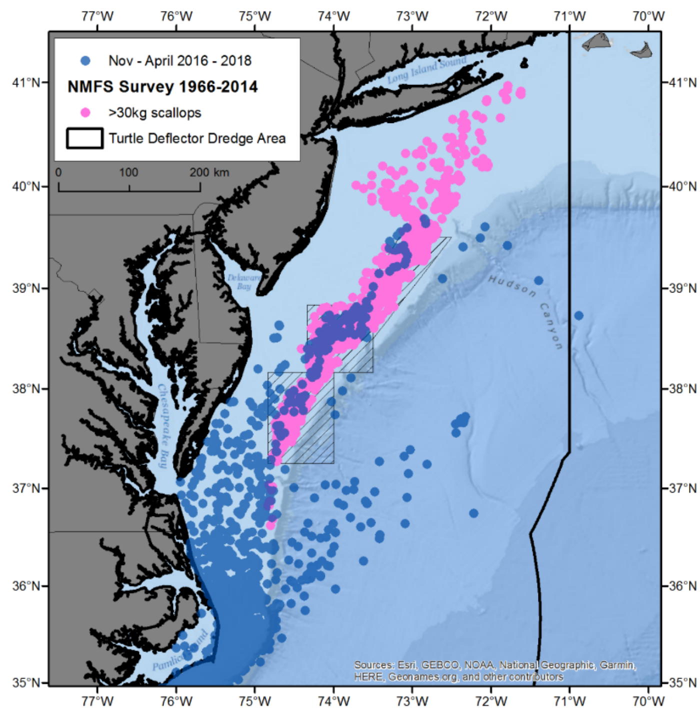

Figure 16: Turtle locations from November through April 2016 – 2018.

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Appendix 1: Publications and select presentations resulting from past RSA funding.

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