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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Executive Summary:

Coonamessett Farm Foundation's (CFF) 2023/24 turtle research project has continued to add invaluable data to our historical dataset on loggerheads. The focus of this effort is to monitor and evaluate changes in the distribution and behavior of loggerhead 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 from turtle takes by scallop dredges.

Two tagging trips occurred during this funding cycle to deploy a total of 23 tags. The first set of tags were deployed in early June 2023 during an offshore trip within the southern Mid-Atlantic Bight (MAB) aboard the F/V Kathy Ann (KA). Across four days at sea (DAS) we deployed 15 tags. In March 2024 near Cape Hatteras, NC aboard the F/V Salvation, we conducted the second tagging trip. During this trip there was a difficulty capturing turtles compared to previous attempts, and we deployed eight tags. Combined, this added ~3,300 days of tracking data, which is similar to previous years, to monitor the health and condition of sea turtles that overlap scallop grounds, and we collected critical temperature through depth data to help evaluate scallop survival in the MAB.

Compared to previous years. the turtles tagged in NC behaved similarly by exhibiting a broader range of movement patterns with some turtles residing in nearshore waters, while others remained farther offshore and migrated north into the NY Bright region. The turtles tagged in the MAB displayed a wider range of movement patterns which was more like turtles tagged in 2018 and earlier, and quite different than those tagged in 2019 – 2022. In recent years, turtles tagged in the MAB have generally remained south of Hudson Canyon and localized to the 50 m isobath. In 2018 and earlier, turtles tended to cover a larger range of the MAB, migrating north of Hudson Canyon, with occasional individuals venturing nearshore.

With nearly 340 turtles captured since 2009, we have started identifying trends regarding the demographics of loggerheads foraging within the MAB. In general, we have seen an increasing trend in size of caught turtles since the tagging work began. This may be an indicator of improved health of the loggerhead population associated with improved fisheries management. One or both of the following two scenarios likely explains this rise in turtle size. The first is that more turtles are surviving and thus continuing to grow; the second is that more larger turtles are moving north in search of prey due to warming ocean temperatures. Regardless, the sizes of these turtles indicates that the MAB is seasonally home to a large cohort of loggerheads with a high reproductive value, making protecting them critically important for the sustainability of fisheries in the region.

Since the end of the previously funded loggerhead tagging project (FY22/23), we have contributed data to three planned publications, establishing baseline information about turtles in the region necessary for understanding future impacts. Two are written by YiWynn Chan who researched the heavy metal contamination levels in sea turtles and prey species in the northwest Atlantic Ocean. The third, written by Elizabeth Clark, establishes protocols necessary for using eDNA to determine the presence of sea turtles in ocean water samples.

1. Purpose

The National Marine Fisheries Service (NMFS) expects scallop dredge and trawl gear to interact with ~1,110 loggerheads every five years with an estimated mortality rate of 35% (NMFS 2021). As a result, nearly 80 loggerheads in the NW Atlantic are expected to perish from scallop gear interactions annually (NMFS 2021). Within the Biological Opinions for each managed fishery, Reasonable and Prudent Measures (RPMs) are established and deemed necessary to minimize estimated incidental mortality of protected species. For the scallop fishery, the RSA-funded sea turtle research directly addresses RPMs #2, #3, #4, #5, and #7 (NMFS 2021; **Table 1**). There is a necessity to continually review available data to determine whether there are areas or conditions 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, as a result this sea turtle research is required by law. In the absence of NMFS funding for the NEFSC, the scallop RSA is the only current source of funding available to allow the scallop fishery to continue meeting ESA requirements.

This project continues nearly 20 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

Table 1: 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 chain specifications, correst size for turtles within the region? (RPM#1) Demographic information for population estimates (RPM#7) Calculating Body Condition Index (BCI) (RPM#2)
Blood Sample (12 ml)	Health status, hormone levels (gender), stable istotope values, genetics	Are turtles eating scallops? (RPM#2) Population health and stress levels (RPM#3, 4 and 5)
Skin Sample	Genetics, stable isotope values	Have turtles been eating scallops? (RPM#2) Population health and structure (RPM#4 and 7)
Cloacal Lavage	Identify nematode presence gut microbiome	Nematodes and foraging preferences (RPM#2)
Physical Health Assessment	Check for injuries, both new and healed	Sources of injury, including from fisheries interactions (RPM#4 and 5) Relationship with calculated BCI (RPM#2)
Passive Tagging	For population estimates	Population size and distribution -> likelihood of interactions (RPM#7)
Body Temperature	Health status	Baseline for healthy turtles to improve survival of incidentally taken turtles (RPM#4 and 5)

advanced the ability to locate, track, and observe loggerhead sea turtles through innovative use of dredge and ROV-mounted video cameras, side-scan sonar, aerial surveys, and satellite tags. 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 interacting at the surface (Smolowitz et al. 2015; Patel et al. 2016). Over the duration of these past projects, this CFF/NMFS joint effort has resulted in the tagging of nearly 340 loggerheads, totaling ~80,000 days of tracking data. 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 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 RSA-funded turtle research continually yields a broad range of publications, including many that were used to help determine, in the most recent ESA Biological Opinion, that offshore scalloping was not likley to jeopardize the continued existence of loggerheads in the NW Atlantic (NMFS 2021). However, as has occurred with most management decisions, continued data collection is essential to maintain accuracy, and outdated information typically results in a disconnect between protocols and reality. For example, since that BiOp, a new estimate of loggerhead abundance throughout the US eastern seaboard was published by DiMatteo et al. (2024). They used data collected from 20 years of aerial surveys and calculated that there is an average annual abundance of ~200,000 loggerheads inhabiting the the US from Florida to Canada (DiMatteo et al. 2024). This is substantially less than what was reported by NMFS (2011) of over 1 million loggerheads within the same spatial range. This shift in understanding of the size of the loggerhead population could have substantial consequences on the number of takes allocated to the fishery.

The CFF RSA-funded sea turtle research is a collaborative program, most notably with the 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. 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. As such, the sea turtle research program is like most annual fisheries surveys, which 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 12 peer-reviewed publications with four more currently pending (**Appendix 1**). Furthermore, the data and field work from this program has been leveraged to obtain additional funding including multiple Saltonstall-Kennedy Grants, internal NOAA funding, awards from the Massachusetts Environmental Trust, and funding through the New Jersey Research and Monitoring Initiative. This has strengthened the RSA-funded research by infusing additional resources to improve understanding of sea turtle ecology that are otherwise prohibitively expensive. For example, most recently NJ RMI is contributing funding to analyze the inventory of biological samples that have been collected through RSA funding for stable isotopes, stress hormones, and blood chemistry levels.

In general, the annual goals are objectives for the current funding cycle, while programmatic goals are those to be achieved across several years. The programmatic goals were developed to help determine if there are any factors that may be impacting anticipated turtle take rates, a key requirement for initiating an ESA Section 7 Consultation. The 2012 estimated take rates (NMFS 2012) were higher than those calculated in the 2021 Biological Opinion, and this is a direct result of an improved understanding of loggerhead interactions with scallop fishing (NMFS 2021). The 2021 Biological Opinion has now raised the number of exempted takes available to the scallop fishery, including lethal takes available to scallop dredging, in part due to this RSA-funded research verifying that the loggerhead population in the MAB is healthy (NMFS 2021).

Annual goals:

1. *Collect samples from 25 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 and anthropogenic waste in lavage samples.*
4. *Use videography to document potential prey species.*
5. *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?*

2. Methods

At-sea Operations

F/V Kathy Ann Deployments:

CFF and NEFSC provided at-sea scientists for the research trip, which occurred in June 2023, while Jim Gutowski at Viking Village Fisheries oversaw vessel coordination and operations of the KA.

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 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, an NMFS-approved ARC twelve-foot hoop net was used to capture it. The zodiac with the captured turtle 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 KA.

Figure 1: Turtle safely being returned to the sea after sampling during trip aboard the F/V Kathy Ann. The location and orientation of the tag on this turtle is representative of all tag placements.

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 at the point where the first and second vertebral scutes meet (**Figure 1**). Biological samples were collected, including blood, tissue and lavage samples for onshore 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 we switched to using Wildlife Computers SPLASH tags that provide similar data outputs compared to previously deployed Sea Mammal Research Unit (SMRU) tags. A benefit of the SPLASH tags is that we received GPS data throughout the entire deployment, while the SMRU tags were programmed to only provide GPS during the first 3 months to conserve battery.

North Carolina Deployments:

During March 2024, we spent two weeks conducting daytrips out of Cape Hatteras aboard the F/V Salvation, ~5 – 10 km from shore in areas where turtles were spotted at the surface. Overall, due to high wind conditions, we were only able to capture eight turtles. We spent 6.5 days on the water, using an entanglement net to capture turtles. Due to poor weather, we struggled to capture turtles as easily as in 2022. We caught two turtles on the first DAS, then did not capture a turtle again until the second the last day, during which we caught two more. We then had our best weather day and travelled to a new reef east of Hatteras locally called Avon Rocks. On this day, we caught four turtles and saw many more. Each turtle was outfitted with a satellite tag and was also measured, equipped with passive internal and external flipper tags and the full suite of biological samples were taken (blood, fecal samples, skin, and scute scrapings).

At Avon Rocks, we also deployed a stationary system with an acoustic receiver, hydrophone, continuous video camera, and a time-lapse camera. We documented several animals, including multiple turtles passing through the frame, and picked up acoustic tags from a shark. Acoustic data have been uploaded to the Mid-Atlantic Acoustic Telemetry Observation System (MATOS), which is part of the larger Atlantic Cooperative Telemetry (ACT) network.

Fecal Sample Analyses

All fecal samples were analyzed at Roger Williams University in the Aquatic Diagnostics Lab (ADL) now run by Dr. Galit Sharon. Analysis protocols were developed by the ADL 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.

This year we continued to subsample the feces to determine the gut microbiome for live healthy loggerheads in offshore waters. Gut microbiome compositions can be used to determine health status and foraging preferences (Arizza et al. 2019). We developed protocols for this analysis from samples collected during the 2019 cold stun necropsies managed by MA Audubon Wellfleet Bay Wildlife Sanctuary. An assay was developed to extract genetic material from the samples, amplify the genes using PCR, and then analyze the subsequent reads to determine bacteria types found within each turtle. This led to a publication by Forbes et al. (2023) on the composition of the gut microbiome of the necropsied turtles. We have now completed this analysis on the live loggerheads sampled from 2021 – 2023, and a manuscript synthesizing the results is in preparation.

Data Analysis

To complete the annual goals, we summarized telemetry data received from all 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 used modern location filtering tools (R package Animotum) to generate interpolated tracks for all tagged turtles. This technique removes errant locations, generates location points at a specified time interval, and uses the error radius information for each transmitted location to generate the most likely position. We compared the FY23/24 tag data to those from previous seasons.

We investigated diving behavior and transmitted environmental data both throughout the duration of tag deployments and specifically in the MAB during the TDD-required months. We compared the turtles tagged in NC with those tagged on the KA. We compared distribution, dive behavior, and transmitted temperature through depth data. We compared the amount of 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 a percentage of time spent at the surface over six-hour bins. We then compared day of the year with time spent at the surface using a generalized additive model (GAM; family = gaussian; R package = mgcv). We also compared SST with dive behavior using a GAM (gaussian; mgcv) to determine the 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.

We had two turtles that tested positive for nematodes during this year's sampling, one tagged in 2023 and one in 2024. We compared these turtles' distribution with those that tested positive in previous years and mapped the results. During the cold stun necropsies, we sampled an additional 30 turtles, and none contained *S. sulcata* in their fecal material.

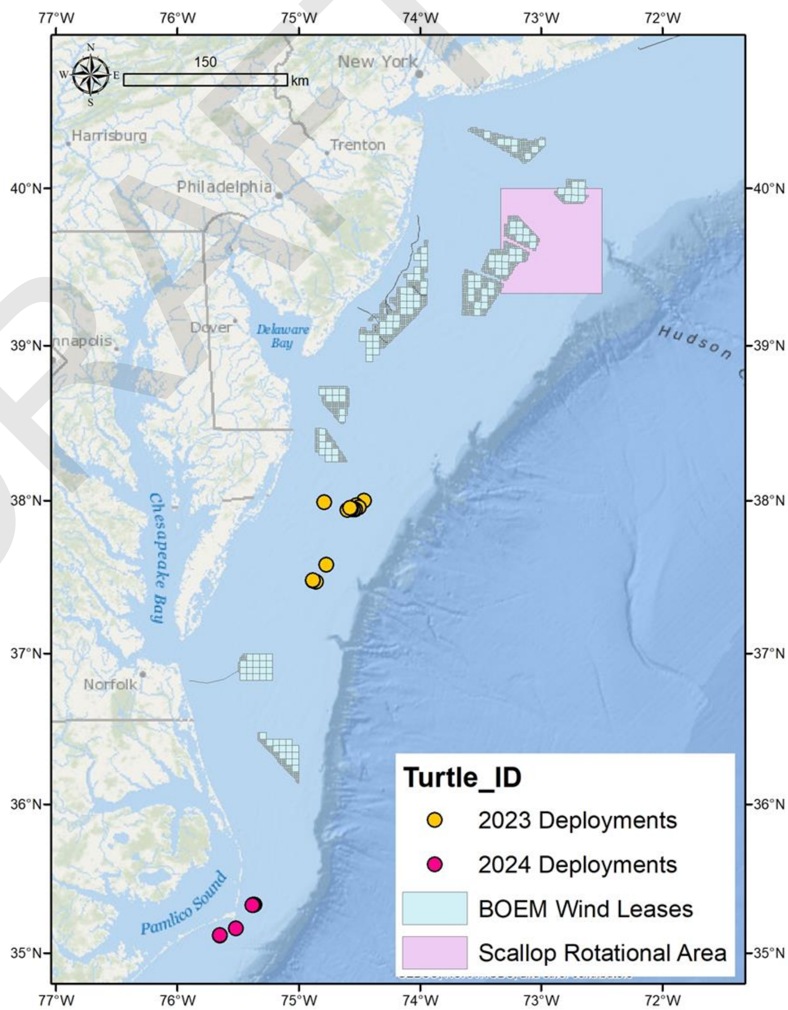

Figure 2: Deployment locations for the NC (right) and KA (left) turtles in 2023/24, along with SST layer. (Unpublished CFF and NEFSC data).

3. Results and Discussion

Annual Goal #1: *Collect samples from a minimum of 25 loggerhead turtles caught at-sea.*

During the FY23/24 season, a total of 23 satellite tags were deployed (**Figure 2**). Fifteen tags were deployed in the southern MAB aboard the KA and 8 tags were deployed in the nearshore waters near Cape Hatteras, NC aboard the F/V Salvation. One of the tags deployed in NC was contributed by Dr. Lindsay Dubbs of the Coastal Studies Institute and continues the multi-year collaboration of deploying tags on hard-shelled turtles.

The 2023 late-spring trip occurred from June 5 – 10, and we deployed all 15 tags. During the first day of the cruise, we only spotted one turtle and it dove before we captured it. During the second day, we captured nine and spotted an additional 10, then on the third day we captured two and spotted an additional eight, and finally on the last day we caught four and spotted four more. Sea surface temperature (SST) ranged from 15.6° – 17.9°C with an average of 16.7°C during the cruise.

During the NC trip, SST ranged from 11.7° – 15.4° C. Turtles were tagged on March 5th, 13th and 14th. Similar to 2022, turtles caught in NC were smaller on average (curved carapace length notch to tip [CCLnt] mean ± SD = 83.9 ± 14.1 cm) than those caught in the MAB (88.7 ± 12.0 cm). Again, we documented an inshore migration from some turtles tagged in NC. This expands our understanding of loggerhead habitat usage in the MAB, because during our offshore trips we do not typically document inshore habitat usage. Turtle size did not seem to relate to migratory path, with five turtles migrating inshore having a CCLnt range of 64.5 – 105.0 cm and those offshore ranging in size from 74.7 – 98.5 cm.

Table 2: Summary table for tags deployed in FY23/24. **Green highlighted turtles were positive for nematodes** (unpublished CFF and NEFSC data).

Turtle ID	Trip	Deploy LAT	Deploy LON	Date Deployed	CCL (N-T)	SST
2023.11	KA2023_01	38.00	-74.46	6/7/2023	98.5	15.6
2023.12	KA2023_01	37.99	-74.79	6/7/2023	95.5	15.8
2023.13	KA2023_01	37.97	-74.53	6/7/2023	102.7	16.8
2023.14	KA2023_01	37.96	-74.51	6/7/2023	86.4	16.7
2023.15	KA2023_01	37.96	-74.51	6/7/2023	85.4	17.2
2023.16	KA2023_01	37.94	-74.54	6/7/2023	109.6	17.6
2023.17	KA2023_01	37.94	-74.54	6/7/2023	77.2	16.7
2023.18	KA2023_01	37.94	-74.55	6/7/2023	88.5	16.3
2023.19	KA2023_01	37.95	-74.57	6/7/2023	61	16.2
2023.20	KA2023_01	37.94	-74.60	6/8/2023	83.7	16.4
2023.21	KA2023_01	37.95	-74.58	6/8/2023	93.4	17.2
2023.22	KA2023_01	37.58	-74.78	6/9/2023	93.6	15.8
2023.23	KA2023_01	37.47	-74.86	6/9/2023	85.5	17.2
2023.24	KA2023_01	37.48	-74.88	6/9/2023	75.1	16.8
2023.25	KA2023_01	37.48	-74.88	6/9/2023	95.2	17.9
2024.01	SA2024_01	35.12	-75.65	3/5/2024	88	13.6
2024.02	SA2024_01	35.12	-75.65	3/5/2024	105	14.2
2024.03	SA2024_01	35.12	-75.65	3/13/2024	74.7	15.0
2024.04	SA2024_01	35.17	-75.52	3/13/2024	64.5	15.4
2024.05	SA2024_01	35.33	-75.37	3/14/2024	91.9	13.0
2024.06	SA2024_01	35.33	-75.38	3/14/2024	76.2	13.0
2024.07	SA2024_01	35.33	-75.38	3/14/2024	98.5	12.3
2024.08	SA2024_01	35.33	-75.38	3/14/2024	72	11.7

This year, during the offshore trip, we continued the trend of capturing turtles generally larger than the average size for loggerheads caught during previous MAB trips. During the 2023 trip, the mean (±SD) curved carapace length notch to tip (CCLnt) was 88.8 ± 12.0 cm and weight was 88.3 ± 31.8 kg. When compared to data from all previous years (2009 – 2023) the averages are slightly smaller with CCLnt = 81.8 ± 10.7 cm and weight = 71.1 ± 28.7 kg. Compared to 2022, the turtles in 2023 were smaller, but this continues the trend of generally capturing larger turtles in the MAB.

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

Turtles tagged in 2023 and 2024 exhibited multiple different movement patterns (**Figures 3 and 4**). This is in contrast to recent years with MAB tagged turtles remaining offshore and south of

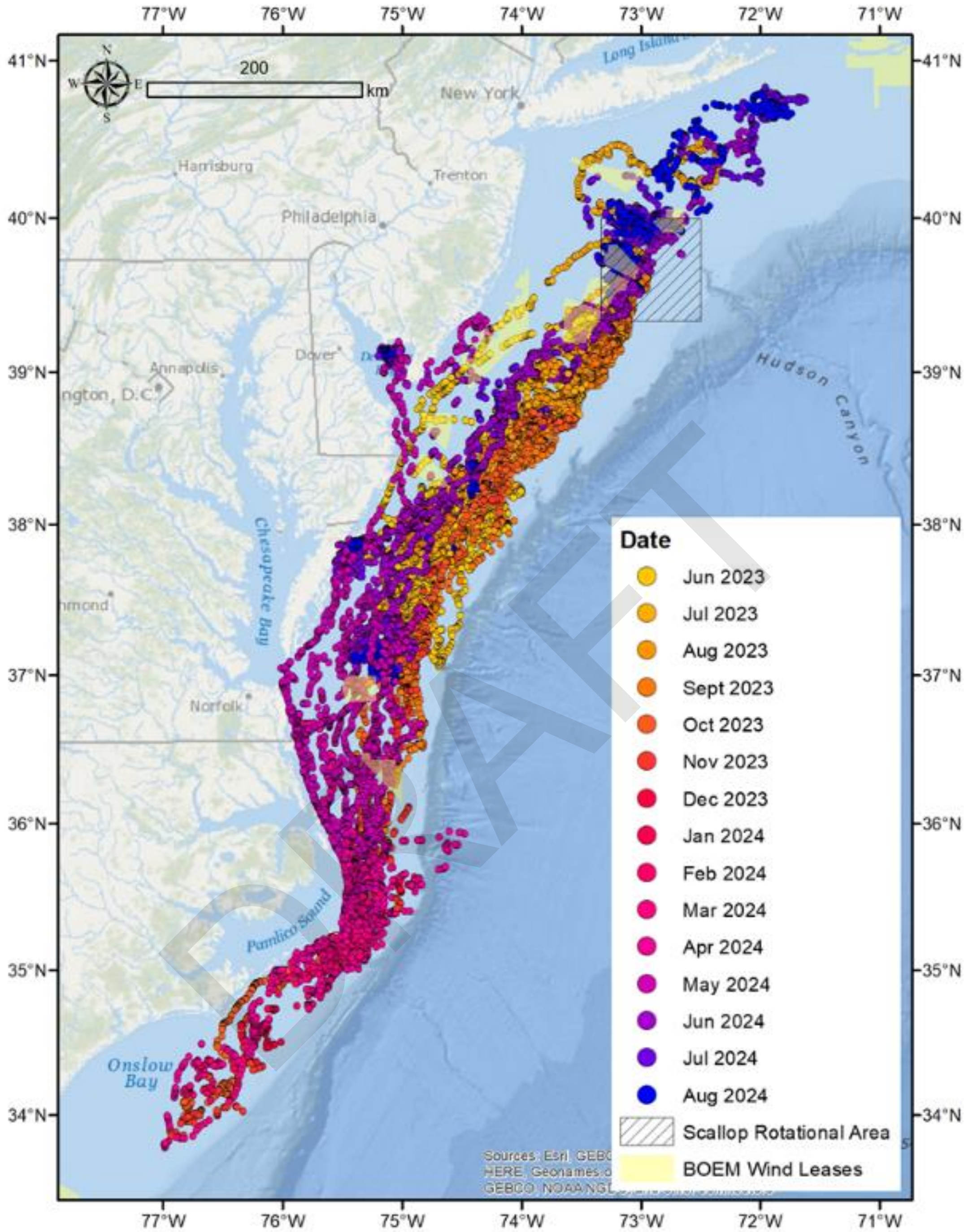

Figure 3: Location data for all turtles tagged during FY23/24. (Unpublished CFF and NEFSC data)

Hudson Canyon and turtles tagged in NC exhibiting the broader distribution. During 2023, turtles tagged in MAB exhibited a much more varied distribution, with several turtles moving inshore, some inhabiting the northwestern portion of the rotational area, and one turtle migrating north of Hudson Canyon. This is more reminiscent of turtles tagged prior to 2018, that regularly would inhabit the NY Bight. It is unclear why turtles in 2019 – 2022 exhibited a narrower range

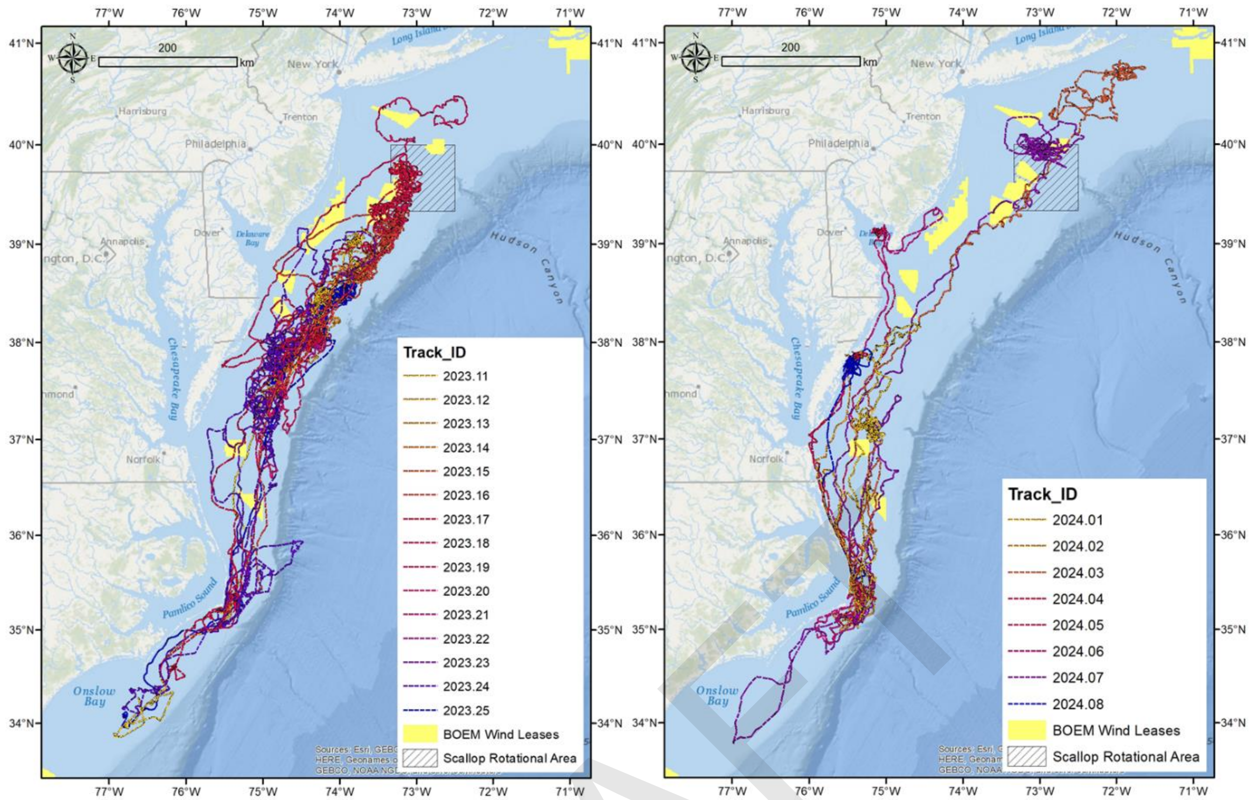

Figure 4: Location data for turtles tagged in MAB in 2023 (right) and tagged in NC in 2024 (left). (Unpublished CFF and NEFSC data)

of remaining along the 50 m isobath and staying south of Hudson Canyon, but it seems as though turtles are returning to previously established behaviors of using a larger portion of the MAB.

Turtles tagged in NC behaved similarly to previous years of either taking an inshore path northward or following an offshore trajectory along the 50 m isobath. NC turtles also exhibited a broader foraging range, with some remining at sites inshore, in the southern MAB, and farther north nearing the western edge of Long Island, NY. This distribution helps expand our understanding of the region, as the NC turtles essentially provided data from the portions of the MAB not typically inhabited by the turtles tagged directly in offshore waters.

Dive behavior also varied between years. Compared to last year, turtles tagged in the MAB, generally spent less time at the surface and remained more active later in the season, before quickly reducing dive behavior once they arrived at their southern overwintering site (**Figure 5**). Turtles tagged in NC quickly shifted from overwintering behavior of very little time at the surface to more active diving as they migrated north. The 2023 NC turtles seemed to exhibit a two-step shift from overwintering to more active diving, and this may have been due to slightly cooler temperatures in the southern MAB in the late-spring/early-summer. Although, in 2024, there did not seem to be a corresponding trend of increasing time spent at the surface and higher SST (**Figure 6**). This may have been due to the narrow range in temperatures in 2024 resulting in turtles not exhibiting variation in dive behavior.

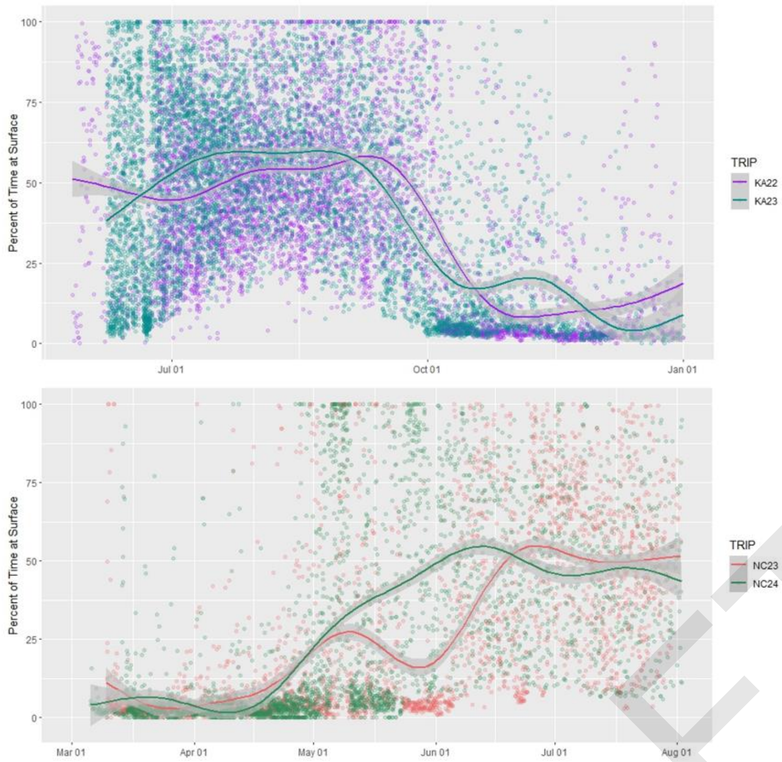

Figure 5: Turtle dive behavior comparing FY22/23 and FY23/24 data. (Unpublished CFF and NEFSC data)

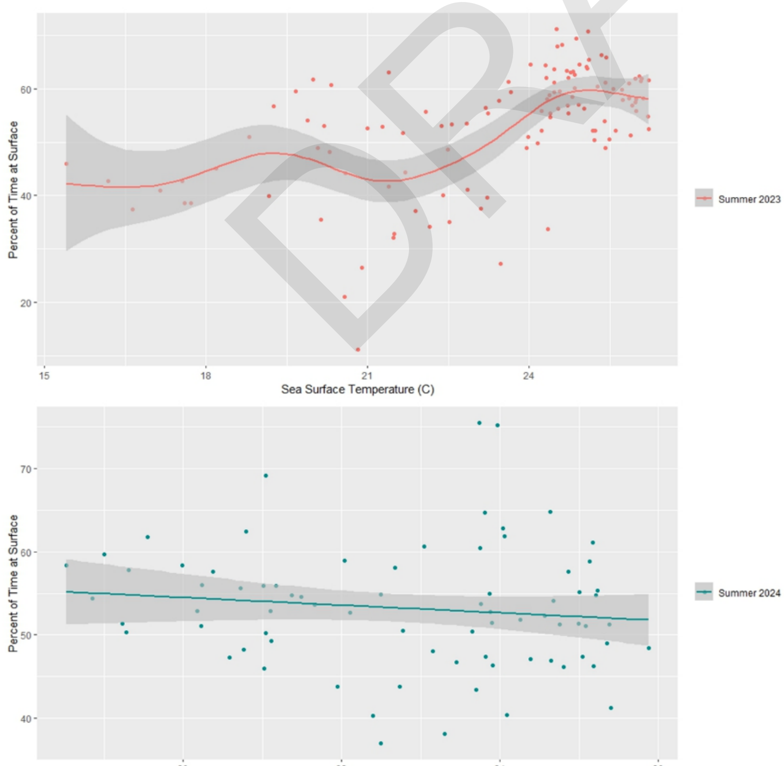

Figure 6: Turtle dive behavior compared to SST. (Unpublished CFF and NEFSC data)

Two turtles tagged in 2023 continued to transmit data for over a year, providing insight into their foraging site fidelity and seasonal shifts in dive patterns (**Figure 7**). Turtle 2023.18 first migrated inshore and then returned offshore and meandered north, foraging within the rotational area. This turtle took a quick and direct path south, settled near Cape Hatteras for a month, and then continued south and spent the winter essentially at the same location. This turtle took a similar two-step approach to returning to the MAB, first moving towards Cape Hatteras while maintaining overwintering dive patterns, and then quickly moving north to again forage within the rotational area. Turtle 2023.24 exhibited a less predictable pattern, remaining relatively nearby the tagging site for the first summer. This turtle migrated south at a similar time to 2023.18, however, returned north for approximately a month, before committing to remain near NC for the winter. This turtle continued to meander during the winter, inhabiting a few different sites; however, dive behavior remained consistent with very little time near surface during the colder months. This turtle also seemed to become active

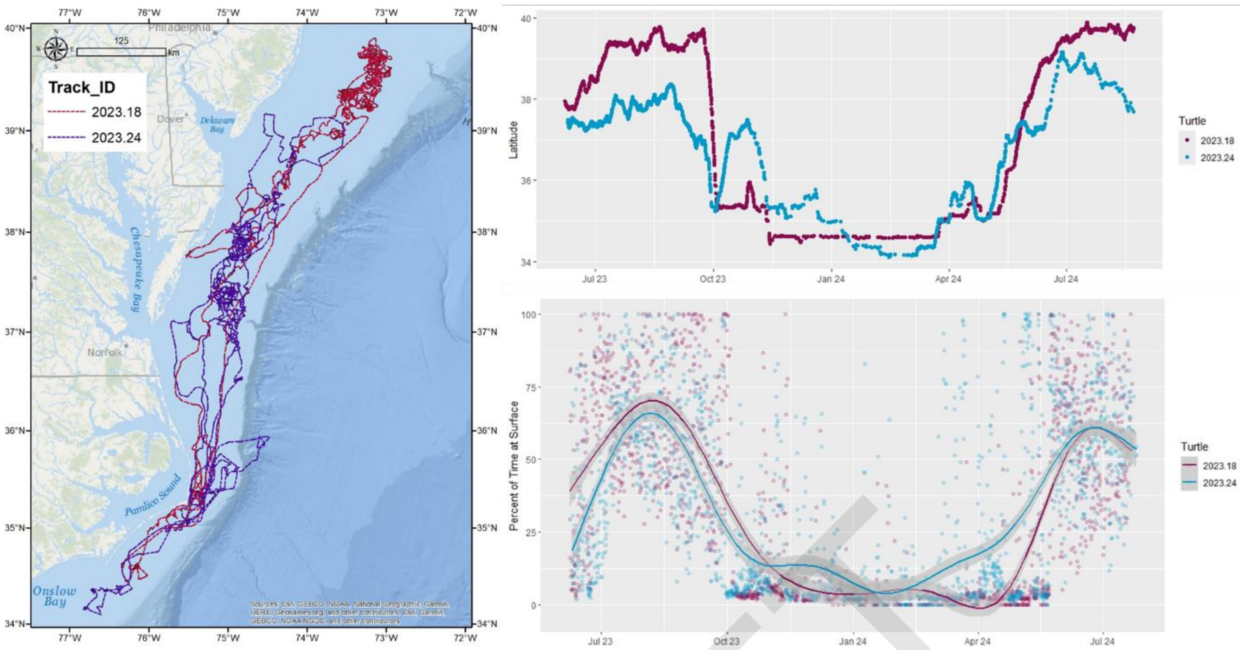

Figure 7: Location and dive data for the two turtles that continued transmitting for over one year. (Unpublished CFF and NEFSC data)

slightly earlier than 2023.18, increasing dive activity and migrating north. This turtle, however, foraged at a site slightly farther north in 2024 than in 2023. Although it stayed primarily in the southern MAB, it did exhibit a slight shift in foraging site, including a very long meander north. Loggerheads are known to have foraging site fidelity, likely on a regional scale, and this urge to return to the same foraging grounds seems to be quite strong. For example, a turtle from 2022 that was monitored for over a year, migrated to Florida to nest in the late-spring/early-summer of 2023, and then spent a month migrating north along the coastline to forage in the MAB during the late summer, despite known foraging grounds within the South Atlantic Bight (Evans et al. 2019).

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

Of the 23 sampled turtles, two were positive for nematodes as determined by the Roger Williams University Aquatic Diagnostics Lab. One turtle (2023.21) was tagged during the cruise in the MAB and one turtle (2024.01) tagged during the NC trip (**Figure 8**). Each turtle had few *S. sulcata* eggs but did have other eggs within their lavage samples. Unknown eggs were identified in several samples, particularly from the MAB, and one turtle had an adult worm.

Tag duration for turtle 2023.21 weas unfortunately short, and we only captured a few weeks of this turtle's migratory behavior as it meandered north after tagging. Turtle 2024.01 transmitted for the full duration of its summer foraging and return to NC. Both turtles stayed in the southern MAB, particularly turtle 2024.01. Turtle 2023.21 may have been continuing north; however, it was not moving in a clear directed path.

With the NC tagging, we have now determined that turtles may already have the nematode parasite prior to entering the MAB. As a result, the timeline for infection may be that the turtles acquire the nematode while in the MAB, and then the eggs are retained and perhaps transmitted back to the benthos in the following foraging season. Also consistent with previous years, turtles positive for the nematode tend to remain in the southern MAB.

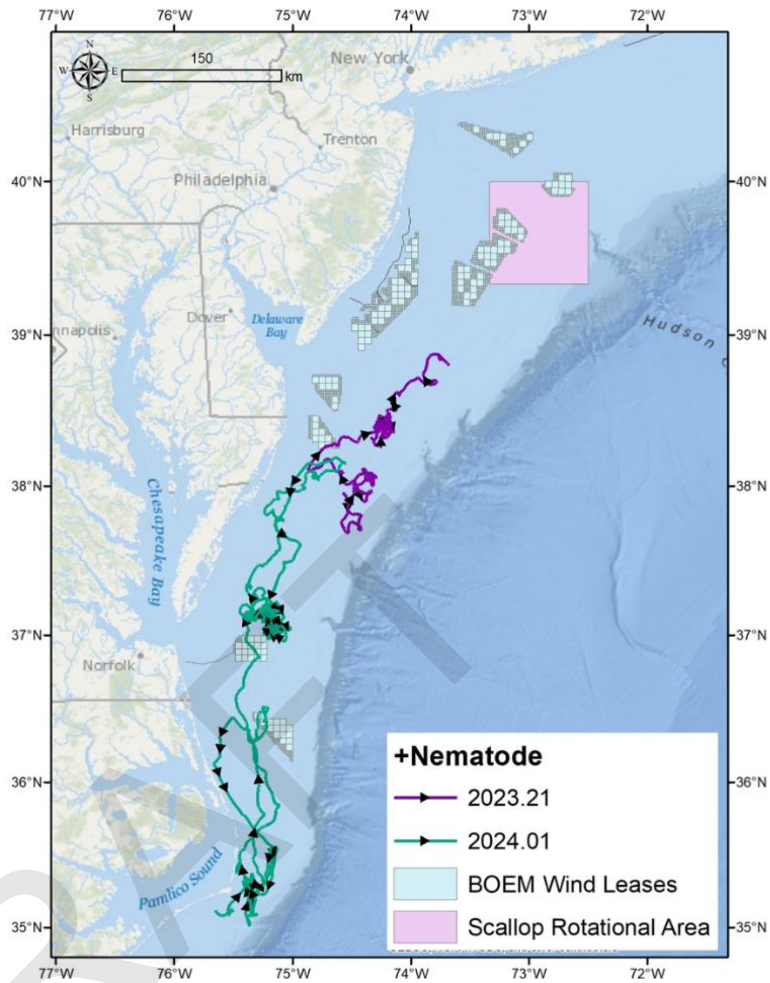

Figure 8: Location data for the two turtles positive for *S. sulcata.* (Unpublished CFF and NEFSC data)

From the turtles that stranded along the Cape Cod beaches in 2023, we did not identify the presence of *S. sulcata* in the gut and fecal samples. Typically, these samples had a lower likelihood of being positive for the nematode. This may be due to the different foraging preferences, or the range of the nematode may not be so far north.

Annual Goal #4: *Use videography to document potential prey species.*

During both the KA and NC trips we did not encounter weather suitable for deploying the ROV, however, we did deploy stationary cameras at both sites to try and document turtles near-bottom (**Figure 9**). In the MAB, we deployed a stationary video camera that recorded for two separate days during daylight hours. Although during both of those days we spotted and captured turtles near-surface, we did not record a turtle at the bottom, indicating a low density of turtles or low probability of turtles taking dives to the bottom during this migratory phase northward.

In NC, the stationary camera captured four turtles over the course of the day. We deployed the camera system at a reef called Avon Rocks, at which we also had our most successful day capturing turtles. At this reef, we also documented black sea bass, trigger fish, and sharks, similar to what we recorded during the previous field season in NC at nearby reefs. Considering the amount of turtles we spotted at the surface, we expected to capture more than four in the footage. However, turtles are typically sedentary in NC, and during ROV deployments in 2023, of the 17 filmed turtles, we only documented four actively swimming or walking along the bottom.

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

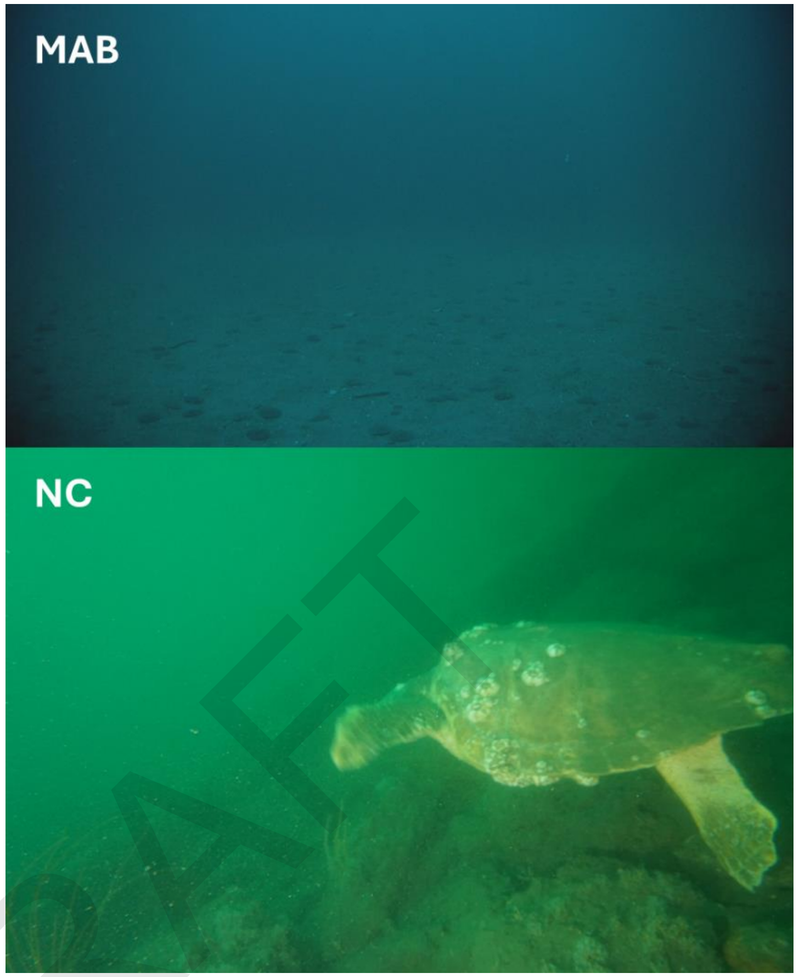

Figure 9: Image extracted from stationary camera footage during each trip. (Unpublished CFF and NEFSC data).

This year we expanded the database on loggerhead biology and ecology in several ways. We continued to collect data on the temperature through depth within the MAB and surrounding regions inhabited by the tagged loggerheads. The tags transmit a data product with a temperature recorded at every 8 m depth interval. This creates a more consistent assessment of the water column throughout all regions turtles are inhabiting. From this year's samples, we again noticed the strong thermocline in the MAB during the summer months, followed by the turnover event in early October (**Figure 10a**; Patel et al. 2018). As turtles moved to NC and south, they inhabited warm water that was mixed including through deep environments farther south (**Figure 10b**). Near NC, turtles remained in shallow water during the over-wintering period before returning to the MAB and again recording the presence of the cold pool water mass (**Figure 10c**). The 2024 data indicates a slightly cooler SST and a less pronounced thermocline until later in the season. This is likely due to the differences in habitat usage between the 2023 turtles tagged offshore and 2024 turtles tagged near NC.

During this funding year we continued to collect water samples during field research to test for sea turtle eDNA. The genetic primer development was funded by the Massachusetts Environmental Trust (MET) grants program. This project is a partnership between CFF, NOAA, MA DMF, Wellfleet Bay Wildlife Sanctuary, and UMass Amherst. The objective of this project is to develop methods for water collection and genetic analysis to detect sea turtle eDNA within marine ecosystems. For the RSA trips, we were in regions with known high densities of sea turtles making them great locations to test the efficacy of the primers to detect turtle DNA in water samples collected at sites that should be positive for loggerheads and in NC also Kemp's and potentially green turtles. The MET funding led to the complete development and testing of the leatherback and Kemp's primers using at-sea water samples and aquarium samples.

Loggerhead and green turtle primers are nearly complete. For Kemp's ridleys, we collected water from Cape Cod Bay over the course of three years to correspond with the annual cold stun stranding event. Turtle eDNA was detected at a beach where turtles typically wash ashore during the stranding season (November, December, and January), while results were negative in the summer and early fall (**Figure 11**). Samples were all collected from the shore, indicating that as cold stunning occurs and turtles get pushed onto the beach by prevailing winds, this leads to an increase in their DNA within that water. However, although Kemp's are present in the months leading up to cold stunning, they may be far enough from shore or in low enough densities for their DNA to not be detectable from land-based sampling. Temperature may also play a role in preserving DNA, with warmer temperatures causing it to break down faster (McCartin et al. 2022). Developing the assays required for eDNA detections of sea turtles from ocean samples is important for understanding presence, distribution, and seasonality of turtles in regions with limited sightings opportunities.

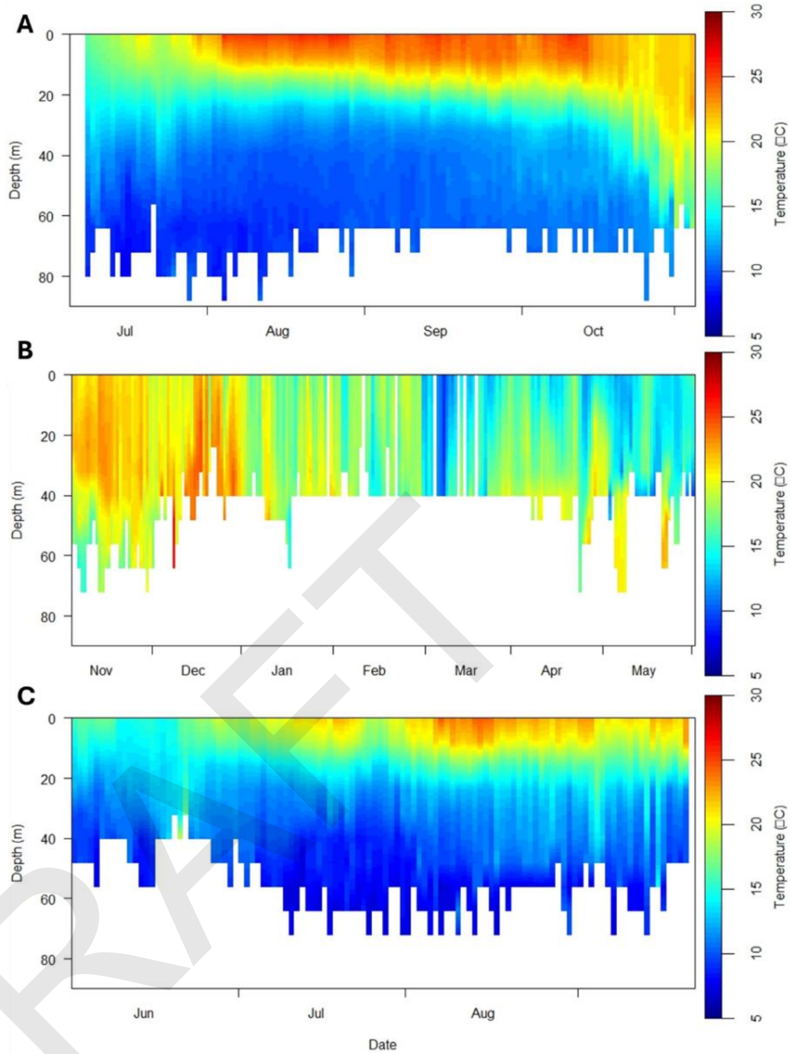

Figure 10: Temperature through depth data transmitted from the tags in (A) 2023, (B) 2023 – 2024 and (C) 2024. (Unpublished CFF and NEFSC data).

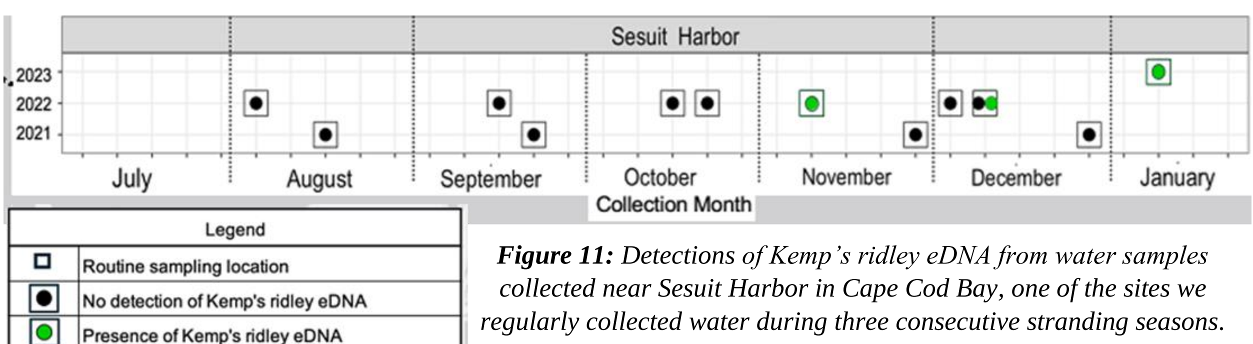

Figure 11: *Detections of Kemp's ridley eDNA from water samples collected near Sesuit Harbor in Cape Cod Bay, one of the sites we regularly collected water during three consecutive stranding seasons. (Figure created by Elizabeth Clark for Clark et al. in prep.)*

During the past year we progressed with tissue sample analysis by testing scute samples collected from loggerheads for heavy metal (HM) contamination levels and prey samples collected from the MAB. HM (Ag = silver, Al = aluminum, As = arsenic, Cd = cadmium, Co = cobalt, Cr = chromium, Fe = iron, Mn = manganese, Ni = nickel, Pb = lead, Se = selenium, Zn = zinc) levels were tested in a total of 17 stranded loggerheads, 37 live loggerheads captured in the MAB and 9 near NC (**Figure 12**). Prey samples included crabs, scallops, and whelks. Scallops were separated into flesh and shell, and whelk were separated into operculum, flesh, and shell. Crabs were kept whole. In general, loggerheads had similar HM concentration levels, with some variability depending on the specific metal. However, compared to the prey samples, loggerheads were much more similar as a species. Interestingly, scallop shell was more like loggerhead scutes than to its own flesh, which may be an indicator of how these metals are stored and allocated within the tissue types. This study is a collaboration with Purdue University Fort Wayne and was completed by YiWynn Chan for her Master's thesis.

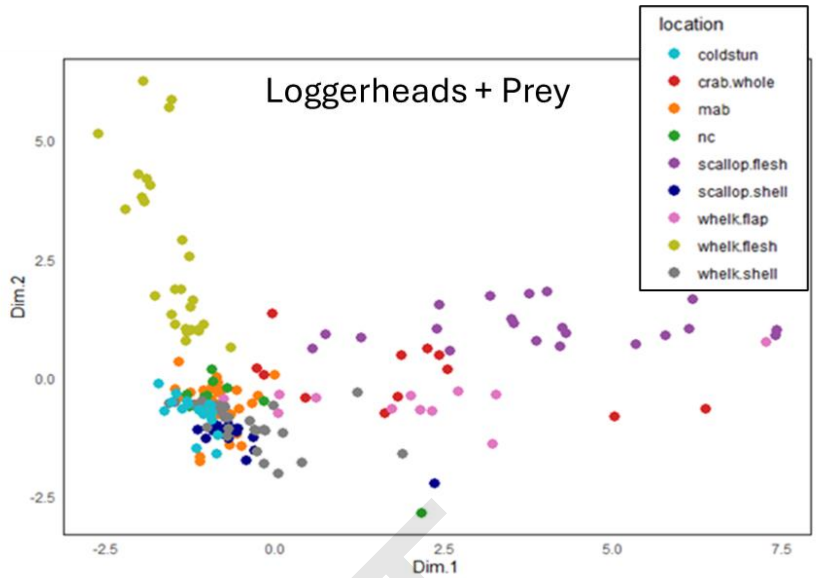

Figure 12: *PCA plot of the heavy metal concentration levels for loggerhead scutes and the prey species representing overlap between species and tissue types. (Figure creates by YiWynn Chan for Chan et al. in prep.)*

Programmatic Goals

During FY2023/24, 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, with some reports remaining relatively unchanged from the previous year due to prioritizing other portions of the project. 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), and recently updated by Hatch et al. 2023, 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. Since 2021, with deployments in NC, we continue to acquire data on seasonal movement patterns that shift our expectations of when and where loggerheads are likely to be located while in the MAB. The NC cohort follows a broader range of migratory pathways, including inshore, offshore, and more northerly movement patterns than turtles tagged in offshore MAB. However, FY2023/24, saw a return to more northern foraging from the offshore cohort as well, including time spent in the NY Bight scallop rotational area. From 2019 – 2022, we did not track many turtles into the current rotational area, and the last year during which turtles tagged in MAB foraged so far north was in 2018 (**Figure 13**). This interannual variation is unpredictable prior to tagging, making it essential to continue monitoring sea turtle movement patterns to ensure they do not encroach on scallop management protocols.

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

Hatch et al. (2022) improved our understanding of when and where loggerheads are exhibiting various dive behaviors, specifically increased time at the surface vs at-depth. From Hatch et al. (2022): "Spatially, the predicted average dive durations were higher inshore, compared to offshore areas defined by bottom depths >200m; although, this pattern was less apparent north of Cape Hatteras, North Carolina. The longest dives appeared to be concentrated along the continental shelf near the coasts of North and South Carolina. Additionally, longer dives were predicted farther south in January, relative to the shorter dives in August along the Mid-Atlantic

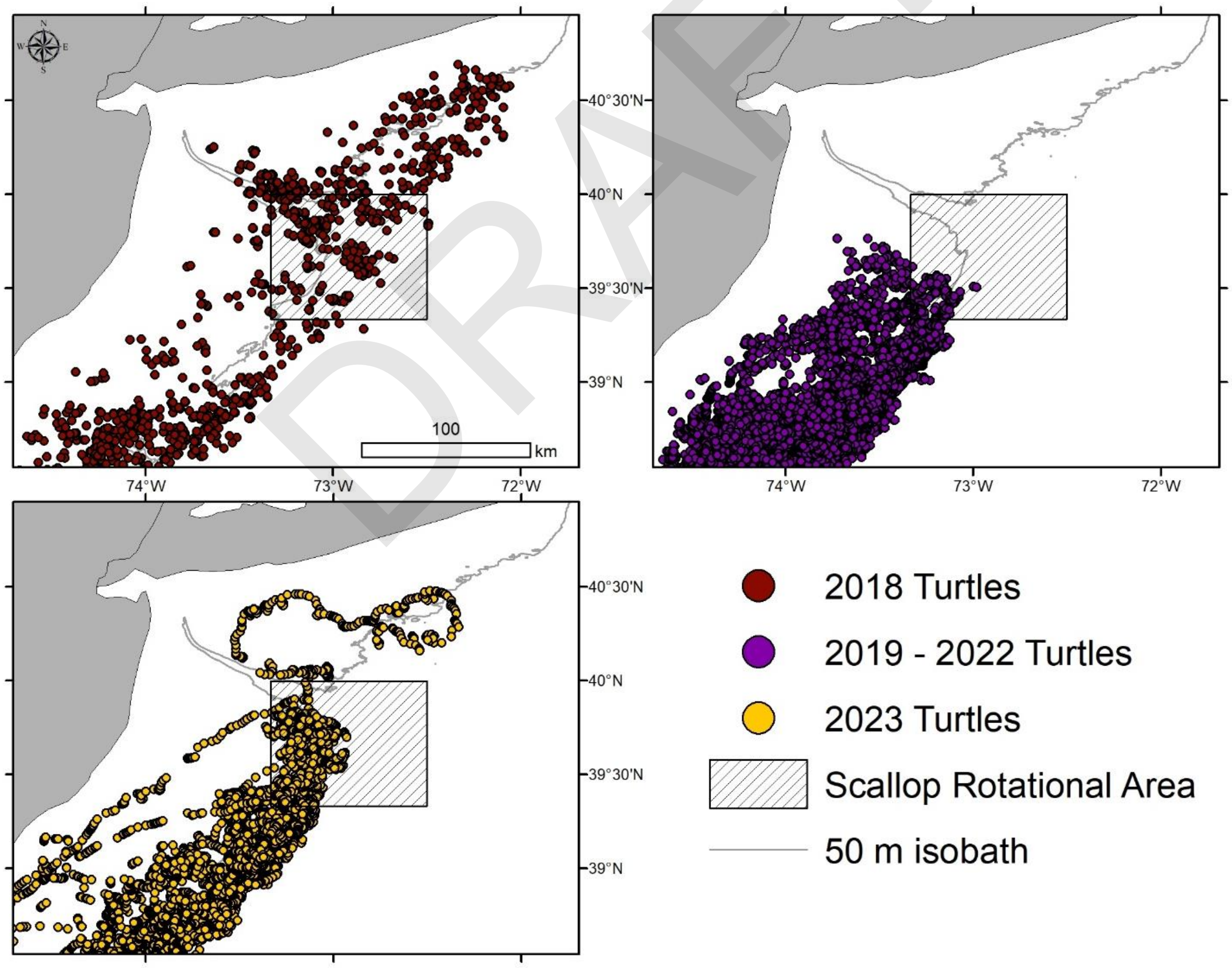

Figure 13: *Annual variation in movement patterns of turtles tagged in the MAB in relation to the current scallop rotational area in the MAB. (Unpublished CFF and NEFSC data)*

Bight. We also estimated significantly greater spatiotemporal than spatial variation for the estimated average dive durations, with a relative increase in the marginal standard deviations of roughly 1.5 times. Seasonally, along the continental shelf, the average dive duration was highest during October–May, relative to the warmer summer months of June–September. More variability in average dive duration occurred from October–May, with sharp declines in this pattern during summer. The longest dives occurred farther south in the Carolinas and Chesapeake Bay regions, following a similar seasonal pattern as demonstrated across the entire continental shelf. In the New York Bight area, average dive duration was relatively more stable with consistently shorter dives throughout the year, again with slightly longer dives from October–May." This trend continued in FY23/24, with turtles in NC and south taking very long over-wintering dives. Uniquely in 2024, we did not identify a clear trend of increasing surface time with higher SST in the MAB; however, time near surface did similarly average ~50% in summer 2023 and 2024 regardless of temperature.

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. Recently, we have noticed a trend of smaller turtles captured while in NC and inhabiting more nearshore environments when migrating north. Although the trend of capturing on average smaller turtles in NC continued during this funding year, the size range of turtles inhabiting inshore (smaller turtles) vs offshore (larger turtles) foraging sites did not follow previous trends (**Figure 14**). Additionally, we documented a turtle tagged offshore migrate to eastern shore Maryland, spend time nearshore before returning to deeper waters. Typically, we have not identified turtles shifting from offshore to inshore and back, adding to the uniqueness of this tagging cycle. This continues to exemplify the need for annual tagging, as each year we document new and unique behaviors that have the potential to impact fisheries management.

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

This goal is being addressed by using long-term tags. The first attempt with these types of tags from Wildlife Computers is fully discussed in the FY2018/19 final report. During this funding year we did identify fidelity to the NC region with turtles tagged there returning to the same region at the end of their summer foraging season. From all the years of tagging, we have over 100 tag deployments that lasted at least one year, and this year we have added data from two more tags that functioned for over a year. Although prevailing understanding of sea turtle behavior is that they exhibit foraging site fidelity, this doesn't seem to be so specific to a localized spot, but rather to a larger region. Our long-term deployments indicate that turtles do return to the MAB to forage in the summer months but may adjust where they spend most of their time. For example, this year both turtles tracked for over a year returned to the MAB, but one migrated farther north and inhabited a different foraging site. We plan to develop a more comprehensive assessment of our long-term tags to identify the extent of foraging site fidelity.

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

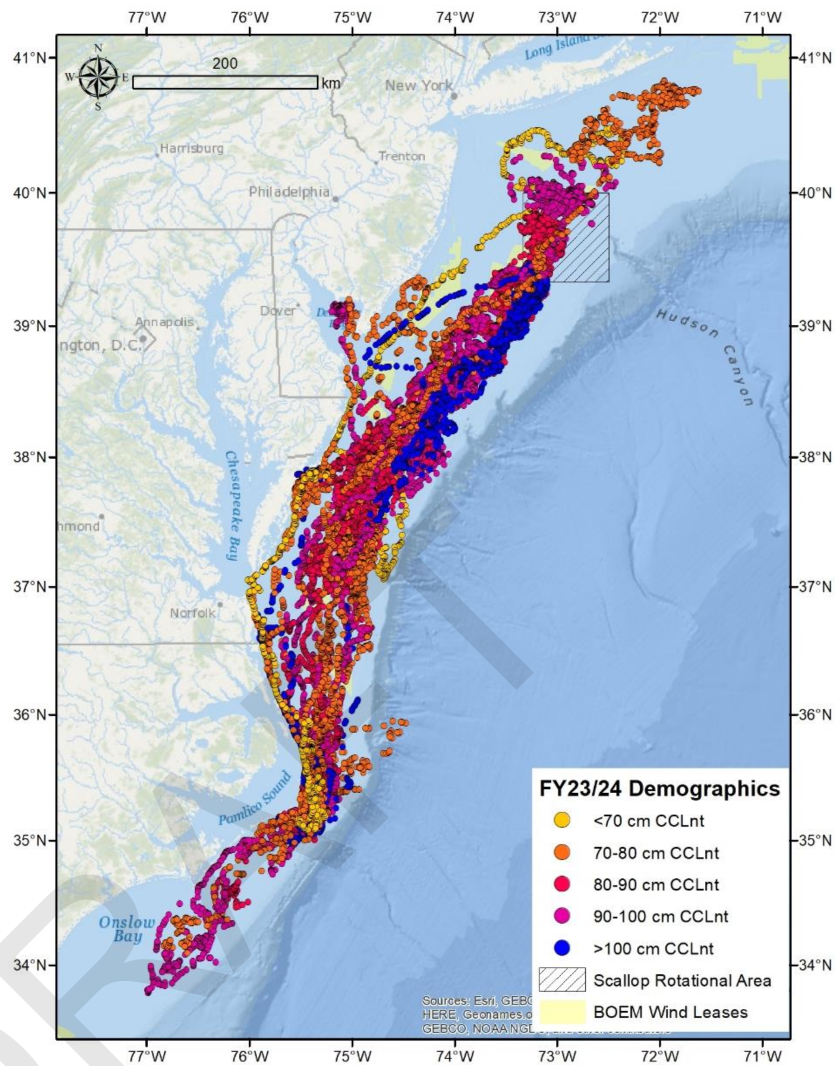

Figure 14: *Differences in movement patterns in 2023 and 2024 based on demographics. (Unpublished CFF and NEFSC data).*

Patel et al. (2021) addressed this goal in a larger context by examining how a shift in SST over the next 80 years will impact loggerhead distribution patterns. During their time in the MAB, we found that turtles tend to prefer waters where the SST ranged from 11° - 29.7° C. We combined this with the depth preferences for loggerheads (0 – 105 m) to create a habitat envelope. We then used climate change projections for the NW Atlantic to determine where and when this habitat envelop would occur over the next 80 years. We concluded that the available habitat for loggerheads will increase northward during the spring and fall seasons in particular. With fall showing the largest change in SST. As a result, we expect loggerheads to migrate into the MAB earlier in the year, reach more northern foraging ground, and then return south later into the fall. Meaning sea turtle movement patterns may shift to include regions and months outside of the current spatiotemporal range for the TDD. In terms of dive behavior, we generally notice a trend of increasing time spend near surface as SST warms, however, in 2024 we noticed a slightly opposite trend. However, in terms of distribution, after several years of turtles not migrating north of Hudson Canyon, adding the deployments in NC has led to more tagged turtles foraging in the NY Bight. As a result, temperature is likely one of many factors controlling the distribution patterns of loggerheads. We plan to continue monitoring these trends and researching how environmental variables will impact turtle behavior in more detail (e.g. dive behavior).

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 stable isotope analysis. 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. We have also taken steps to analyze foraging preferences based on gut microbiome (Forbes et al. 2023) and plan to start developing assays to determine prey species from the fecal samples using genetic markers. Forbes et al. (in prep) will cover the results of the gut microbiome analysis on live loggerheads captured both near NC and in offshore MAB. This will provide understanding on the shifting gut bacteria associated with regional foraging differences both in terms of prey species and feeding activity level. We also are planning to start deploying cameras on loggerheads to document their in-water behavior and ideally their foraging preferences.

7. *Do oceanographic features impact migratory patterns?*

As mentioned previously, we have recently published a manuscript describing how a rise in SST will impact the habitat envelop for loggerheads that forage in the MAB (Patel et al. 2021). Regarding other oceanographic features, we have documented turtles inhabiting the Gulf Stream as they move offshore or northward. As we accrue more data, we will investigate how ocean current may play a role in migratory patterns. Furthermore, with the addition of many more tags from nearshore environments, including the large Bays along the US northeastern seaboard, we can investigate how depth, temperature, and salinity impact behavior and movement patterns.

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

This goal was addressed in Patel et al. (2021), specifically regarding temperature. However, climate models are constantly being updated and so we will continue to monitor the environment based on the data collected from the satellite tags themselves. We also plan to take a close examination of other environmental variables as oceanographic models become more readily available and accurate. For example, with the wind farm construction in the MAB, not only will the oceanography be greatly altered, but there will also be a large influx of data from the various sensors deployed in and around the lease areas, including from the turtle tags. This will increase accuracy and resolution of bottom temperature, which is critical to both sea turtles and scallops.

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. As written above, we have reexamined the turtle temperature data to help generate updated temperature-depth profiles for the MAB. Although the turtles are not inhabiting this region year-round, they transmit the only high resolution *in situ* dataset for the region covering the entire water column from June – October. Currently, it seems as though the water temperature may be too warm for the survival of the scallop spat generated during the fall spawning event as they reach the Delmarva region. CFF is working with the NOAA study fleet team to infuse turtle data into the oceanographic models and with the eMOLT program to add oceanographic sensors to scallop dredges throughout the NW Atlantic.

Conclusions

During FY23/24, CFF collected samples from 23 loggerheads, specifically documenting their seasonal locations in the MAB, morphometrics, health statuses, nematode presence, genetics and stable isotope values. Since 2009, CFF has contributed to the sampling of nearly 340 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) and using simple metrics like overlap don't always provide the best indicator of the chance of interaction (Hatch et al. 2023). 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 direct research on loggerheads primarily regarding 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. Despite the most recent ESA Biological Opinion of the Atlantic sea scallop fishery, the data acquired through RSA-funded research, which demonstrates that the loggerhead population in the MAB is healthy, provided the best defense that the fishery is not causing additional harm to turtles despite having triggered the consultation. With a recent influx of funding from wind development, we can now fully analyze the inventory of biological samples to update assessments of the health, stress levels, stable isotope values, and pollutants in the turtles. These samples collected through past RSA funding will be critical for establishing baseline data on the loggerhead population of the MAB, which is essential for determining how a changing ecosystem impacts a species. Continued funding from the RSA means more data can be collected to compare with this baseline information and ensures results of these efforts are incorporated into scallop management instead of being prioritized solely to the other stakeholders that may also provide financial resources.

One of the few alternative research paths to monitor the loggerhead population is to conduct an aerial survey multiple times a year to ensure that the 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 surface availability estimates from satellite telemetry data to calculate the population estimates (Hatch et al. 2022) 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, Barco et al. 2018, DiMatteo et al. 2024). Aerial surveys are also limited to counting turtles of a large enough size to be seen by the observers, biasing results towards bigger species and demographics. The most recent analysis of the aerial survey data along the US eastern seaboard estimated that there were over 50% less loggerheads (DiMatteo et al. 2024) than was previously counted by NMFS (2011). Although it's unlikely that the turtle population has crashed in the last decade, this shift in understanding of the number of loggerheads potentially inhabiting the NW Atlantic could dramatically impact the number of takes allocated to the scallop fishery reinforcing the need for more targeted research.

Furthermore, with the impending construction of thousands of wind turbines, the NW Atlantic is expected to change dramatically, and it is unknown how this could displace both turtles and scallopers. Without continued monitoring, interactions could increase in unexpected regions, like Southern New England or Georges Bank, where turtle thermal habitat is expected to become available during a larger portion of the year (Patel et al. 2021). Tagging in NC is already resulting in data on novel movement patterns and a broader range of species and demographics otherwise minimally documented through previous sampling efforts in the southern MAB. Finding alternative and cost-effective research paths like using unmanned aerial vehicles for surveys, animal borne camera tags, and stationary camera systems can help add many more details and context to the telemetry and biological data already collected. Taking advantage of these new opportunities for effective capture and sampling could be the key to obtaining the best dataset for projecting sea turtle movement patterns in these ever-changing oceans. As a result, continued sea turtle research, ideally funded by the RSA, is essential to avoid regulatory burdens imposed by the ESA.

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Appendix 1: Peer-reviewed publications (**bold**) and select reports and presentations resulting from RSA funding.

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- National Marine Fisheries Service, Northeast Fisheries Science Center. 2011. Preliminary summer 2010 regional abundance estimate of loggerhead turtles (*Caretta caretta*) in northwestern Atlantic Ocean continental shelf waters. US Dept. Commer, Northeast Fish Sci Cent Ref Doc. 11-03; 33 p.
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- Lockhart, G., H. Haas, S. Barco, R. Smolowitz, J. Bort, R. DiGiovanni, M. Swingle. Sharing a Limited Space: The Importance of Including Biological Monitoring Results in Marine Spatial Planning. Virginia Wind Energy Symposium, June, 2012.
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- **Ceriani, S. A., J. D. Roth, C. R. Sasso, C. M. McClellan, M. C. James, H. L. Haas, R. J. Smolowitz, D. R. Evans, D. S. Addison, D. A. Bagley, L. M. Ehrhart, and J. F. Weishampel. 2014. Modeling and mapping isotopic patterns in the Northwest Atlantic derived from loggerhead sea turtles. Ecosphere 5(9):122.**
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- NEFSC and SEFSC. 2014. Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US Waters of the Western North Atlantic Ocean. NMFS and AMAPPS Annual Report.
- **Smolowitz, R. J., Patel, S. H., Haas, H. L. and Miller, S. A. 2015. Using a remotely operated vehicle (ROV) to observe loggerhead sea turtle (*Caretta caretta*) behavior on foraging grounds off the mid-Atlantic United States. Journal of Experimental Marine Biology and Ecology, 471, 84-91.**
- Smolowitz, R.J., Matzen, E, Milliken, H.O., Patel, S.H. and Haas, H.L. 2015. Overlap between the sea scallop fishery and loggerhead turtle habitats in the northwest Atlantic

Ocean. Poster Presentation 35th Annual International Sea Turtle Symposium, Dalaman, Turkey.

- Miller, S.A., Haas, H.L., Patel, S.H. and Smolowitz, R.J. 2015. Utilizing a remotely operated vehicle (ROV) to observe loggerhead sea turtle (*Caretta caretta*) behavior on foraging grounds off the mid-Atlantic United States. Oral Presentation 35th Annual International Sea Turtle Symposium, Dalaman, Turkey.
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