Understanding Impacts of the Sea Scallop Fishery on Loggerhead Sea Turtles through Satellite Tagging

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Project Summary:

This research focused on assessing and reducing loggerhead sea turtle (*Caretta caretta*) bycatch in the sea scallop fisheries of the Northwest Atlantic Ocean, specifically in the Mid-Atlantic Bight (MAB) and off Southern New England, by examining loggerhead behavior in areas impacted by scallop fishing. Our primary objectives were to examine sea turtle distributions and behavior, improve sea turtle bycatch estimates, and identify factors impacting bycatch rates. The information collected will aid in evaluating loggerhead abundance estimates, developing scallop-harvesting strategies that minimize harm to sea turtles, and defining critical habitat for loggerheads.

For the 2014 project, CFF purchased thirteen 9000x Satellite Relay Data Loggers (SRDL) with Argos Fastloc GPS tags through the University of St. Andrews's Sea Mammal Research Unit (SMRU). The data from the tags, relayed through the Argos satellite system, provided detailed surfacing locations, temperature through depth, and individual dive (max depth, shape, time at depth, etc.) records which were essential for this project. These data were collected and analyzed to evaluate seasonal distribution, migration patterns, dive profiles, and foraging sites in conjunction with satellite-derived oceanographic data to identify spatiotemporal "hot spots" on the fishing grounds. Furthermore, temperature data from the turtles were used to compare to oceanographic models to identify the value of animal-borne sensors for oceanography along with the accuracy of oceanographic temperature models compared to *in situ* observations.

During the 2014 research season, we spent a total of 12 days at sea, spread across three trips, to deploy satellite transmitters, take biological samples and track turtles using the ROV. Through our collaboration with NEFSC, we deployed 19 transmitters on loggerheads during the first trip in late May and 1 transmitter during the research trip in early September. During this September trip, we tracked a leatherback turtle with a radio transmitter and a temperature-depth logger. We also deployed a camera system to film jellyfish presence through depth. We took 5 specific jellyfish surveys during this trip. We took one more research trip in mid-September specifically to use the ROV to film turtles at-sea and to investigate the *Sargassum* mats. A total of 19 ROV dives were taken within and around the *Sargassum* mats with a total of 8 turtle encounters and 3 followed by the ROV. Further video was taken to assess the species associated with the mats and samples were retrieved from the mats to be identified in the lab.

We again focused our deployments and research trips on turtles found within the Mid-Atlantic Bight, with satellite and ROV deployments for loggerheads occurring within a latitudinal range of 40.1° – 36.9°. Two vessels conducted visual surveys for turtles for the entire cruise and were equipped with zodiac boats used to capture turtles for tagging. All tagging procedures, ROV deployments and jellyfish surveys were conducted aboard the F/V Kathy Ann.

Introduction:

Scallop gear is expected 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 RPM's #3, #4, and #5. 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 ESA these RPM's, which are non-discretionary, must be implemented for the scallop fishery to continue. While not the highest research priority, this research is required under the law. In the absence of NMFS NEFSC funding, the scallop RSA is the only current source of funding to allow the scallop fishery to continue meeting ESA requirements.

This research continues over ten years of turtle research and has evolved from a multitude of studies conducted since 2004 under Scallop RSA funding and National Marine Fisheries Service (NMFS) contracts. These projects, besides developing sea turtle excluder gear, have 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. Over the duration of these past projects, this CFF/NMFS joint effort has resulted in the tagging of over one hundred loggerheads, and has tracked these turtles for 32,600 days total. We have demonstrated exceptional success in tracking and observing sea turtles throughout the water column with an ROV, from obtaining footage of sea turtles foraging on the sea floor to socializing at the surface. The data from these tags allowed for the first estimate of absolute abundance of loggerheads in the shelf waters of the east coast and has helped to define critical habitat for loggerheads. In addition to morphometric measurements, blood and genetic samples were taken from each turtle tagged.

Methods

At Sea Operations

CFF and NEFSC provided at-sea scientists and crew, while Jim Gutowski at Viking Village Fisheries oversaw vessel coordination and operations. The F/V Kathy Ann and F/V Ms. Manya conducted turtle sighting transects on the tagging trip, although tagging and sampling procedures were conducted solely aboard the F/V Kathy Ann.

Turtle spotting efforts were focused during maximum daylight between 0700 and 1800 hours. Once a turtle was spotted, the vessel maneuvered to within 50 meters of the animal and stopped when in close proximity to the spotted turtle(s). Once the vessel was in the appropriate position, the collection boat, an open 14' Achilles soft bottom zodiac, was launched. Once 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 crewmember. The zodiac was brought alongside the F/V Kathy Ann, and the handle of the dip net was removed and the net was attached (as a brailer) to a specially rigged winch and boom to transfer the turtle aboard.

Upon the transfer of the turtle to the F/V Kathy Ann, the turtle was positively photo-identified as a loggerhead sea turtle with 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 it to ensure that it was in suitable condition. Epibionts were removed from the carapace at the intended bonding site of the tag on approved turtles. The transmitters were attached with a two-part cool setting epoxy with the antenna oriented forward, at the point where the first and second vertebral scutes meet. Our NEFSC partners retrieved blood and tissue samples for on-shore analysis. Sea turtles were released over the stern of the boat, with engine gears in a neutral position, in areas where they were unlikely to be recaptured or injured by vessels.

For ROV deployments, when a turtle was spotted, two handlers at the rear of the boat are notified to deploy the ROV. Spotters help guide the ROV driver in acquiring the turtle on screen. The ROV driver attempts to maintain contact with the turtle for as long as possible, both in horizontal and vertical movements.

The jellyfish survey system was comprised of a light weight frame, with a camera mounted in the middle. The frame was used as a reference of volume and distance for the camera view. We used a GoPro Hero 3+ to film the descent and ascent of the system to capture all items, including jellyfish that happened to pass through the field of view. We are currently in development to improve upon this system to gain a more complete assessment of jellyfish density via horizontal and vertical profiles.

During the 2014 research season, we spent a total of 12 days at sea, spread across three trips, to deploy satellite transmitters and track turtles using the ROV. During the first trip, in May 2014, nineteen turtles were captured for biological sampling and satellite telemetry deployments. All data from the satellite transmitters has been continuously downloaded into our database from Argos and SMRU websites. In addition to tagging, morphometric measurements as well as blood and genetic samples are taken from each captured turtle.

During the second trip in early September 2014, one turtle was captured for biological sampling and transmitter deployment. We also tracked a leatherback turtle with a radio transmitter and a temperature-depth logger. The leatherback tracking lasted a few hours, and included a camera mounted to the carapace to film with the same field of view of the leatherback's sight. During this trip, we also tested our first jellyfish survey system to monitor the presence of jellyfish within the environment key for sea turtle foraging. We deployed the system 5 times, each time descending to the sea floor and capturing footage throughout the descent and ascent.

During the third trip in mid-September, we focused on using the ROV to track sea turtles as well as assess the *Sargassum* mats loggerheads tend to associate with. We deployed the ROV 19 times, with a total of 8 turtle encounters and 3 turtles tracked. We also filmed within the *Sargassum* mats and took samples to identify species and run stable isotope analyses.

Data Analysis

We continued to monitor the turtles we track via satellite telemetry. This included monitoring the dive behavior, along with identifying variations in seasonal home range throughout the year. We recovered two transmitters during the past year, and were able to download the entire data set collected by these tags. This allows for a complete assessment of the at-sea behavior of the turtles these transmitters were monitoring. We compiled location data from all years to be presented at the International Sea Turtle Symposium in Dalaman, Turkey, April 2015 (**Figure 1**).

During this past year, a portion of the biological data, specifically from 2011, was used for a stable isotope study authored by Ceriani et al. (2014), identifying the isotopic signature of the various loggerhead foraging populations in the northwest Atlantic Ocean. Several excerpts from this publication are included in this final report. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses were done on the blood and skin biopsies of 214 loggerheads from the west Atlantic. These include samples from 25 turtles obtained by the collaboration between CFF and NEFSC. Results from the stable isotope analyses were correlated to locations based on telemetry data from the sampled turtles, along with body size. This allowed Ceriani et al. (2014) to generate isoscapes, one based on locations and the other based on body size for those turtles bigger than 64.0 cm to focus the study to benthically foraging loggerheads.

Additionally, research was conducted to compare the temperature data from the transmitters on the turtles, with shipboard CTD casts and ocean models, with a manuscript focused on this research in preparation being led by Jim Manning at NEFSC. Several excerpts from this manuscript are included in this final report. Due to the high specificity, in terms of locations and depth, of the temperature data from the satellite transmitters, these data provided a unique comparison to the broader scale approaches to determining sea temperature. Comparisons are made between the satellite transmitter data and a) 30+ nearby shipboard CTD cast and b) publically-available ocean models. Since the differences between the shipboard observations and the turtle-derived observations are an order of magnitude less that the difference between the shipboard observations and the models, we can begin to quantify the performance of models in different areas of the shelf and at different times of the year. By way of examples, we looked primarily at the local ROMS ESPRESSO model but another local (FVCOM) and global (HYCOM) model as well.

We also focused analysis this year on compiling and assessing the ROV footage, resulting in a manuscript (Smolowitz et al. 2015) focused on the methodology and novel results accepted for publication at the Journal of Experimental Marine Biology and Ecology, along with an oral presentation at the International Sea Turtle Symposium in Dalaman Turkey, April 2015. Several excerpts from the accepted manuscript are included in this final report. In continuing to analyze the ROV footage, we have started using a program specifically designed to compile video footage into data that can be statistically analyzed. The program is called Noldus Observer XT. This is a collaborative effort, with 4 people working in conjunction to code the approximately 45 hours of video footage to ensure a level of consistency within a subjective assessment of sea turtle behavior. We developed a coding scheme to account for a range of events and characteristics found in the footage. The coding accounts for depth zone of the turtle, feeding behavior, inter/intra-species observation, reaction to the ROV, potential prey in view and specific events including breathing, flipper beats, defecating and general body adjustments. The results of this coding are currently being prepared for a manuscript.

Results

Satellite Telemetry

From the 2014 satellite transmitter deployments, as of May 6, 2015, we have compiled 4595 days of data, with an average lifespan for these 20 transmitters of 241.9 days (**Figure 2**). We had a single transmitter not function upon deployment, while two others lasted only 37 and 59 days respectively. The remaining 17 transmitters functioned well for a duration ranging from 124 – 342 days, again as of May 6, 2015. Currently, all transmitters deployed in previous years have stopped transmitting, while 7 transmitters deployed in 2014 continue to send data. Overall, turtles tagged during 2013 and 2014 reached more northern foraging grounds than turtles tagged during previous years.

Isotope Analyses

Northern, Central and Southern foraging areas used by the 58 tracked loggerheads (32 nesting females and 26 juveniles) segregated by their combined bivariate ($\delta^{13}C$ and $\delta^{15}N$) isotopic signatures (MANOVA, Pillai's trace test, $F_{4,110} = 21.128$, $p < 0.001$), and in univariate analyses where both $\delta^{13}C$ (ANOVA, $F_{2,55} = 130.286$, p , 0.001) and $\delta^{15}N$ values ($F_{2,55} = 26.305$, p , 0.001) differed among foraging aggregations (**Figure 3a and 3b**) (Ceriani et al 2014). Significant differences were also found in body size ($F_{2,55} = 9.310$, $p < 0.001$) among loggerheads using the three isotopically distinct foraging areas (Ceriani et al. 2014). This result was not surprising because the northern and central groups in the known data set included both tracked adult females and juveniles, while the southern group included only adult females as none of the juveniles equipped with satellite tags used the southern foraging area (Ceriani et al. 2014).

Satellite Transmitter Temperature Data

Between 2009 and 2013, a total of 12,608 quality temperature-depth profiles were recorded and telemetered by more than 100 different tagged turtles in the Mid-Atlantic Bight. With average distance between dives of <10km and dives typically recorded to the bottom on a near-daily frequency, a considerable dataset was obtained so that spatial and temporal variability can be investigated. In summary from Manning et al. (*in prep*), the mean values of the temperature data from the transmitters mounted on the turtles were an order of magnitude closer to shipboard CTD sampling than to the models. The modeled data tended to be warmer than data from direct observations, particularly near the thermocline. The level of difference between the modelled data and direct observations increased depending on the scale of the modelled data. Local scale models performed better than global scale models when compared to direct observation data. Local models also did well in predicting the range of temperatures experienced by turtles within the same region. The temperature data from the turtles also was able to document the change in thermal structure from passing storms. The data shows how the surface layers can cool by several degrees and deepen by 10+ meters.

ROV

Below are excerpts from Smolowitz et al. (2015); more detailed results can be found in the publication. A video compilation of some of the results can be found at the following link: https://www.youtube.com/watch?v=CgOXXgf2GFs. From 2008 – 2014, we took 10 ROV trips (**Table 1**) varying in time of year from late spring to late summer. For all attempts, usable video, with a turtle retained in view for a minimum of 30 seconds, was produced at a rate of 43.5% of effort, for a total of 44.7 hours of turtle video. We averaged (mean ± SD) 42.5 ± 68.7 minutes with a range of up to 426.1 minutes of consecutive turtle observation. We tracked 70 turtles with the ROV, two identified as male based on the length of the tail (**Figure 4a**). Since we did not capture turtles onboard, it was not possible to accurately determine turtle size or age class.

With the temperature-depth logger attached to the ROV, we measured temperature through the water column during 4 trips, one trip each in 2008 and 2009 and two in 2012. In 2008, during the August 19 – 22 trip, average sea surface temperature (SST) was 26.3 ± 3.3 °C. In 2009, during the July 9 – 15 trip, average SST was 22.1 ± 1.6 °C. During this trip, we followed two turtles during 6 benthic dives to ~50 m depth, with water temperatures reaching as low as 7.08 °C. At these low temperatures, the turtles continued to actively forage. Of these six benthic dives, five were from a single turtle tracked continuously for 426.1 minutes. We tracked this turtle through 4 complete dives (descent and ascent), with the 5^{th} dive being incomplete due to losing contact with the turtle at depth. For the 4 complete dives, the turtle remained at depth for an average (± SD) of 30.1 ± 7.8 minutes and a range of 19.4 – 37.8 minutes. During these foraging dives, this turtle primarily fed on unidentified species of hermit crabs, and on occasion actively chased these prey as they attempted to escape. Not all benthic prey items were identifiable due to the positioning of the camera. Between dives, this turtle spent on average 65.3 ± 28.8 minutes with a range of 37.0 – 105.0 minutes at between 0 – 5 m depth, in water ~15 °C warmer than at the sea floor. At the surface, this turtle breached a total of 29 times, remaining breached continuously for between 3 – 6 minutes immediately prior to the benthic dive. This turtle remained breached for 5 minutes only one other time, otherwise breaching events lasted less than 2 minutes.

We identified a broad range of associated species with the turtles, both pelagically and benthically. We observed loggerheads pelagically feeding on Lion's mane jellies (*Cyanea capillata*), comb jellies (*Ctenophora*) and salps (*Salpidae*); while benthically foraging on hermit crabs (*Paguroidea*), rock crabs (*Cancer irroratus*), and Atlantic sea scallops (*Placopecten magellanicus*) (**Figures 4b and 4c**). For non-prey species associated with the turtles in pelagic waters, we identified Mahi Mahi (*Coryphaena hippurus*), grey triggerfish (*Balistes capriscus*), unidentified shark species, barrelfish (*Hyperoglyphe perciformis*), common dolphin (*Delphinus delphis*), and pilot fish (*Naucrates ductor*) (**Figure 4d**). Barrelfish, on occasion, did maintain contact with the turtle through the benthic dive; however the most commonly associated non-prey species at the sea floor was the red hake (*Urophycis chuss*). Red hake seemed generally associated with disturbance on the sea floor, congregating around the ROV as well when it landed creating a cloud of particulate.

The smaller fish species, barrelfish, triggerfish and pilotfish, were associated with turtles having a noticeably high amount of epibionts attached to their carapace. The fish interacted with the turtles in several ways. Some fish would forage directly off the carapace feeding on the epibionts, while other fish maintained close contact using the turtle as a type of refuge. It is unclear if this second relationship is as a form of protection for the fish, or if the fish are waiting for food scraps from the turtle foraging. Mahi Mahi maintained a relationship with individual turtles but remained farther away compared to the smaller fish species. Occasionally the Mahi Mahi would rub against the turtle's carapace, with the turtle exhibiting no clear reaction to this behavior. Turtles did not seem to react to these non-threatening fish species. However, we did identify a turtle reacting to an unidentified shark species, shifting its body perpendicular to the shark, thus exposing its carapace, while simultaneously turning away from the shark's path (**Figure 5**). This seemed like a predator avoidance technique, even though the shark did not seem to make an attempt to attack.

We observed intraspecies interactions which have been previously undocumented on offshore Mid-Atlantic foraging grounds. On 19 occasions we identified turtles congregated in small groups. Groups ranged in size from 2 – 4 turtles. We spotted groups of 2 turtles together 17 times and larger groups of 3 and 4 turtles together once each, possibly representing social behavior on foraging grounds. We observed turtles flapping their flippers with each other, carapace rubbing, nudging, biting and generally being in close proximity (**Figures 4e and 4f**). Flipper flapping interactions could be seen best from the vessel, as the turtles would repeatedly slap their flippers upon the surface of the water. Carapace rubbing involved a turtle swimming alongside another turtle and rotating its carapace to lightly rub against the carapace of the opposite turtle; this too was a repetitive action. Nudging involved one turtle using its snout to gently push onto the edge of another turtle's carapace. Biting involved a turtle biting the epibionts of another turtle's carapace, it is unclear if this was foraging or cleaning.

Discussion

Satellite Telemetry

Since 2013, we started deploying transmitters at the end of May to track turtles as they transit north. Previously, we tagged turtles that had already established residency in the MAB. By tracking turtles during their migration phase, we have uncovered that loggerheads are establishing residency further north than previously identified, reaching the southern coast of Long Island, NY. This could indicate several new features of this population. For example, the loggerheads residing during the summer months in the MAB, may be increasing their range north. This behavior has been identified in leatherbacks residing in North Atlantic waters (McMahon and Hays 2006). In contrast, we could be tracking a different set of turtles that have always resided in a more northern portion of the MAB. This level of plasticity within this foraging population could have implications on how these turtles might react to varying environmental conditions. Furthermore, by identifying more accurately the range and size of the foraging ground in the MAB we can immediately make better informed management decisions.

We plan to continue the effort of deploying transmitters on turtles in late-May to identify in more detail the habitat usage of this more northern foraging sub-population. Additionally, we are investigating deploying transmitters from more southern locations with the MAB, to capture more data during the migration phase.

Isotope Analyses

Below are excerpts from Ceriani et al. (2014); a more detailed discussion can be found in the publication.

This study generated the first species-specific isoscapes for a marine predator (the loggerhead turtle) in the Atlantic Ocean. We found clear spatial patterns in loggerhead $\delta^{13}C$ and $\delta^{15}N$ in the northwest Atlantic. Latitudinal differences in $\delta^{13}C$ are due to temperature, surface water CO2 concentrations, and differences in plankton biosynthesis or metabolism (Rubenstein and Hobson 2004). Recently, MacKenzie et al. (2011) showed that differences in marine organism $\delta^{13}C$ values correlate with SST because water temperature affects both cell growth rates and dissolved carbonate concentrations, and thus have a direct effect on the $\delta^{13}C$ values of primary producers. Therefore, an environmental parameter (SST) appears to be a good proxy for phytoplankton $\delta^{13}C$, which, in turn, is reflected in the $\delta^{13}C$ values of marine organisms at higher trophic levels.

While $\delta^{13}C$ isopleths exhibited a clear latitudinal trend, $\delta^{15}N$ patterns were less linear. We attribute these patterns to a combination of three factors: (1) a baseline shift in primary producer $\delta^{15}N$, (2) differences in foraging strategies among the aggregations we sampled and, in particular, between CAN loggerheads off the Scotian Shelf Slope and the other areas sampled, and (3) an anthropogenic effect. Loggerheads specifically on the continental shelf may forage on a variety of benthic prey; thus, variation in $\delta^{15}N$ values may be due also to differences in diet (trophic differences) among individuals within and among sites.

Overall, this research helped validate the value of using stable isotopes to assess foraging strategy in loggerheads within the northwestern Atlantic. This will allow us to infer foraging location from biological sampling alone. By increasing the number of turtles from which biological samples are taken, a more complete assessment of foraging populations can be made.

Satellite Transmitter Temperature Data

Below are excerpts from Manning et al. (*in prep*); a more thorough discussion of the results can be found in the paper upon publication.

While the turtle-derived data is limited to a particular region of the shelf (~30m-~70m) and time of year (~May-~Nov), the number of turtle dives are at least an order of magnitude greater than the shipboard cast. While the accuracy of the turtle-derived readings is arguably less than most shipboard CTD data today, it is apparently capable of resolving the thermocline structure and is certainly better than most ocean models (**Figure 6**). As both the instrumentation and models have improved during the course of preparing this report and will continue to improve in the future, we also present this strategy as a means of collecting deep temperatures, a possible contribution to the local ocean observing system, and potential addition to data for real-time assimilation models.

Due to the large difference between the modelled data and the temperature data from the direct observations, it is apparent that more appropriate direct sampling of the water column within the Northwest Atlantic is required to obtain more accurate assessments of the regional oceanography. By using animal-borne sensors, loggerheads sampled in a stratified portion of the year (including the hurricane season), thus creating the potential for these animals to feed valuable information to the weather models including heat content in the upper layer of the ocean.

More discussion on the validity of these temperature readings is needed. We cannot expect these temperature sensors to provide profiles as good as some of the fast response CTD casts. An error may arise if, for example, the turtles are rising to up the water column faster than the sensor can detect the temperatures. However, since the response times of the SRDL sensors are fairly quick on the order of a few seconds we have shown they are apparently resolving the vertical structure significantly better than the local models.

ROV

Below are excerpts from Smolowitz et al. (2015); a more detailed discussion can be found in the publication.

Determining at-sea behavior of large marine animals has typically been determined by telemetry or animal-borne video systems, and more broadly through visual surveys. All of these methods have their drawbacks, with the ROV adding a new technique that complements existing technologies while overcoming several of the limitations. Using an ROV fills the data gap between the high volume yet uncertain data of telemetry and the low volume, high resolution data of boat and in-water surveys. Firstly, it is the safest method of *in situ* observation with no direct interaction between the researcher and the animal and no requirement of the researcher to enter the water. Secondly, it allows for continuous observation throughout the water column, without requiring the target species to simply happen through the field of vision of the camera. We used 250 m of tether, allowing us to track the turtle horizontally and vertically. Thirdly, impact to the animal is directly observable. Similar to all *in situ* observation methods mentioned in the introduction, we identified reactions to the survey tool, for example turtles interacting with the ROV and tether, occasionally becoming startled or simply swimming in wide circles around the ROV. As a result, we found that it was best to approach with the ROV from the turtle's front to within 3 - 5 m while in their direct line of sight and not from behind to avoid startling the animal and causing it to dive.

The footage from the ROV was particularly valuable when combined with data from the TDR. We were able to observe loggerheads maintaining a high level of activity in temperatures below 10 °C. In 2009 and 2012 we identified loggerheads foraging at the sea floor within temperatures as low as 7.1 °C and 9.3 °C respectively, even with prey resources available in warmer pelagic waters. Although the temperatures were low, turtles actively foraged and remained at depth for periods comparable to warm water loggerhead benthic foraging periods as documented by satellite telemetry (Hochscheid et al. 2007, Patel 2013). When measured, bottom temperatures from 2008 - 2012 reached below 10 °C from July through September. At this temperature range, turtles are known to become cold stunned (Spotila et al. 1997). Previous studies have identified loggerheads maintaining activity throughout the colder season, while turtles residing within the same region exhibited an overwintering behavior of both reducing number of dives and increasing dive durations (Hochscheid et al. 2007, Patel 2013). It seems there is a similarly high level of plasticity within this northwest Atlantic loggerhead population in having the ability to remain active at a broad range of temperatures.

Overall, using the ROV provided great insight into loggerhead at-sea behavior, otherwise unattainable using previously established techniques. We were safely able to track turtles for an extended period of time to depths and temperatures inaccessible through previous non-invasive *in situ* observation techniques. Furthermore, we were able to validate behaviors otherwise only implied by telemetry studies. The plasticity of this small population has implications of the range of behaviors that may be exhibited by loggerheads throughout the world. The next step for ROV videography is to quantify the behaviors, including assessment of flipper beating and breathing patterns, inter- and intra-species interactions, and foraging throughout the water column.

Assessments of breathing patterns and foraging ecology have been based on carapace-mounted cameras viewing leatherback heads and vicinity (Reina et al. 2005, Wallace et al. 2015), and using an ROV to film the entire body of the animal could provide a more complete assessment of in-water ecology. Additionally, comparing ROV video with data acquired through sympatric satellite transmitters could provide more defensible explanations of sea turtle behavior inferred from satellite tags. Overall, data derived from ROV platforms can be used to document the broad range of at-sea behaviors, and ultimately it can be used to evaluate and improve gear designs for fisheries interacting with protected species.

Summary

During the past research year, we have continued to meet our goals of assessing loggerheads residing in the MAB through satellite telemetry, biological sampling and ROV tracking, along with expanding on this research through our work with new species and habitats. A portion of our biological and telemetry data were included in a publication in Ecosphere by Ceriani et al. (2014), with the results of this study having strong implications on our ability to assess loggerheads foraging in the MAB, both financially and scientifically. Although currently we did not expand on our analysis of loggerhead behavior from telemetry data, we have greatly increased our understanding of behavior from analysis of the ROV footage with a manuscript accepted for publication (Smolowitz et al. 2015), along with another within the beginning stages of preparation. Furthermore, we have identified a unique value in the large telemetry dataset, through our work with Jim Manning, in comparing the direct observation data with models. This has far reaching application, as modelled oceanographic data continues to increase in accuracy and ease of use, along with the ever increasing number of telemetry deployments. Finally, we have started to reach a global audience with this work, presenting both the telemetry research and the ROV methods and novel results at the International Sea Turtle Symposium in April, 2015.

In response to the case of Oceana, Inc., v. Penny Pritzker, United States Secretary of Commerce, et al., we are convinced, based on our previous research, the Reasonable and Prudent Measures outlined in the report are appropriate to help monitor the interactions between loggerheads and the scallop fisheries.

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Tables and Figures

Table 1: Summary information for the 10 ROV trips.

Trip	Date	Turtles Filmed	Turtle Footage (min)	Total Footage (min)	% Turtle Footage
1	17/6 - 21/6/2008	14	650.4	1547.3	42.0
2	19/8 - 22/8/2008	3	13.8	418	3.3
3	12/6 - 16/6/2009	16	756.0	1171	64.6
4	9/7 - 15/7/2009	14	958.9	1649	58.2
5	12/9 - 15/9/2009	6	96.9	331	29.3
6	9/8 - 12/8/2010	5	21.0	211	10.0
7	26/7 - 27/7/2011	3	19.0	118	16.1
8	24/7 - 28/7/2012	2	51.0	144	35.4
9	11/9 - 14/9/2012	4	88.0	358	24.6
10	16/9 - 18/9/2014	3	24.0	211	11.4
TOTAL		**70**	**2679.0**	**6158.3**	**43.5**

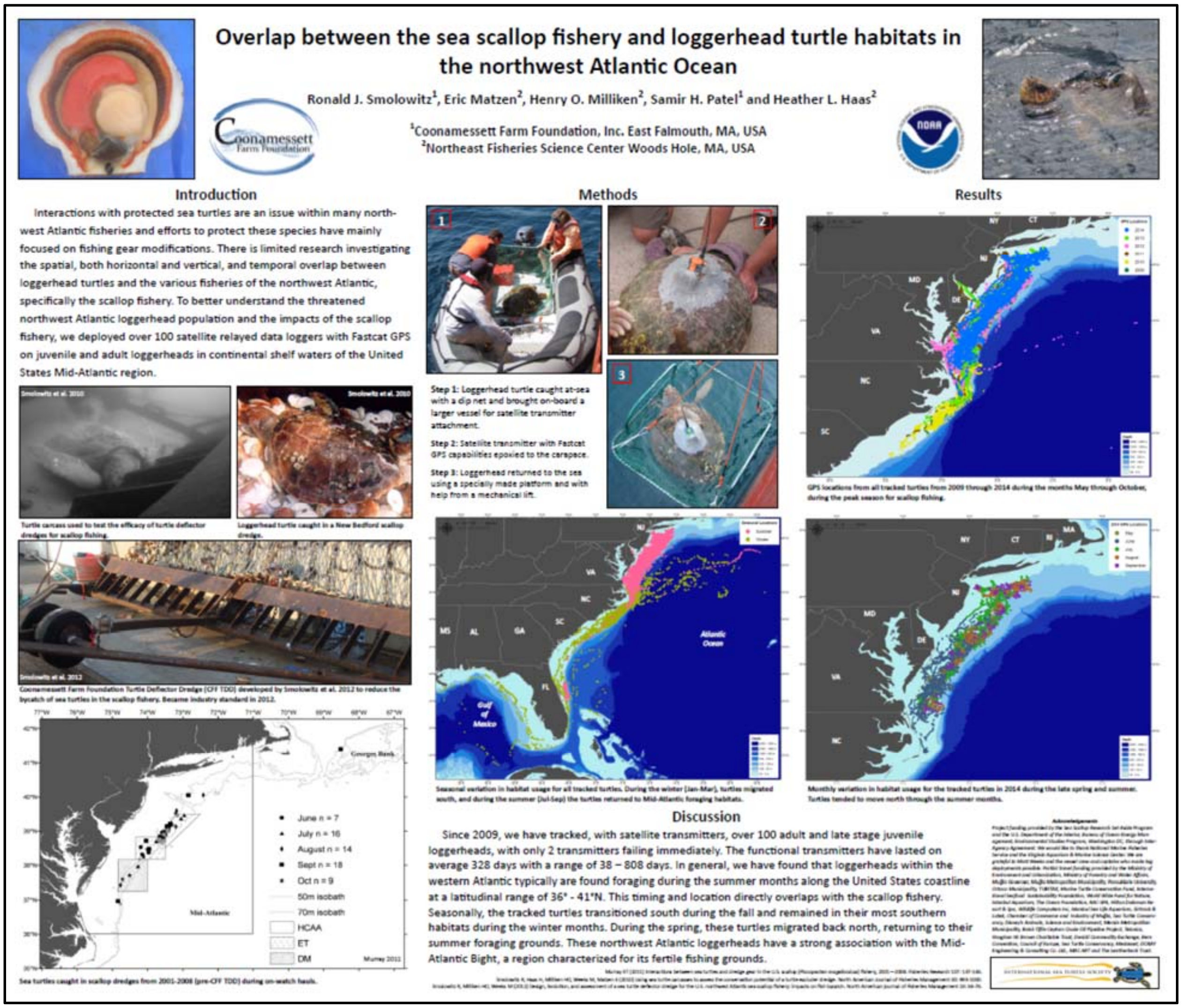

Figure 1: Poster presented in April 2015 at the International Sea Turtle Symposium in Dalaman, Turkey by Samir Patel of CFF on the satellite telemetry research program started in 2009, in collaboration with NEFSC and funded by the Scallop RSA.

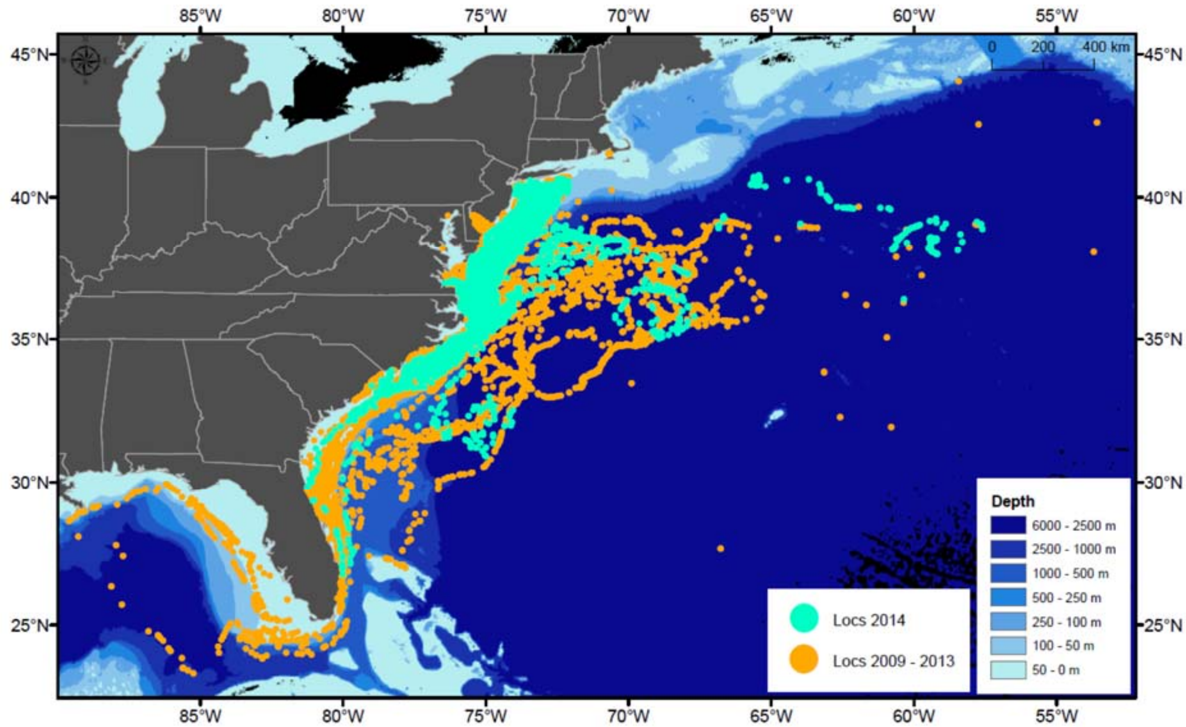

Figure 2: Map of the Argos and GPS locations from all the tracked turtles since 2009.

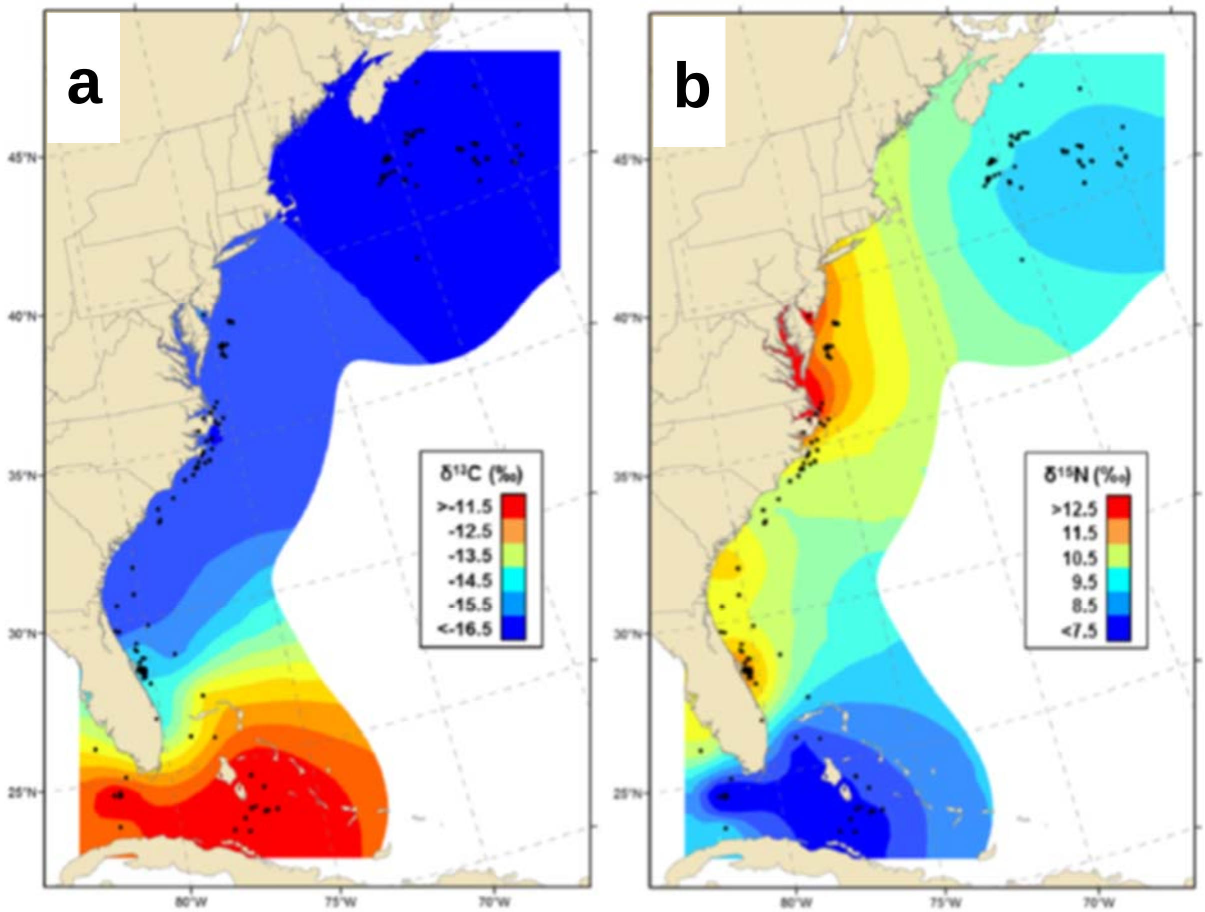

Figure 3: a) Isoscapes of $\delta^{13}C$ derived from loggerhead epidermal tissue. b) Isoscapes of $\delta^{15}N$ derived from loggerhead epidermal tissue. Figure modified from Ceriani et al. (2014).

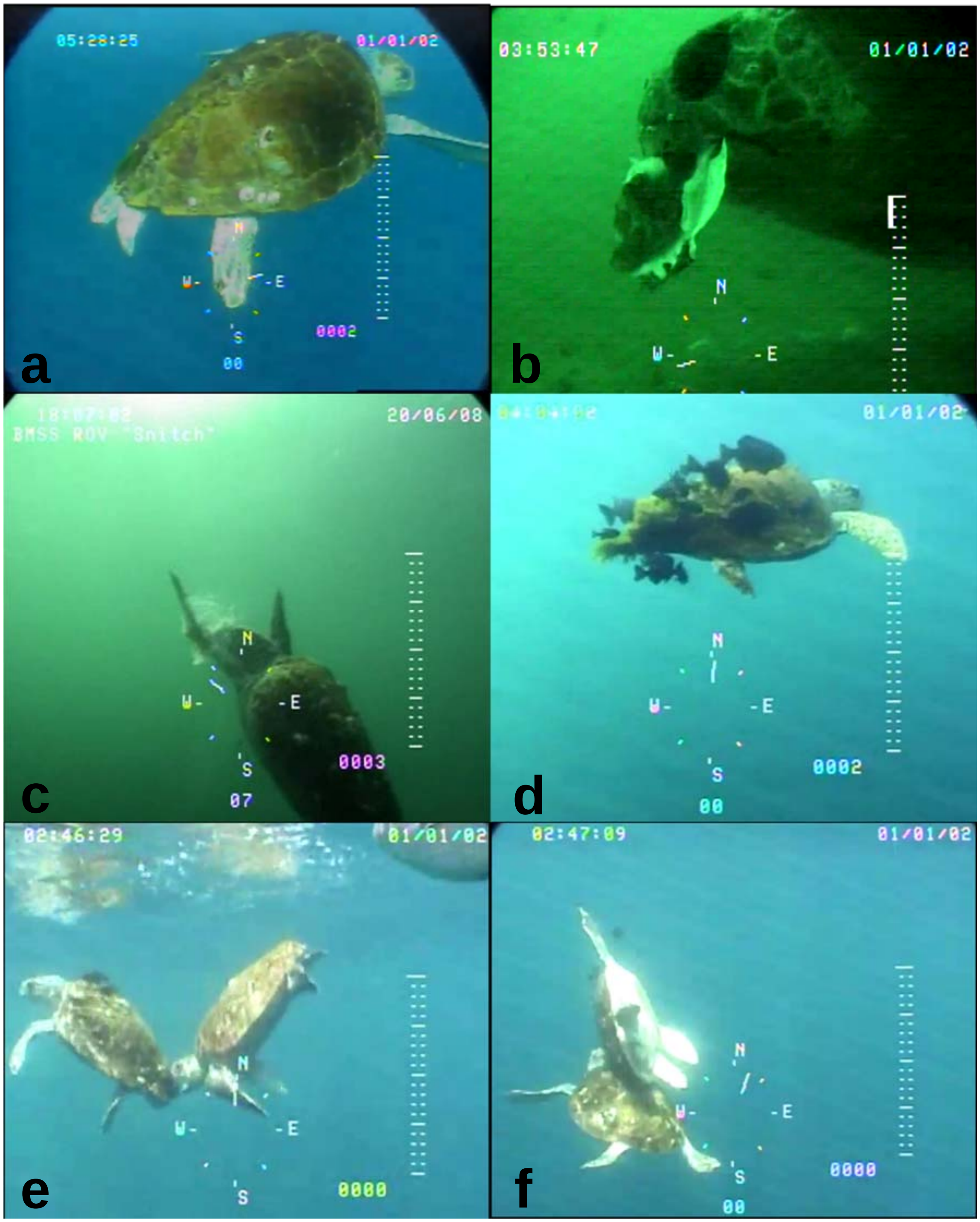

Figure 4: a) Footage of one of the male turtles tracked. This turtle was tracked on July 11, 2009 for 33 minutes. b) Turtle foraging on an Atlantic Sea Scallop. c) Turtle foraging on a Lion's Mane Jellyfish. d) Turtle with several barrelfish and triggerfish associated, along with a large clump of algae attached to the carapace. This turtle was also missing its back left flipper. e) Turtle biting the carapace of another turtle. f) Carapace rubbing between the same two turtles. These turtles remained interacting with each other for ~5 minutes. (Figure taken from Smolowitz et al. *in press*)

Figure 5: Turtle reaction to a shark presence. Blue arrow is identifying the shark. Turtle shifted its body suddenly such that its carapace was facing the shark along with swimming at a very acute angle turning away from the shark. (Figure taken from Smolowitz et al. *in press*)

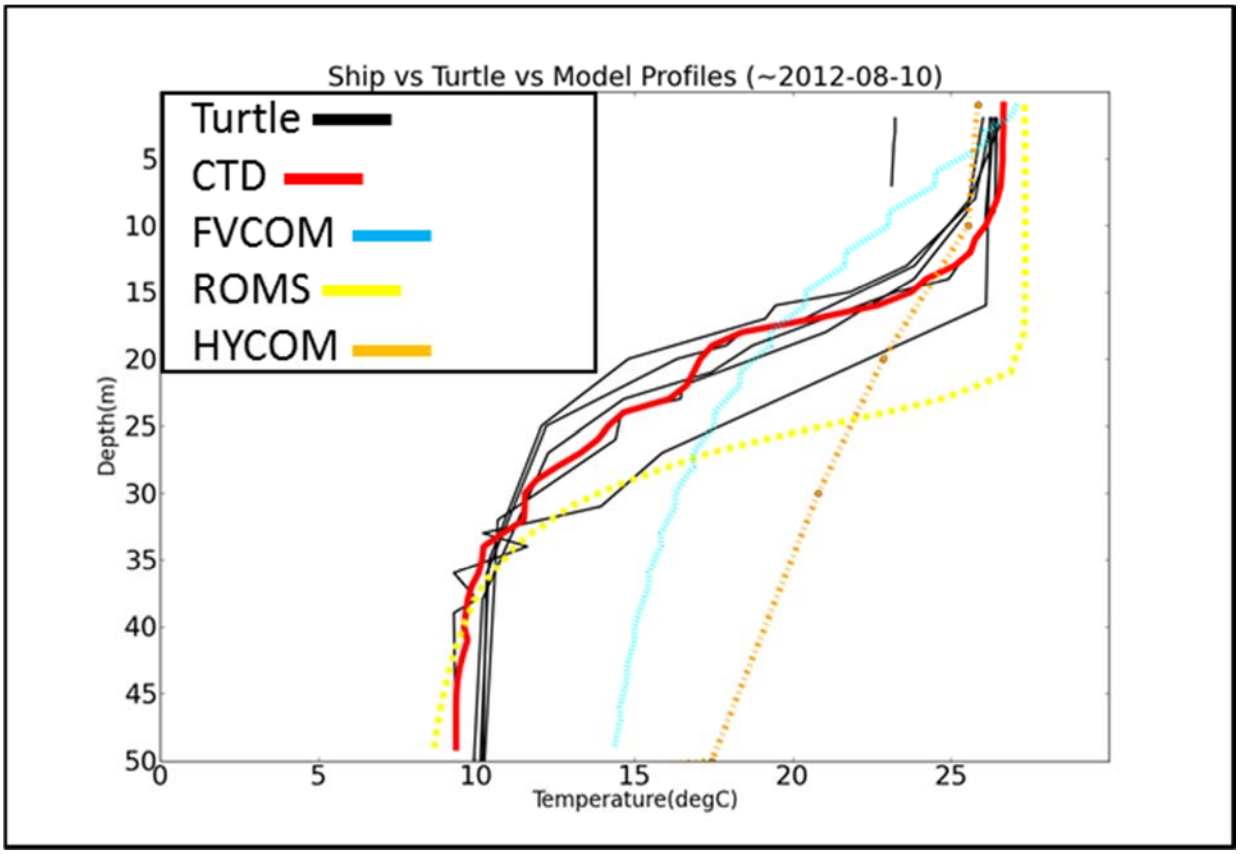

Figure 6: Example profiles where turtle observations (thinner lines) align closer to shipboard cast (bolder red) than model simulations (ROMS yellow dashed, FVCOM cyan dotted, and HYCOM pink dash-dot). Note that the shape of ROMS structure is better than FVCOM but FVCOM mean and RMS difference was less. (Figure modified from Manning et al. *in prep*)