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

Final Report for 2015 Sea Scallop Research Set-Aside (RSA) Program
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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 2015 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.

During the 2015 research season, we spent a total of 20 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 8 transmitters on loggerheads during the first trip in late May, 2 transmitters during the research trip in June and no tags in the September trip. Due to a delay in receiving the satellite tags from SMRU, we were able to only deploy 8 tags during the May trip within the south Mid-Atlantic Bight. In June, we collaborated with NEFSC to search for and tag turtle on and near Georges Bank using the NOAA Ship Henry Bigelow. Due to poor weather and sighting conditions, we only deployed 2 tags on this trip; however we did take footage of the water column to assess the region for pelagic prey. Finally, during the September trip, we departed from Woods Hole and transected southeast, but again due to poor weather and sighting conditions we did not deploy any tags. Poor weather also restricted our ability to conduct ROV dives as well.

In addition to research trips focused on turtles within the Mid-Atlantic Bight, we spent time spotting and tagging turtles farther northeast than in past years. From our previous tag data, we have noticed a slow northward trend in habitat use within the Mid-Atlantic continental shelf; however from the recent cold stunning events on Cape Cod it is clear loggerheads are inhabiting areas farther northeast of this region. As a result, the research trip on the Bigelow was focused in Georges Bank, and we plan to continue this type of research in conjunction with our Mid-Atlantic tagging and sampling program.

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, #5 and #6. 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 over 50,000 days. 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 of the F/V Kathy Ann and NOAA provided vessel coordination for the Bigelow.

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 larger vessel, 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 larger vessel, 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 backward, at the point where the first and second vertebral scutes meet. Our NEFSC partners retrieved blood and tissue samples for on-shore analyses. 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.

The jellyfish survey system was comprised of a light weight frame, with 2 cameras mounted facing each other approximately 2 meters apart, along with a Didson Sonar System. The frame was used as a reference of volume and distance for the camera view. We used 2 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 2015 research season, we spent a total of 20 days at sea, spread across three trips, to deploy satellite transmitters and perform habitat assessments. During the first trip, in May 2015, eight turtles were captured for biological sampling and satellite telemetry deployments. This trip took place in the southern Delmarva region, similar to previous tagging efforts. All data from the satellite transmitters have 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 late June 2015, 2 turtles were captured for biological sampling and transmitter deployment. This trip took place in eastern Georges Bank, a new location for our sea turtle ecology studies. During this trip, we also tested our jellyfish survey system to monitor the presence of jellyfish within the environment key for sea turtle foraging. We deployed the system 8 times, primarily at night, each time descending for 15+ minutes and capturing footage throughout the descent and ascent.

During the third trip in September 2015, we did not sample from any turtles due to poor weather and sighting conditions. Although we did spot 13 turtles, we were unable to capture them. This trip departed from Woods Hole, and we steamed southwest to interact with the turtles residing in Southern New England waters and those residing farther offshore in northern Mid-Atlantic waters.

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 have also begun to compare spatial overlap between tagged loggerheads and oceanographic features as potential driving forces for their migrating and foraging behaviors. We are continuing to investigate, through the biological and morphometric sampling, the population structure and health of this population.

A substantial portion of the data analyses this year went into coding the over 2700 minutes of footage from the ROV. This is an excerpt from a manuscript (Patel et al. *in review*) on the methods of analyzing these data.

Behavioral Analysis

Video footage was analyzed with the Observer XT Version 12 software package (Noldus Information Technology, Virginia, USA). We developed a coding scheme to characterize turtle behaviors including state events (duration and frequency), point events (frequency only) and habitat variables (state events only). Full details on the 27 parameters that comprise the coding scheme can be found in Table 1. Habitat variables included depth zones of the subject turtle, inter- and intra-species observations, and potential prey in view. Depth range was determined using the ROV depth sensor, which provided a live output of the ROV's depth. As it was sometimes difficult to gauge if the turtle was within the same horizontal plane as the ROV, we could not specify the actual depth of the turtle and instead used descriptive values for depth zones. We categorized potential prey as unidentified material, gelatinous or non-gelatinous, and identified potential prey to species level when possible. Inter- and intra-species observations included other sea turtles, fish (including sharks), and marine mammals. Turtle behavior variables included feeding and reaction to the ROV. Point events all corresponded to the actions of the subject turtle. We included four point events: adjustment, flipper beat, breath and defecation. Although we did not code for buoyancy, during deep dives, we identified a turtle as being negatively buoyant once it stopped active flipper beating yet continued to descend at a high rate.

Results

Satellite Telemetry

From the 2015 satellite transmitter deployments, as of June 6, 2015, we have compiled 2268 days of data, with an average lifespan for these 10 transmitters of 226.9 days. Transmitters deployed in 2015 lasted between 23 – 375 days. Seven transmitters from 2014 continued to send data, with the longest deployment duration of 486 days and the final transmission on September 28, 2015.

From the 2015 tagging cohort, we documented new and unique behaviors not previously seen in our tagging studies (Figure 1). From those tagged in the Mid-Atlantic, we tracked turtles using more northern habitats within the region, coming much closer to the southern edge of Long Island than previous years. These turtles also moved east within the offshore region of Southern New England, an area with known turtle sightings (http://www.seaturtlesightings.org), however never before utilized by turtles tagged in the Mid-Atlantic through this program. These turtles migrated south during the winter months, with one turtle following the warm Gulf Stream, before returning to shelf waters. Although, as of June 6, 2016, transmissions were only being received from one turtle on the shelf, this turtle migrated back north into the Mid-Atlantic region during the spring, similar to turtles tracked in previous seasons.

The two turtles tagged in Georges Bank exhibited contrasting behaviors, with one remaining far offshore in very deep waters, beyond the scope of loggerhead diving for benthic foraging; while the other migrated west into shelf waters, most likely foraging on both pelagic and benthic prey. The offshore turtle remained in these waters through the seasons, even entering waters of SST in the single digits Celsius (Figure 2). As of June 6, 2016, the offshore turtle is continuing to send data, and this turtle is maintaining residency in the same region.

Summer SST in the MAB for 2015 was warmer than 2014, and this may have resulted in turtles utilizing more northern habitats. Even though we tracked turtles much farther north in 2015, the average summer SST in which all tracked turtles resided was 22.8°C, while in 2014, for the same time period, the average SST in which turtles resided was 22.6°C in a more southern and concentrated region of the Mid-Atlantic shelf. The range of temperatures experienced by each cohort also varied substantially, yet there was a slight skew towards warmer temperatures for the 2015 summer locations (Figures 3, 4)

Habitat Analysis

We did not have success identifying jellyfish through the use of the jellycam survey system due to a general lack of jellyfish within the water column. The footage from the jellycam was clear and useable; however there was a lack of fauna to be identified from the instrument (Figure 5). The Didson did not provide additional insight as its field of view was narrow and it was hard to identify animals from the sonar output.

ROV Analysis

This is an excerpt from the manuscript (Patel et al. *in review*) on the results of the ROV footage data analysis. Table 1 is a summary of all of the results. Figure 6 represents the frequency of each state event for each depth zone, figure 7a depicts footage of a turtle interacting with the tether and Figures 7b-d depicts footage of each point event.

Depth Zones

Tracked turtles were found most commonly swimming within the near surface region (42.0% of total time) or water column (44.3% of total time). We filmed turtles at the surface 7.3% of time, with time spent in this depth zone specifically related to breathing events. Turtles spent 0.43% of time near bottom and 6.0% of time directly on the bottom. Time near bottom and on the bottom corresponded to benthic foraging, with near bottom time associated with turtles moving between benthic foraging spots or chasing mobile prey. When turtles were lost from view, most were near surface or in the water column and they swam out of range of the ROV tether or swam too fast for the ROV to follow. The ROV was not quick enough to always follow turtles to the benthic zone, as the turtles became negatively buoyant at depth and could sink at a rate faster than the ROV could fly. We followed 14 turtles on 18 deep dives, losing seven turtles from view during the descent without reacquiring them. Of these 14 turtles, we tracked nine across 13 dives as they reached negative buoyancy. We identified negative buoyancy occurring when the turtles reached between 10 - 33 m. We were able to follow one turtle through 5 deep dives, and this turtle exhibited negative buoyancy at different depths each time. This turtle stopped active flipper beating at approximately 26 m, 31 m, 18 m, 33 m and 29 m for its 5 dives respectively, with each dive reaching between 49 - 53 m.

Feeding

Due to the orientation of the camera as compared to the mouth and face of the turtle, we categorized 82.2% of total film time as unknown if feeding. Of the time when we could see the mouth and face of the turtles (17.8% of total time), we categorized 85.0% of time as not feeding, 13.0% of time as feeding on non-gelatinous prey and 2.0% of time as foraging on gelatinous prey. Foraging on gelatinous prey only occurred near surface or within the water column with an approximate depth range from 1 – 16 meters and a median depth of about 4 meters. We identified five turtles foraging on gelatinous prey 45 times. Foraging on non-gelatinous prey only occurred while the turtle was on the bottom; however we consistently identified the availability of gelatinous prey during this foraging behavior. We identified two turtles foraging on gelatinous prey that also made dives to the benthic environment. Although these turtles dove to the sea floor, we did not observe them foraging on benthic organisms, as we were only able to track them on the bottom for a total of 3.4 minutes.

Discussion

Satellite Telemetry

The 2015 tagging and sampling effort was limited due to logistical complications from vendors and unpredictable weather limiting the sighting conditions while at sea. As a result, across three trips, we tagged a total of 10 loggerheads and did not successfully track a turtle through ROV. Although, the season of field work resulted in a low sample size, the unique methods of the 2015 season and the warmer SST conditions resulted in turtles exhibiting behaviors previously undocumented through past years' research. The turtles tagged in the southern Mid-Atlantic region in May, migrated farther northeast than ever before tracked, and we started to account for the influx of loggerheads on Georges Bank. In recent years, cold stunning events have yielded a large quantity of loggerheads stranding on Massachusetts beaches and researchers have suggested that as ocean temperatures warm, loggerheads will continue to expand their range poleward (Witt et al. 2010).

Currently, scallop dredge regulations require turtle exclusion tools to be used west of 71°; however, we are beginning to document a steady rise in turtle numbers east of this longitude at a time of known scallop dredging. The expectation is that, through intense conservation efforts on the nesting beaches of the southeastern US and in-water protection regulations along with rising ocean temperatures, the loggerhead population will continue to rise and inhabit shelf regions northwest of the Mid-Atlantic. This will directly impact scallop dredging efforts in these regions, specifically Georges Bank. As a result, a concerted effort is required by the scallop industry to stay ahead of what could potentially be a serious bycatch problem similar to that experienced by scallopers in the Mid-Atlantic prior to the implementation of dredge modifications for turtle exclusion. To adjust for this change, a detailed ecological assessment of the loggerheads in the region is required to make potentially new regulations reasonable for fishermen, while also following guidelines set forth by the Atlantic Sea Scallop Biological Opinions and Reasonable and Prudent Measures. For example, by understanding the seasonal distribution of loggerheads, regulations could be implemented requiring turtle exclusion devices during particular months only in areas northeast of 71°. This would ease the transition for scallopers to using new dredges, and allow for sustained year-round effort.

Habitat Analysis

Although we did not have much success during this past season in terms of identifying high concentrations of jellyfish, we are confident with our survey system and plan to continue using it in the upcoming season. We do not plan to continue using the Didson due to the limited value of the output data for our needs.

ROV Analysis

This is an excerpt from the manuscript (Patel et al. *in review*) on the discussion of the ROV data analysis.

With the combined advances in in-water videography and the corresponding development of integrative behavior-coding software, we were able to observe turtles in highly important surface waters. Typically, telemetry devices, due to their inability to accurately gauge the near surface zone below ~1 m of resolution, group depths such that any dive appearing to be above a specified threshold (e.g., ~5 m) is considered "surface" time associated with breathing (Fedak et al. 2002, Polovina et al. 2002). Here we tracked turtles spending a majority of their time within the top few meters of the water column, with only a small percentage of that time breaching the surface to breathe. This result may be slightly skewed, as turtles were easier to track with the ROV while within the surface and near surface zones, and more likely lost from view during benthic dives. Regardless, even though turtles use the entire water column, the top few meters represent an important depth strata where they reside even during the warm foraging months. This has two conservation implications: 1) when sub-surface turtles are used in abundance estimates done through aerial surveys, availability biases of loggerheads to visual observers need to explicitly consider near-surface layers, and 2) gear modifications aimed at conserving Mid-Atlantic loggerheads should be effective in near-surface waters.

Telemetry studies typically group turtles into benthic or pelagic foragers based on the dive behavior and location (Hatase et al. 2002, Hawkes et al. 2006, Luschi et al. 2003). However, here we identified turtles exhibiting both behaviors of active pelagic foraging followed by dives to the benthic environment. Thus, loggerheads may have a higher level of flexibility in their foraging abilities than typically recognized (Luschi et al. 2003, McClellan et al. 2010). Although Mid-Atlantic shelf loggerheads may potentially have a preference towards benthic fauna over pelagic fauna when both are available, they are spending the majority of their time in the water column that is rich with gelata. Previously NMFS expected loggerheads to be more prone to interactions on the bottom (NMFS 2015), but the heavy use of near surface waters and the prevalence of abundant gelata call this assumption into question for Mid-Atlantic shelf loggerheads.

Here, we were able to directly observe, *in situ*, turtles reaching a point of negative buoyancy during their benthic dives. Hays et al. (2004) previously suggested that perhaps turtles exhibit negative buoyancy when diving to the bottom to reduce the likelihood of floating upwards. In our footage, it seems that these turtles are indeed displaying negative buoyancy, making staying at the bottom easier, as they are able to sink after reaching a certain depth without actively swimming and at a rate faster than a powered ROV (~0.35 m s^{-1}). Furthermore, the turtles we filmed swimming within one meter of the bottom either chasing prey or moving between discrete foraging spots, had to continuously push off the bottom or actively flipper beat in order to avoid sinking; while those we filmed returning to the surface from the sea floor had to propel themselves through a majority of the ascent. The strong negative buoyancy and active prey searching of observed loggerheads likely limit the abilities of these turtles to detect and avoid benthic fishing gear. Therefore gear modifications that passively deflect benthic turtles rather than relying on active sea turtle avoidance behavior likely have important conservation value (Smolowitz et al. 2012).

Inadvertent interactions with the tether provide information about sea turtle interactions with vertical lines, a conservation concern that is poorly understood (http://www.greateratlantic.fisheries.noaa.gov/protected/seaturtles/docs/vertical_line_summary_final.pdf). Fortunately, the use of a taut and thick tether on the ROV helped limit the interactions from becoming true entanglements. However, along the northeast US seaboard, from Maine to Virginia, between 2002 and 2014 over 20 sea turtles were reported entangled in vertical fishing line annually (Sampson 2015). No data exists to identify how often turtles interact with vertical lines and do not entangle. Although studies have been conducted to document the occurrence of entanglement between sea turtles and vertical lines from stationary nets (see Gilman et al. 2010), very limited research has been focused on understanding how and why hard shelled turtles become entangled on vertical lines. From our footage, we observed that the entanglement may start with a line becoming caught between the front flipper and head with the turtle reacting by swimming forward in an escape response and forcing more line to cover the individual. It seems likely that entanglements could also be triggered through contact with the back flipper, with both scenarios potentially becoming worse if involving light flexible line that has the ability to create small tight loops at a diameter less than the turtle's flipper or neck.

Summary

During the past research year, we have continued to meet our goals of assessing loggerheads residing in the MAB through satellite telemetry and biological sampling, along with expanding on this research through our work with new species and habitats. We have expanded our analyses of the telemetry data with the inclusion of relevant SST data to help identify habitat preferences. Furthermore, we have completed a major analyses of the ROV footage accumulated over 6 years of effort. This analyses has yielded very unique results that could better inform conservation and management strategies in assessing the population of loggerheads overlapping with several overlapping regional fisheries.

Our next steps include continuing to track loggerheads within the MAB and north, to more thoroughly assess the overlap between this endangered species and scallop fishing. Furthermore, as the concern for parasites in the scallop meats increases, a better understanding of the lifecycle of these organisms is required before action can be taken for mitigating this issue. As a result, for the 2016 season, we are collecting fecal and urine samples from the turtles to understand if these animals are carriers for the nematodes and then where they migrate to potentially depositing the eggs. This will improve our understanding of the spatial ecology of these parasites to determine if this is a regional scale or entire fishery scale threat. We expect 2016 to again provide unique insight into the ecology of this northwest Atlantic loggerhead population, setting up a whole new set of questions requiring investigation in 2017.

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Tables and Figures

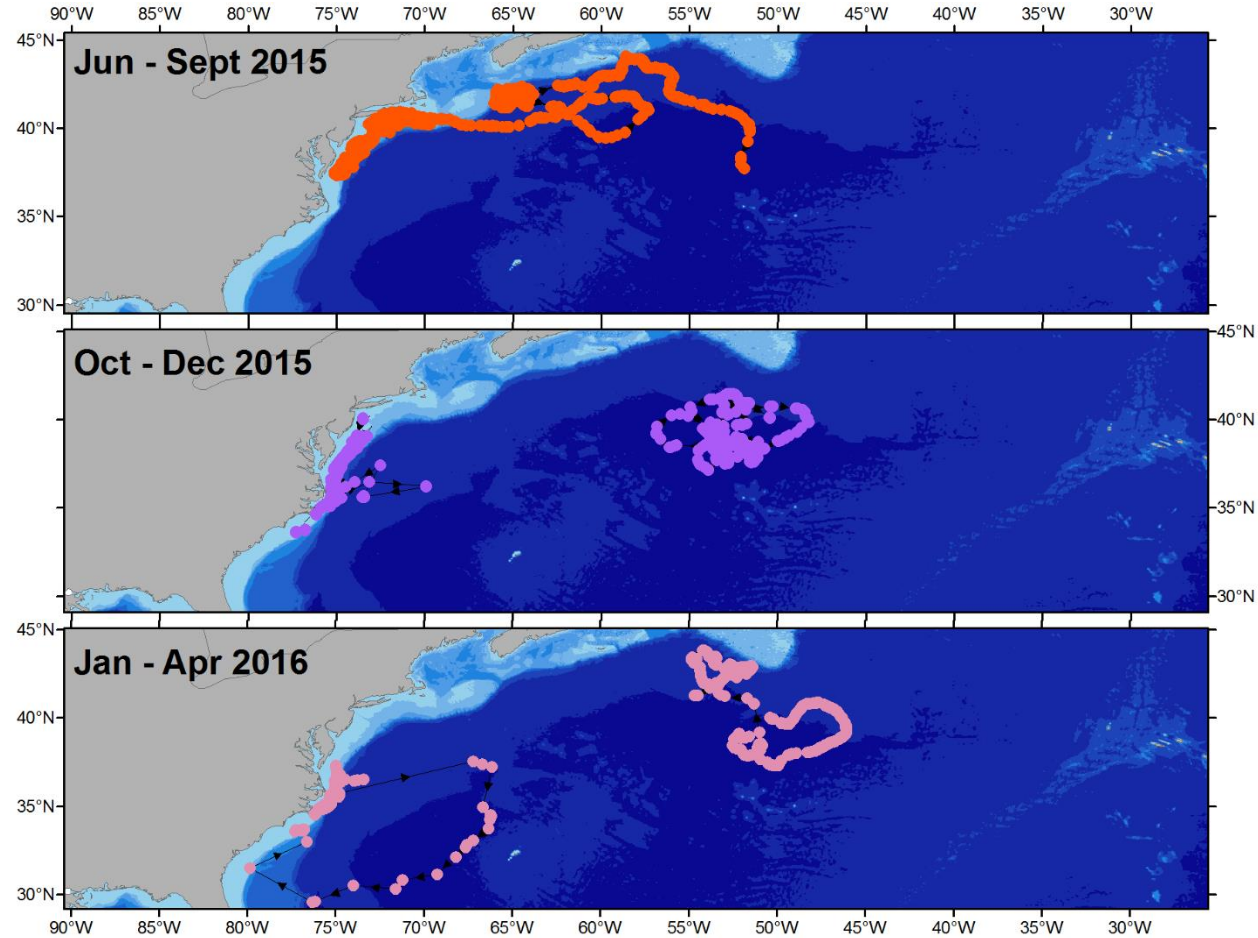

Figure 1: Argos locations for all turtles tagged in 2015 based on season.

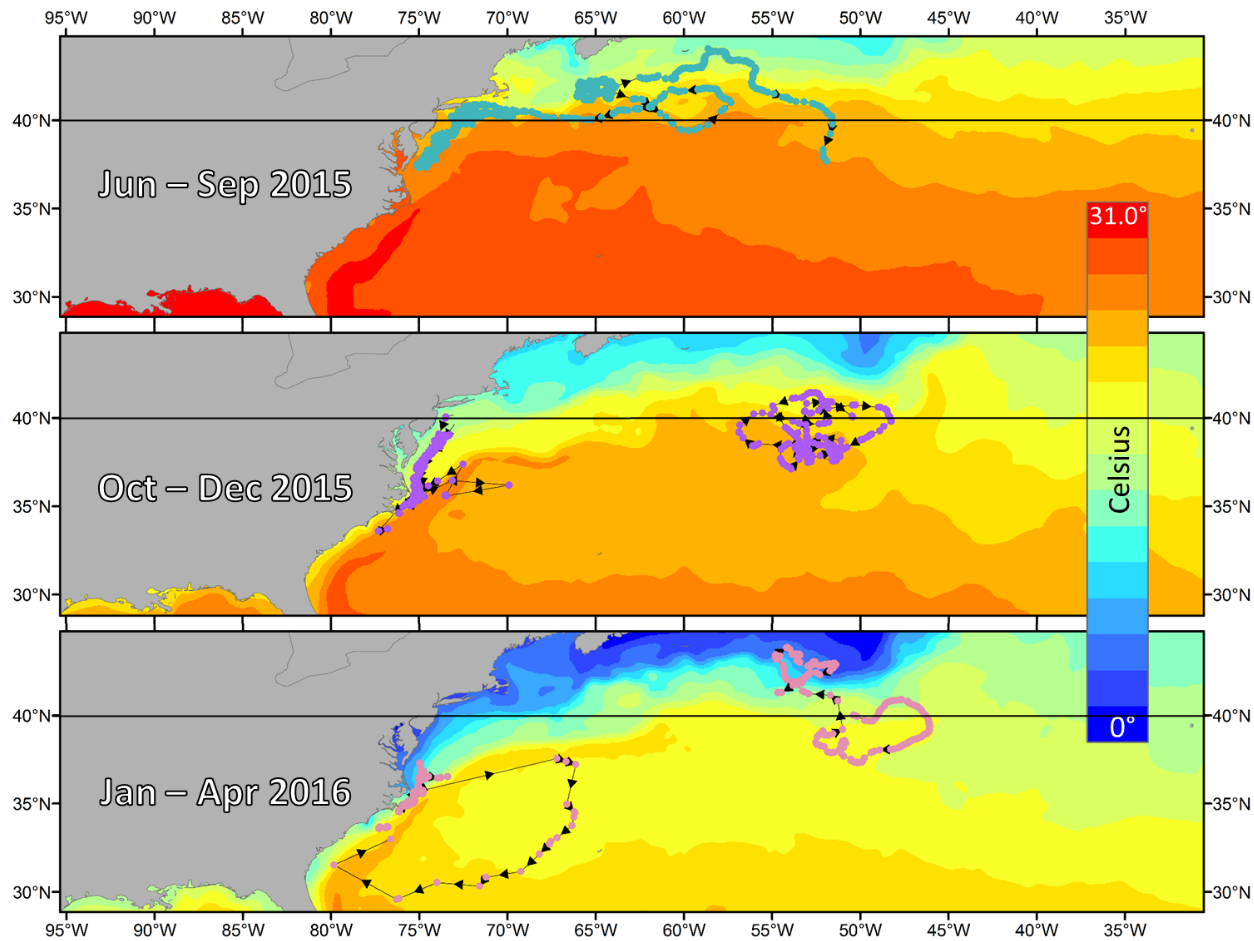

Figure 2: Seasonal variation in loggerhead locations for those tagged in 2015 and SST.

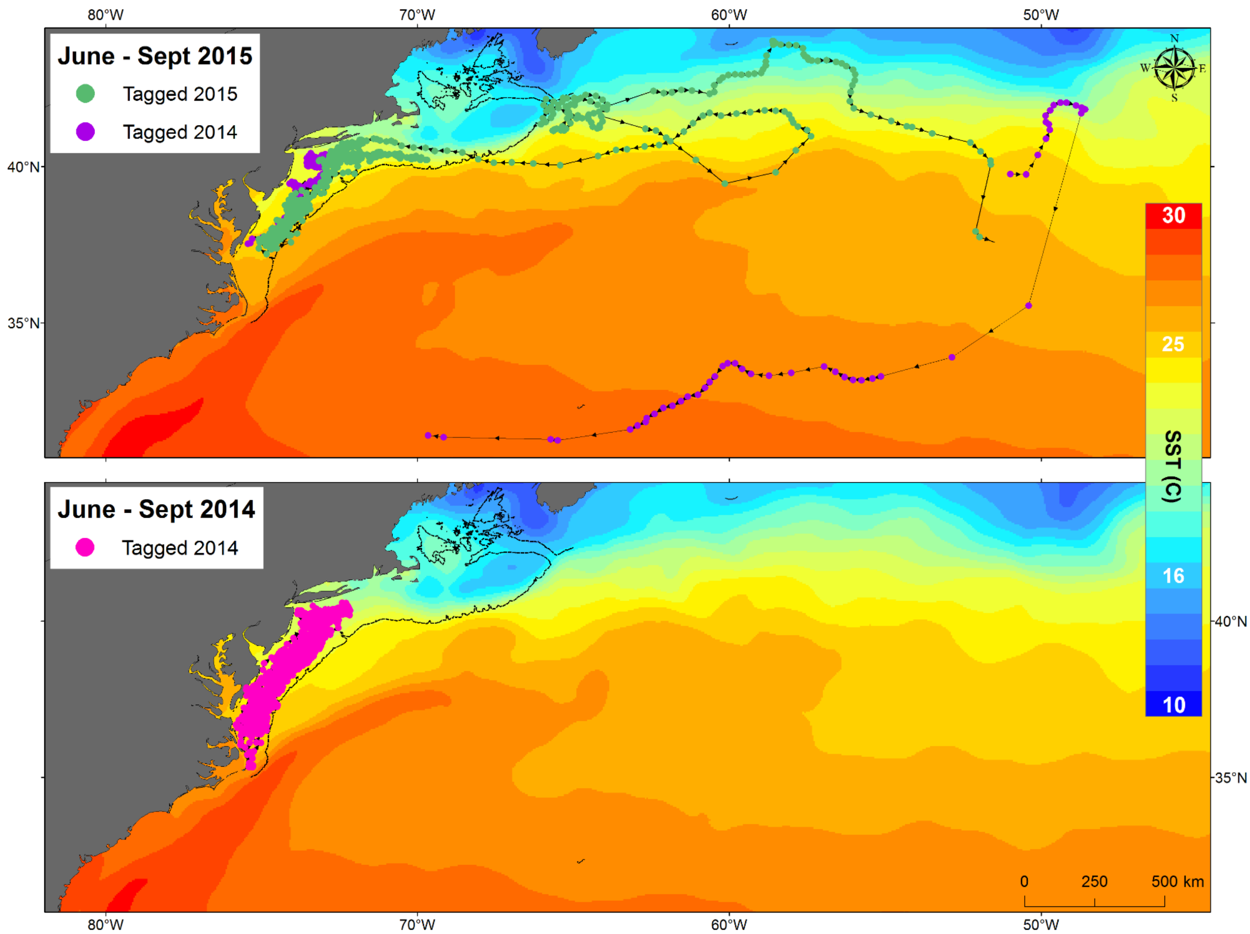

Figure 3: Summer temperatures and distributions for turtles tagged in 2015 and 2014 as comparison.

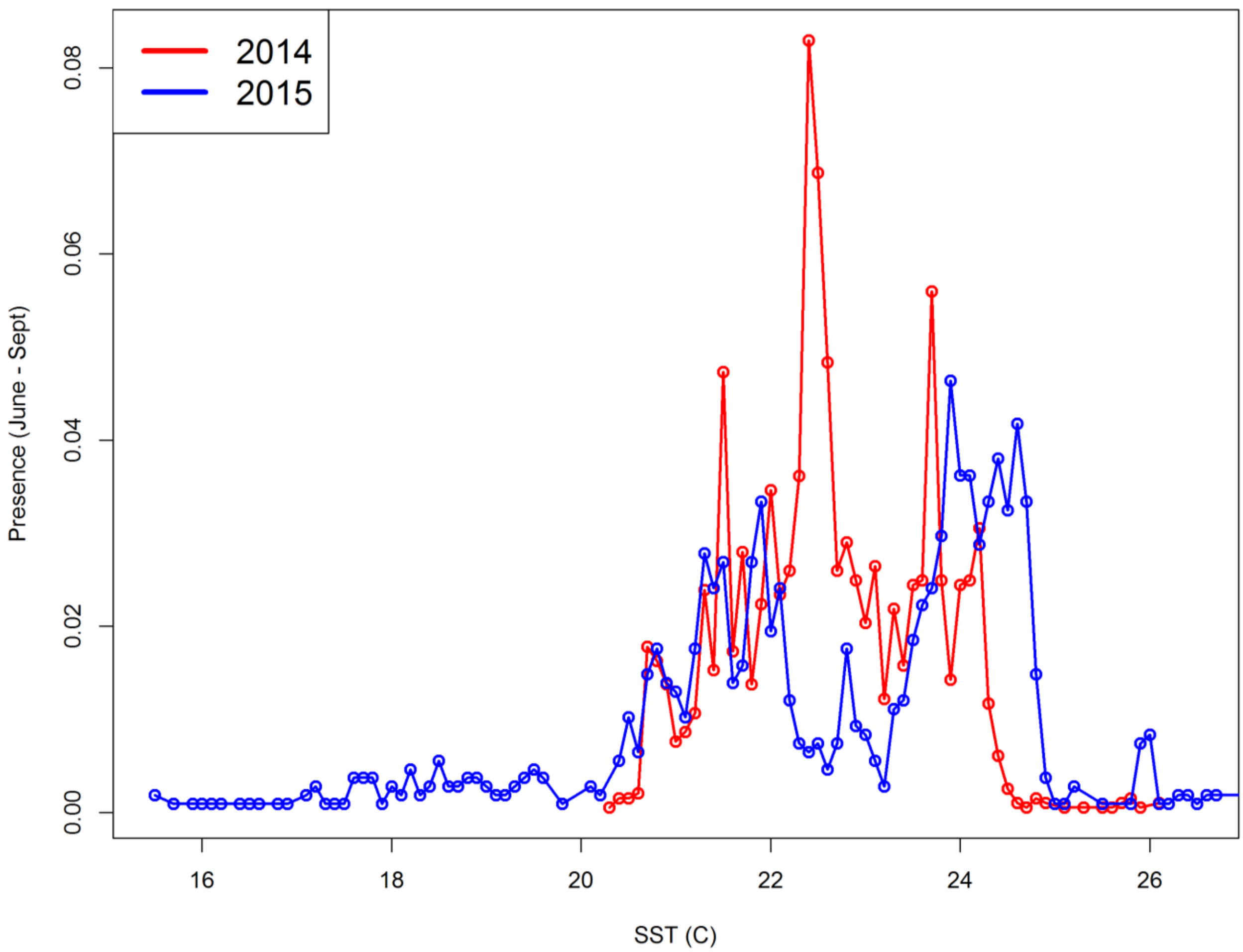

Figure 4: Temperature at which turtles were most commonly found residing in during the summer months of 2014 and 2015. Y axis is a percentage of total Argos locations from June – Sept.

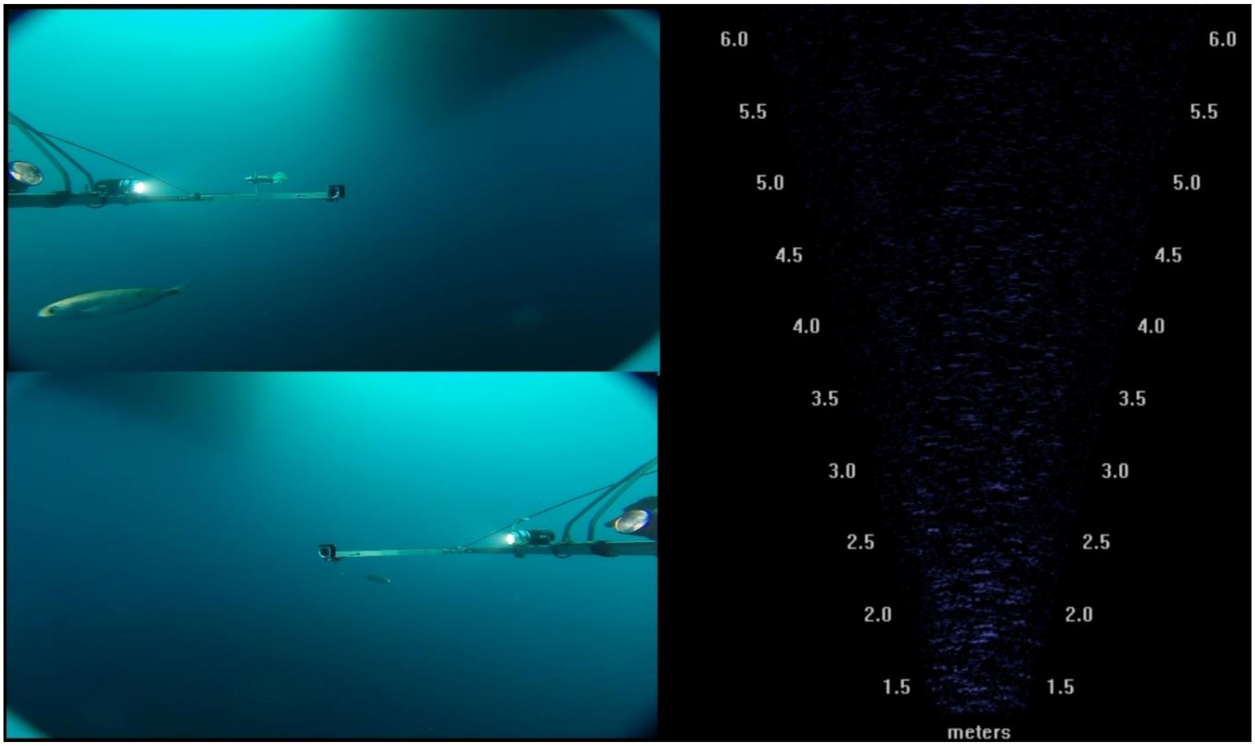

Figure 5: Image from the jellycam survey system of a fish in view, along with corresponding data from the Didson.

Events	# Turtles Exhibiting Behavior	Total Footage (min)	% Total Footage
Surface	54	199.3	7.3
Near Surface	66	1151.6	42.0
Water Column	67	1215.3	44.3
Near Bottom	7	11.9	0.4
Bottom	7	164.1	6.0
Unknown if feeding	73	2254.2	82.2
Not feeding	67	414.8	15.1
Feeding on gelatinous prey	5	9.7	0.4
Feeding on non-gelatinous prey	3	63.4	2.3
Subject turtle only species in view (excluding prey)	62	2022.2	73.7
Multiple turtles in view including subject turtle	3	1.6	0.1
Fish etc. and subject turtle in view	31	707.1	25.8
Fish etc. and multiple turtles in view including subject turtle	5	11.1	0.4
No reaction	72	2541.2	92.7
Reaction	54	200.9	7.3
Adjustment	21	141*	-
Flipper beat	73	39377*	-
Breath	49	1053*	-
Defecation	10	13*	-
No prey and no unidentified material in view	31	233.7	8.5
Unidentified material in view	41	756.6	27.6
Gelatinous prey in view	8	62.5	2.3
Gelatinous prey and unidentified material in view	30	1478.1	53.9
Gelatinous and non-gelatinous prey in view	0	0.0	0.0
Non-gelatinous prey in view	0	0.0	0.0
Non-gelatinous prey and unidentified material in view	3	12.4	0.5
Non-gelatinous and gelatinous prey and unid'ed material in view	6	198.7	7.2
Total	**73**	**2742.1**	-

Table 1: Summary data of the behavioral events documented from all footage. *Total counts of each event.

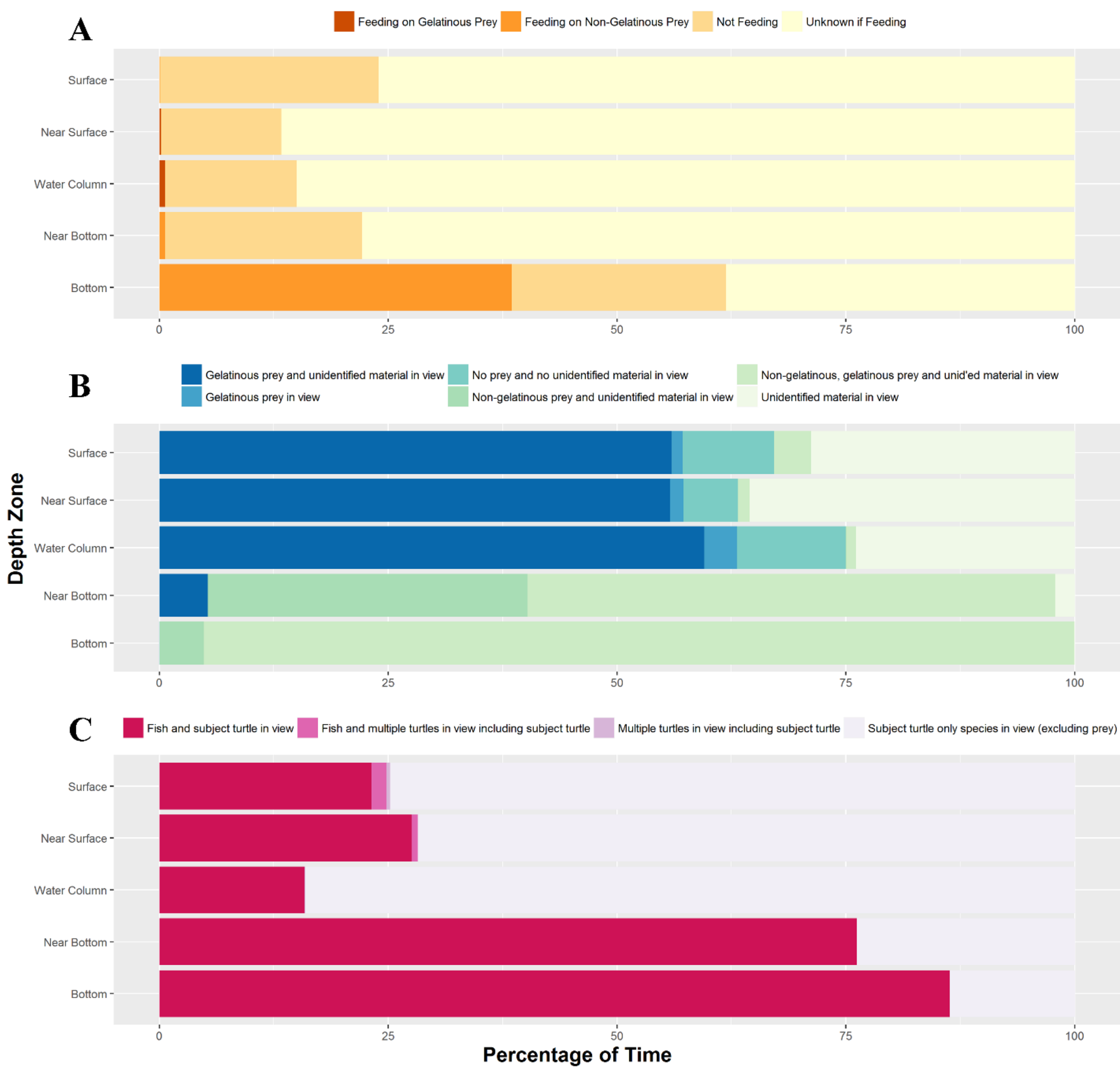

Figure 6: A) Percentage of time all turtles (n = 73) exhibited each type of feeding behavior within each depth zone. B) Percentage of time each prey species category was identified in each depth zone. C) Percentage of time all turtles experienced each type of inter-/intra-species interaction within in each depth zone.

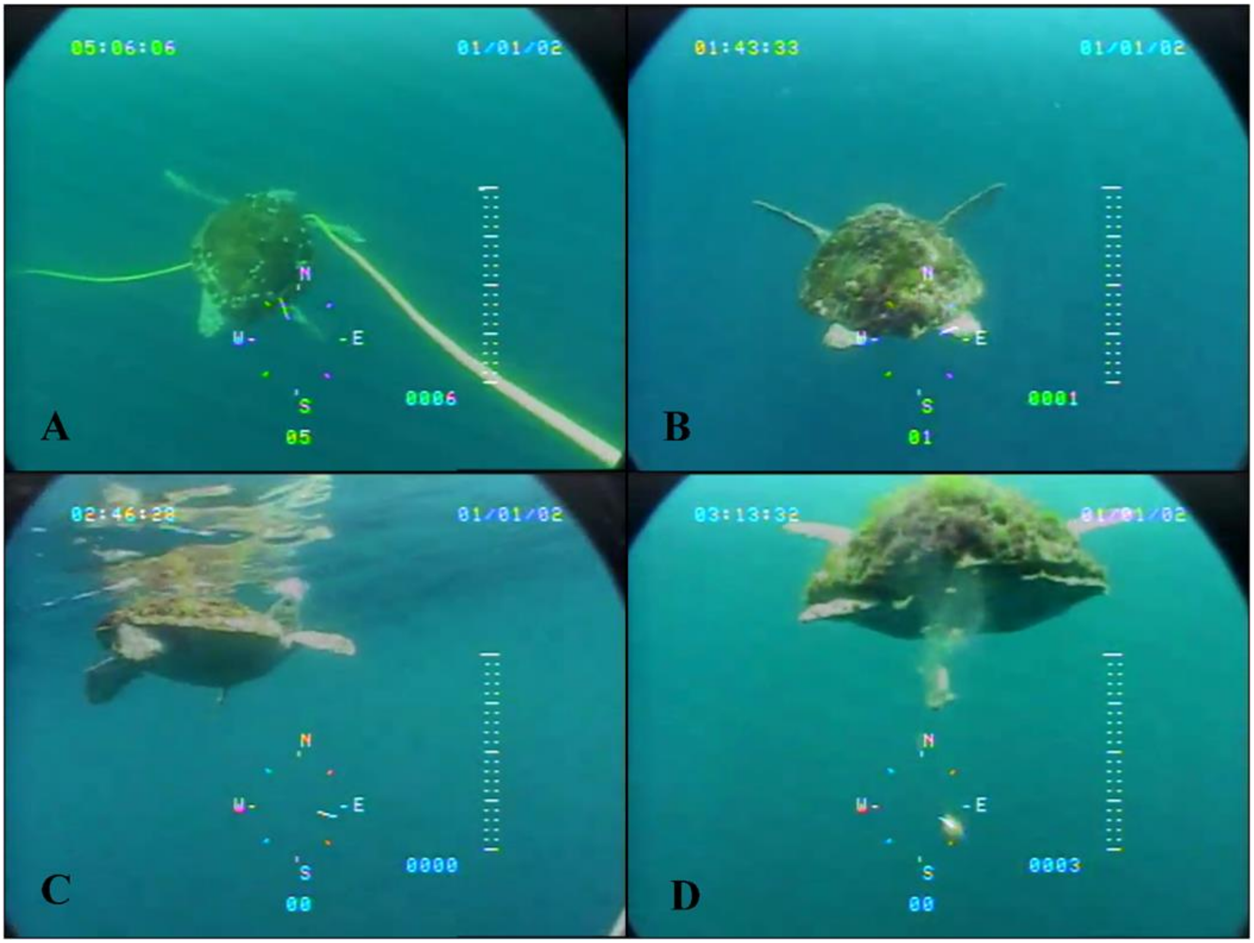

Figure 7: A) Turtle interacting with the ROV tether, briefly getting it caught between its own head and right front flipper. B) Flipper orientation we classified as the start of a flipper beat. C) Footage classified as a breathing event. D) Footage classified as a defecation event.