Sea Turtle Tagging and Tracking in Chesapeake Bay and Costal Waters of Virginia: 2017 Annual Progress Report

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Cover image: Release of Kemp's ridley turtle named 'Purple Heart' in June of 2017. The turtle was hooked by a recrerational angler at the Ocean View fishing pier in late May of 2017 and released by a two-time purple heart recipient at the Virginia Beach oceanfront.

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Acronyms and Abbreviations

°C	degrees Celsius
cm	centimeter(s)
km	kilometer(s)
NMFS	National Marine Fisheries Service
OE	*Ocean Explorer*
PTT	platform transmitter terminal
SCL-NT	straight carapace length-notch to tip
SD	standard deviation
SSM	state-space modeling
UD	utilization distribution
U.S.	United States
VAQF	Virginia Aquarium & Marine Science Center Foundation

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1. Background and Introduction

Five species of sea turtles occur in Chesapeake Bay and the coastal waters of Virginia with varying regularity. They include the loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), and hawksbill turtle (*Eretmochelys imbricata*) (Musick and Limpus 1997). Loggerhead and Kemp's ridley turtles are the most abundant and regularly occurring species, and green turtle numbers have increased over the past two decades in Virginia (Barco et al. 2015, Swingle et al. 2014, 2015, 2016).

This project was initiated in 2013 with ultimate goal of provideing the U.S. Navy with the necessary data to help identify seasonal areas where cheloniid sea turtles are likely to occur in order to support environmental planning and compliance efforts. This project has focused on loggerhead, Kemp's ridley, and green sea turtles with two primary objectives:

- Characterize broad-scale movement patterns using satellite telemetry
- Characterize turtle presence in areas utilized by the U.S. Navy in the lower Chesapeake Bay and nearby Atlantic Ocean using satellite and acoustic telemetry

The focus of our work during 2017 was on deploying additional tags on Kemp's ridley and green sea turtles to increase sample size for analysis, as well as performing a sensitivity analysis on existing loggerhead tagging data to inform See Barco et al. 2017 for a summary of previous work and analyses for loggerhead turtles.

2. Kemp's Ridley and Green Turtle Tagging

2.1 Tagging Methods

2.1.1 Access to Turtles

Turtles for this project have been acquired in three ways: 1) direct capture by researchers, 2) incidental capture in commercial fisheries or trawl operations associated with dredging, or 3) rehabilitation and release of stranded animals, which includes those hooked by recreational fishers. See Barco et al. 2017 for additional details on each method of acquiring turtles for this project. In 2017, tags were only deployed on stranded (hooked) turtles that were rehabilitated and released. Additional data has been provided by the Virginia Aquarium & Marine Science Center Foundation (VAQF) from five tags applied to green and Kemp's ridley turtles from 2007 to 2013.

2.1.2 Tagging and Health Assessment

All turtles tagged for this project in 2017 had undergone rehabilitation and received a full health assessment prior to release. Only tags that produce less than 5% drag are permitted to be deployed on rehabilitated sea turtles based on new rules enacted by the U.S. Fish and Wildlife Service (USFWS) in 2016.

Prior to transmitter attachment, the carapace of each turtle was prepared by removing epibiota and dead scute tissue with putty knives and coarse (60 to 100 grit) sandpaper. After sanding, the scutes were wiped clean and washed with acetone. Researchers used Sika Anchorfix-1™ epoxy for transmitter attachments on larger, >40-cm straight carapace length notch-to-tip (SCL-NT), turtles. The epoxy was used to create a teardrop-shaped footprint with the broad, rounded part of the teardrop facing cranially and the narrow, pointed part of the teardrop facing caudally in order to improve hydrodynamics (Jones et al. 2011). In addition to satellite transmitters, all turtles were individually tagged with Inconel flipper tags and a passive integrated transponder (PIT) tag.

Tag retention can be problematic on smaller, hard-shelled turtles compared to larger size classes of the same species (reviewed in Seney et al. 2010). One hypothesis for poor tag performance on smaller turtles is that rapid growth rate combined with rigid epoxy adhesives can be detrimental to tag retention and/or normal turtle growth (Seney 2008). Thus, for turtles less than 40 cm SCL-NT we employed a technique that includes a layer of flexible neoprene between the carapace and rigid epoxy. The neoprene is affixed to the centers of the scutes using rigid epoxy but the seams between the scutes, where growth occurs, is protected by silicone gasket material, allowing for both the silicone and neoprene to stretch as the animal grows.

Tag types deployed in 2017

We deploted the following three satellite tag models in 2017:

1. Wildlife Computers data-logging SPLASH tags with Argos transmitter, pressure sensor, and ambient temperature sensor.
2. Wildlife Computers Smart Position and Temperature (SPOT) tags with Argos transmitter and ambient temperature sensor.
3. Lotek Sirtrack Kiwisat K2G273 with Argos transmitter

Under NMFS research permit conditions, VAQF could deploy SPLASH tags on turtles that weighed 11 kg or more, and SPOT or Kiwisat K2G273 tags could be deployed on turtles weighing between 8 and 9 kg. Under USFWS' 5 percent drag rule, which was implemented in the spring of 2016 for stranded turtles, none of these tags could be deployed on Kemp's ridley, green, or loggerhead turtles less than 61 cm SCL-NT without a special application and review based on a tag drag tech memo by Jones et al. (2011).

All satellite tags were programed to collect continuous location and sensor data. SPLASH tags were programed to record the percentages of time over 6-hour (hr) periods that turtles spent within defined ambient water temperature and depth intervals. The temperature intervals were defined by every 2 degrees Celsius (°C) from 8°C to 32°C, and >32°C. The programed depth intervals (in meters [m]) were: <1, 1–2, 2–3, 3–4, 4–5, 5–10, 10–20, 20–30, 30–40, 40–50, 50–100, 100–150, 150–200; and >200. SPOT tags have ambient water temperature sensors and were programed to record the percentages of time over 6-hr periods that turtles spent in 2°C temperature intervals from 12 to 32°C. Sirtrack tags were used as location only tags, and we did not utilize sensors.

2.2 Tagging Results

The spring weather in 2017 was unusually warm, and researchers sighted few slow-moving turtles on dip-net capture trips. Researchers caught one large Kemp's ridley on 16 May, but it was suffering from a chronic boat-strike injury and was not a suitable tag candidate. The first hooked turtle report occurred on 26 April 2017, and the first two were recovered on 28 April. One was a large juvenile Kemp's ridley (SCL-NT=43.3; 10.75kg) and the other was a smaller Kemp's ridley (SCL-NT=38.3; 7.55kg) both were hooked by a recreational anglers at the Buckroe Beach fishing pier. Four Kemp's ridley turtles were hooked and recovered in April and an additional fifteen turtles (11 Kemp's ridley, 1 loggerhead and 3 unidentified) were hooked in May. Of the 30 hooked Kemp's ridley turtles recovered in 2017, 21 received either a satellite or acoustic tag (**Table 1**). We also released one cold-stunned green turtle with an acoustic tag in May of 2017.

Table 1: Kemp's ridley and green turtles tagged in 2017.

Field Number	Tag Type	Release Date	Species	SCL-NT (cm)	Weight (kg)	Source
VAQS20162242	VEMCO	10 Jul 2017	Cm	35.7	6.06	Stranded/cold stun
VAQS20172014	VEMCO	5 May 2017	Lk	43.3	10.75	Stranded/hooked
VAQS20172015	VEMCO	5 May 2017	Lk	38.3	16.60	Stranded/hooked
VAQS20172021	SPLASH	6 May 2017	Lk	44.1	11.90	Stranded/hooked
VAQS20172029	Sirtrack	19 May 2017	Lk	42.4	9.25	Stranded/hooked
VAQS20172030	SPOT	20 May 2017	Lk	39.3	8.05	Stranded/hooked
VAQS20172036	Sirtrack	20 May 2017	Lk	40.8	8.05	Stranded/hooked
VAQS20172040	SPLASH	20 May 2017	Lk	45.7	12.00	Stranded/hooked
VAQS20172043	SPOT	1 Jun 2017	Lk	30.1	3.17	Stranded/hooked
VAQS20172050	VEMCO	26 May 2017	Lk	25.9	2.25	Stranded/hooked
VAQS20172061	Sirtrack	17 Jun 2017	Lk	32.1	4.37	Stranded/hooked
VAQS20172065	Sirtrack	8 Jun 2017	Lk	29.2	3.23	Stranded/hooked
VAQS20172080	VEMCO	22 Jun 2017	Lk	27.8	2.67	Stranded/hooked
VAQS20172084	VEMCO	22 Jun 2017	Lk	24.5	2.20	Stranded/hooked
VAQS20172114	VEMCO	10 Jul 2017	Lk	23.5	1.80	Stranded/hooked
VAQS20172116	VEMCO	10 Jul 2017	Lk	26.0	2.63	Stranded/hooked
VAQS20172119	SPOT	11 Jul 2017	Lk	28.9	3.36	Stranded/hooked
VAQS20172145	SPOT	10 Aug 2017	Lk	29.8	3.09	Stranded/hooked
VAQS20172168	VEMCO	10 Jul 2017	Lk	21.0	1.40	Stranded/hooked
VAQS20172179	VEMCO	23 Sep 2017	Lk	28.5	3.10	Stranded/hooked
VAQS20172180	VEMCO	23 Sep 2017	Lk	30.9	3.56	Stranded/hooked
VAQS20172181	VEMCO	23 Sep 2017	Lk	25.4	2.32	Stranded/hooked

Cm=*Chelonia mydas* (green turtle), Lk=*Lepidochelys kempii* (Kemp's ridley turtle), SCL-NT=straight carapace length-notch to tip, cm=centimeters, kg=kilograms

2.2.1 Acoustic Telemetry Results

For the first time since this project began in 2013, all turtles released with acoustic tags were detected within the calendar year (**Table 2**). All but two were detected on the Navy's acoustic receiver array (Hager 2017). Additional receivers were added in the ocean in 2017 and one turtle each were detected in the Sandbridge Burrow Area (VAQS20172179) and Submarine Cable Line (VAQS20172180), both on Nov 10 and the latter on Nov 11 as well (**Figure 1**). Five turtles were detected on receivers in the Chesapeake Bay watershed by other research groups, including the one green turtle tagged in 2017, which was not detected on the Navy array, but was detected on receivers deployed by the Virginia Institute of Marine Science in the Lynnhaven River watershed and by receivers in the mouth of the James River deployed by Virginia Commonwealth University (**Figure 2**).

The numbers of acoustic tag detections per turtle in 2017 were highly variable, ranging from 1 to 225 with a mean of 63 (standard deviation [SD]=64). The minimum tag duration (days from release to last detection) for Kemp's ridley turtles was lower in 2017 compared to 2015 (no acoustic tags were deployed in 2016). Differences among years (excluding 2013 when only one tag was deployed on a Kemp's ridley) were not significant except for a difference in duration between 2014 and 2015 (**Table 3**) when researchers switched from using epoxy attachments to wire and epoxy attachments. The lower duration in 2017 compared to 2015 may be due in part to the number of small turtles (<25 cm SCL-NT) that were tagged in 2017. Smaller turtles have narrower marginal scutes, and, thus, less space between the holes drilled to attach the tag and the edge of the scute, making the possibility and timing of wire migration more likely.

2.2.2 Satellite Telemetry Results

One of the ten satellite transmitters deployed on hooked Kemp's ridley turtles in 2017 failed to transmit (**Table 1**). This Sirtrack™ K2G272, purchased in 2016, most likely had a discharged battery resulting from failure to properly place the tag in stand-by mode between 2016 and 2017. The other nine tags transmitted from 21 to 122 days for a mean of 59 days (SD=40). The small Sirtrack™ K2G172 tags transmitted for similar durations (n=3; range=30–122; median=39; mean=63.5; SD=50.7) as the Wildlife Computer SPOT tags (n=6; range=10–119; median=36; mean=43.3; SD=38.9) even though they weigh almost 6 grams less with a similar frontal area compared to the smallest Wildlife Computer SPOT6 tags.

Kemp's ridley turtles tagged in 2017 moved from release areas along the Virginia Beach oceanfront to river mouths, inland bays, and flats in the mainstem Chesapeake Bay—spending the duration of the tag life in restricted areas (**Figure 3**). This pattern was similar to what has been observed in previous years. This season is the first time a tagged Kemp's ridley turtle spent substantial time in the York River. VAQS20172030, a 30.9-cm SCL-NT Kemp's ridley turtle released on 20 May 2017, moved into Chesapeake Bay from its release site at Virginia Beach and was at the mouth of the York River, approximately 60 kilometers (km) from the release site, on 22 May. From late May until the tag stopped transmitting on July 19, the turtle remained in the York River, moving as far inland as the junction of the Mattaponi and Pamunkey rivers (approximately 50 km) in mid-June. The York River is the only river where researchers on this project have seen at least one of each species tagged—loggerhead, green, and Kemp's ridley—make extensive use of waters inland of a river mouth.

Table 2: Detections of acoustic transmitter tags from May to November 2017

Field Number	Tag ID	Species	Release Date	Detections	Days	Receivers	Duration
VAQS20162242	A69-1601-49830	Cm	7/10/2017	86	5	4	21
VAQS20172014	A69-9001-15501	Lk	5/5/2017	19	2	4	8
VAQS20172015	A69-9001-15503	Lk	5/5/2017	17	1	3	8
VAQS20172050	A69-1601-49832	Lk	5/26/2017	85	5	13	118
VAQS20172080	A69-1601-49835	Lk	6/22/2017	3	1	2	1
VAQS20172084	A69-1601-49836	Lk	6/22/2017	225	23	5	57
VAQS20172114	A69-1601-49831	Lk	7/10/2017	8	2	4	3
VAQS20172116	A69-1601-49834	Lk	7/10/2017	42	4	5	1
VAQS20172168	A69-1601-49837	Lk	7/10/2017	6	1	1	66
VAQS20172179	A69-1601-49838	Lk	9/23/2017	68	4	7	38
VAQS20172180	A69-1601-49829	Lk	9/23/2017	177	4	4	39
VAQS20172181	A69-1601-49833	Lk	9/23/2017	124	5	6	14

'Detections'=total number of detections on all receivers; 'Days'=number of different days detections occurred; 'Receivers'=number of different receivers from all arrays on which a turtle was detected; 'Duration'=number of days from release to last detection. Detection data, from non-Navy receivers were provided Matt Balazik working with Virginia Commonwealth University at the mouth of the James River, Pat Geer working on the Lynnhaven River watershed with the Virginia Institute of Marine Science; Robert Aguilar with the Smithsonian Ecological Research group working near Tangier Island.

Table 3: Comparisons of acoustic detection data for Kemp's ridley turtles among years.

Year	Number tagged	Number detected	Percent detected	Detections				Different Days				Duration (days)			
				Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
2013	1	1	100%	15	15	NA	NA	1	1	NA	NA	5	5	NA	NA
2014	15	11	73%	1	266	67	102	1	10	3	3	3	76	23	24
2015*	14	11	79%	1	280	76	91	1	157	5	4	2	222	73	69
2017	11	11	100%	3	225	70	76	1	23	5	6	1	118	32	37

'Detections'=total number of detections on all receivers; 'Different days'=the number of days on which detections occurred; 'Duration'=number of days from release to last detection]. (*one anomalous turtle in 2015 was eliminated from the analysis).

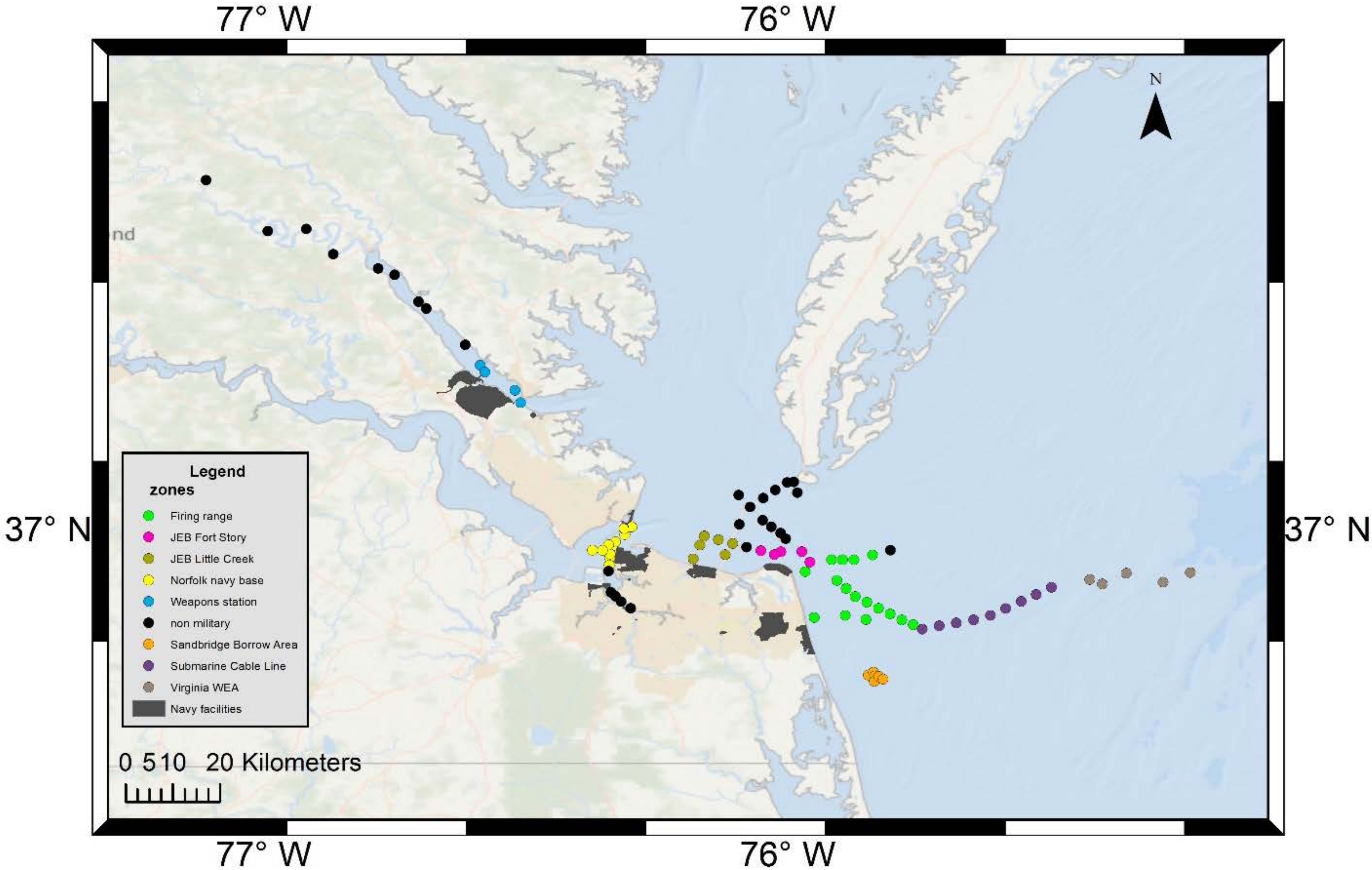

Figure 1: Locations of active Navy acoustic receivers in 2017 color coded by zone.

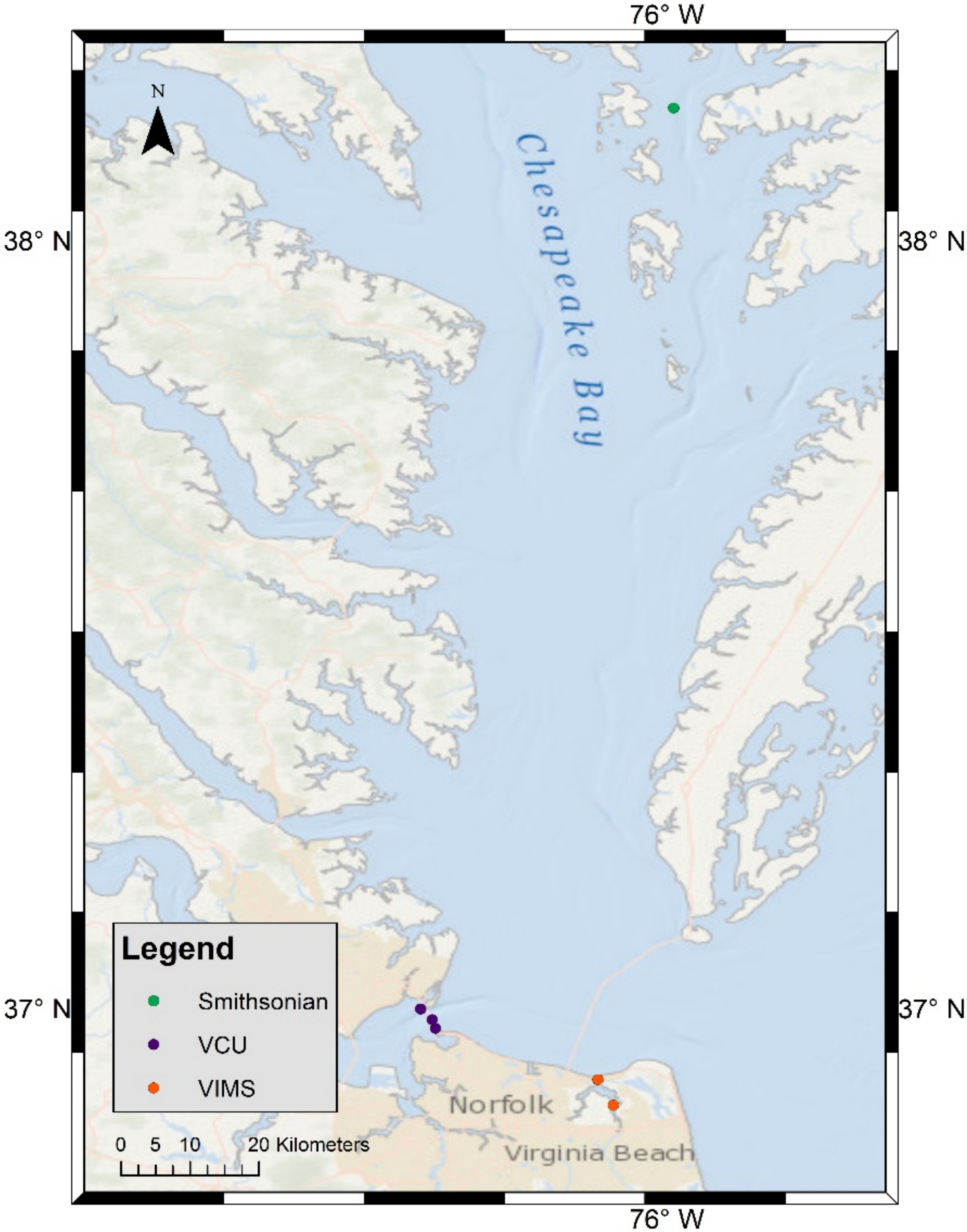

Figure 2: Locations of non-Navy receivers that detected project turtles in 2017 (VCU=Virginia Commonwealth University, VIMS=Virginia Institute of Marine Science).

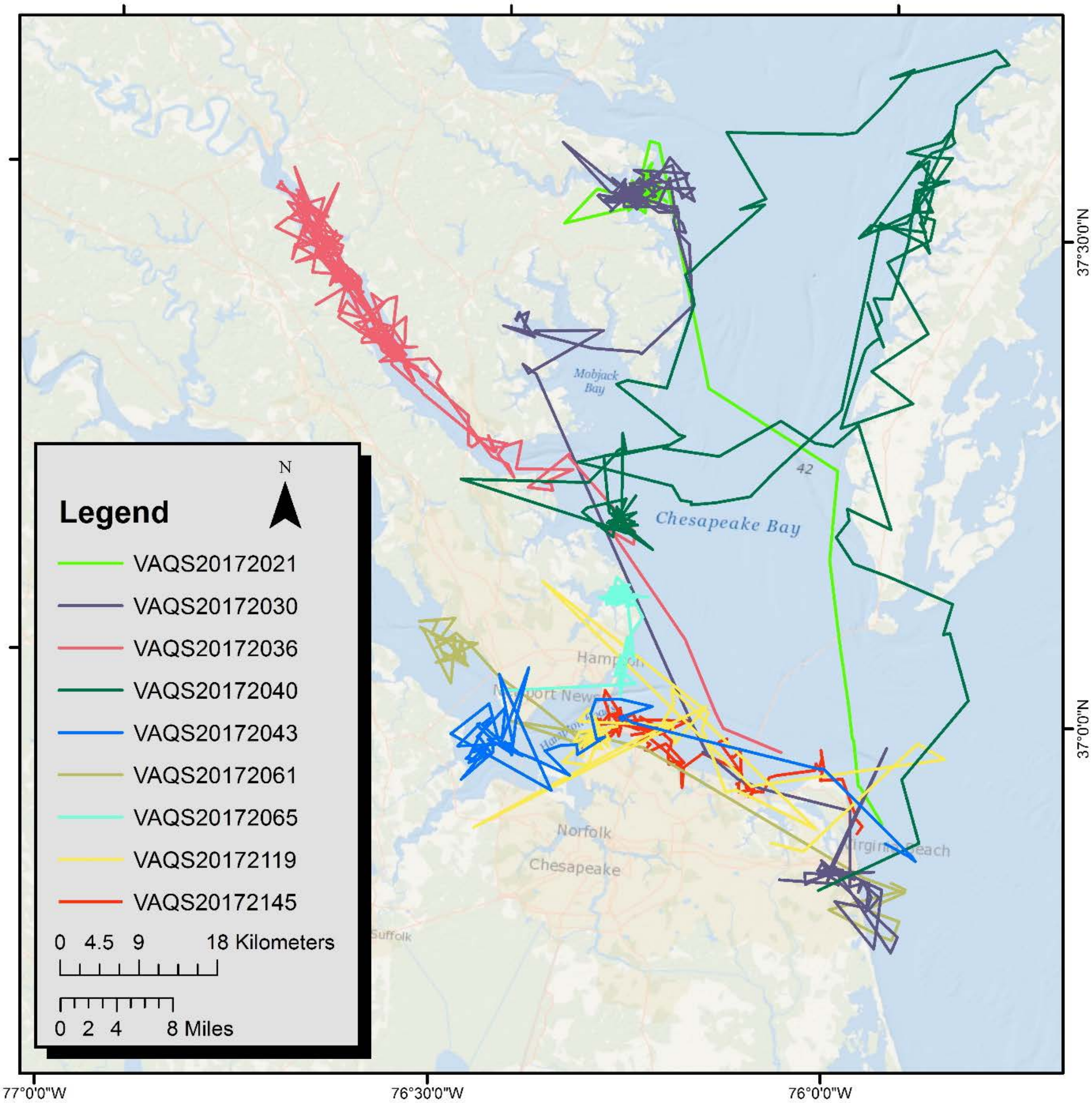

Figure 3: Tracks created from filtered ARGOS data for nine Kemp's ridley turtles tagged in 2017.

3. Kemp's Ridley Preliminary Satellite-Tag Analysis

One of the goals of satellite tagging Kemp's ridley turtles is to replicate analyses done with data from loggerhead turtles (Barco and Lockhart 2016).

3.1 Methods

Switching State-space models (SSM) for marine turtles (Jonsen et al. 2007) can provide inference on animal behavior and movement and reduce spatial autocorrelation by smoothing animal tracks into even time steps. These models explicitly account for location error in Argos tracking data and estimate animal behavior (area restricted search versus traveling) by parameterizing speed and turning angles in the smoothed track via a Monte Carlo Markov chain. The BSAM R package (Jonsen et al 2005; Jonsen 2016) also includes the ability to hierarchically model animal movement, jointly modeling parameters for all tracks. This allows for shorter tracks that may have been difficult to model individually to draw inference from longer tags. This assumes that individual animals have similar movement patterns which, for Kemp's ridley turtles in the Chesapeake Bay, appears to be reasonable. Juvenile Kemp's ridley turtles are small, fast growing, and may engage in foraging behavior that brings tags into contact with natural and man-made features in their environment that can dislodge tags. All this contributes to shorter tag retention times compared to other species in this region. As such, the possibility of hierarchical modeling is appealing.

Data from a combination of satellite tags deployed between 2001 and 2017 manufactured by Microwave Telemetry™ (*n*=2), Sirtrack™ models K2G 172 (*n*=3) and K2G 273 (*n*=1), and Wildlife Computers™ models SPLASH-10 (*n*=5), SPLASH 100 (*n*=3), SPLASH-284A (*n*=1), SPOT 331B (*n*=1), SPOT 5 (*n*=2) and SPOT 6 (*n*=4) were used in this analysis (**Table 4**). The SPLASH transmitters have pressure sensors and transmitted dive profiles through the ARGOS system. All satellite transmitters were programed to collect continuous location and sensor data (e.g. no duty cycle).

Tag data were published via the seaturtle.org Satellite Tracking and Analysis Tool (Project IDs 222 and 866) and on the Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations (Datasets 978 and 410). A Movebank study was also created to manage and filter location data with a live-feed set-up that automatically decoded and stored all ARGOS locations. Historic transmitter data were manually imported into the Movebank study to be used with data collected from the live feeds. Unrealistic locations were identified with the Douglas ARGOS Filter Algorithm (in Movebank version 8.50) using the parameters suggested by the Turtle Expert Working Group (Douglas et al. 2012, Turtle Expert Working Group 2009). All locations that passed filtering were loaded into an ArcGIS™ 10.4 (ESRI, etc.) workspace. Locations reported during the first 24 hours post-release were removed assuming they were not indicative of the animal's natural behavior.

For the Kemp's ridley turtle SSM effort, 2 of the 22 tags that transmitted were dropped from the analysis as there were too few transmissions to expect interpretable results, even with hierarchical modeling. The track for one tag, which ceased transmission for longer than a week and then resumed, was split into two separate deployments for the purpose of analysis. Thus, the final dataset for SSM analysis contained 21 deployments from 20 individual turtles and 8,217 locations (**Figure 4**). All deployments had over 100 reported locations after all filters were applied. The average time between reported locations was approximately 3 hours. As such, no models that smoothed data into time steps smaller than 3 hours were attempted in order to avoid over-interpolation between points.

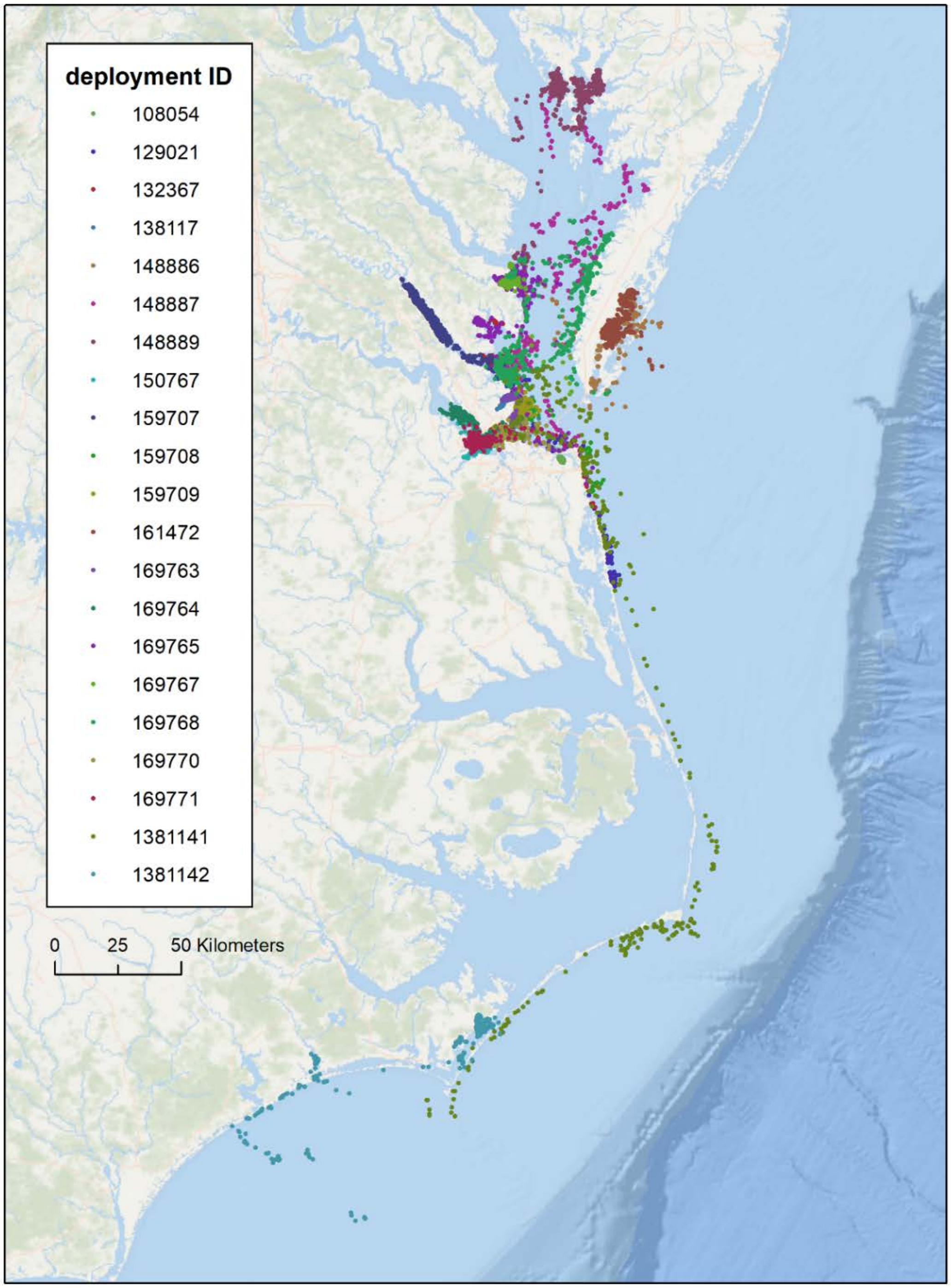

Figure 4: Filtered ARGOS locations used in the Kemp's ridley turtle SSM analysis.

3.2 Preliminary Results

Five tags were randomly chosen for SSM testing. The test models varied time step, model span parameter (which controls the degree of LOESS smoothing used to obtain initial location states) number of adaption runs, and whether tags were modeled hierarchically or individually. After reviewing test model parameters for convergence and visually inspecting outputs, a hierarchical model with a 12-hour time step and span parameter of 0.1 appeared to perform the best. This model was then rerun with all 21 deployments combined (**Figures 5 and 6**). The 12-hour time step limited interpolation but still provided fine-scale movement information. SSM output values less than 1.25 were considered traveling. Values greater than 1.75 were considered area-restricted search (likely foraging). Values between 1.25 and 1.75 were indeterminate, most likely slower travel between or within foraging patches (compared to quick, directed travel).

Table 4: Satellite telemetry data for Kemp's ridley turtles that were considered for use in analyses. This table does not include tags that did not transmit (*n*=2).

Field Number	Tag ID	Deployment Date	Last Transmission	Days*	Source	Tag manufacturer
VAQS20112010	108054	30-Jun-11	15-Jul-11	14.8	stranded	Wildlife Computers
VAQS20122175	129021	22-Jun-13	13-Jul-13	21.1	stranded	Wildlife Computers
VAQS20132229	132367	10-Jul-14	15-Aug-14	35.9	stranded	Wildlife Computers
VAQS20142152	138117	3-Sep-14	10-Oct-14	37.1	stranded	Wildlife Computers
VAQS20132227	138114	21-Oct-14	06-Jun-15	227.7	stranded	Wildlife Computers
VAQR201502	148887	16-May-15	24-Jun-15	39.3	dip net	Wildlife Computers
VAQS20142244	148889	17-May-15	14-Jul-15	58.2	stranded	Wildlife Computers
VAQS20152008	148881	17-May-15	23-Jun-15	37.1	stranded	Microwave Telemetry
VAQR201503	148882	19-May-15	30-May-15	11.1	dip net	Microwave Telemetry
VAQR201505	148886	30-May-15	12-Jul-15	43.1	dip net	Wildlife Computers
VAQS20152049	150767	25-Jun-15	05-Jul-15	9.7	stranded	Wildlife Computers
VAQS20162089	159708	3-Jul-16	05-Aug-16	33.3	stranded	Wildlife Computers
VAQS20162029	161472	23-Jul-16	31-Aug-16	38.8	stranded	Sirtrack
VAQS20162016	159709	27-Jul-16	27-Aug-16	31.3	stranded	Wildlife Computers
VAQS20172021	169767	6-May-17	02-Jul-17	57.2	stranded	Wildlife Computers
VAQS20172030	159707	20-May-17	17-Sep-17	119.4	stranded	Wildlife Computers
VAQS20172036	169765	20-May-17	19-Sep-17	121.8	stranded	Sirtrack
VAQS20172040	169768	20-May-17	03-Jul-17	44.3	stranded	Wildlife Computers
VAQS20172043	169771	1-Jun-17	21-Jun-17	20.9	stranded	Wildlife Computers
VAQS20172065	169763	8-Jun-17	08-Jul-17	30.1	stranded	Sirtrack
VAQS20172061	169764	17-Jun-17	25-Jul-17	38.6	stranded	Sirtrack
VAQS20172119	169770	11-Jul-17	17-Aug-17	36.7	stranded	Wildlife Computers

* indicates the number of days from release to last transmission

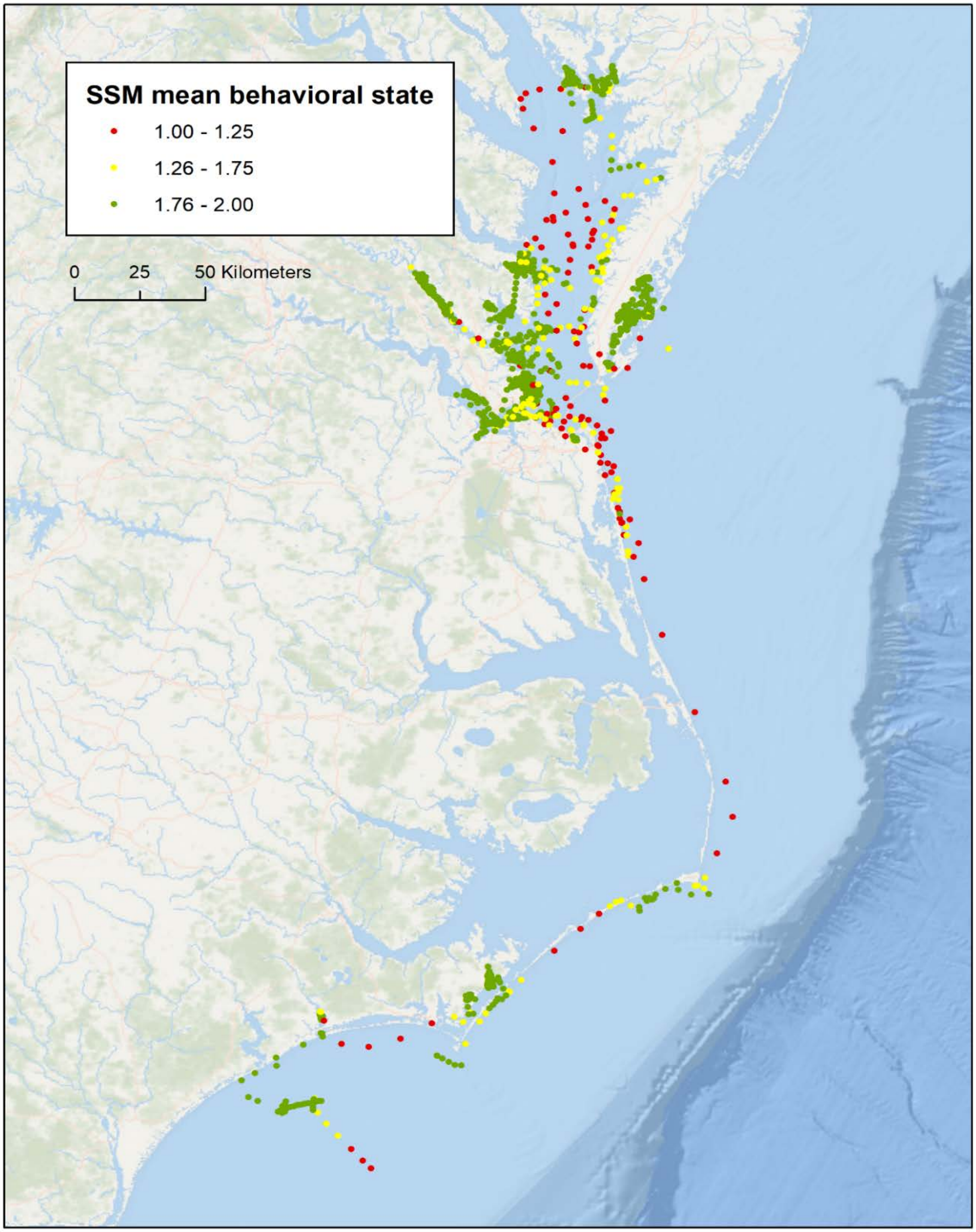

Figure 5: SMM analysis output overlaid on filtered ARGOS locations. Green points represent area-restricted search consistent with foraging and red points represent movement consistent with traveling or migration. Intermediate points in yellow could not clearly be classified as either area-restricted or travel.

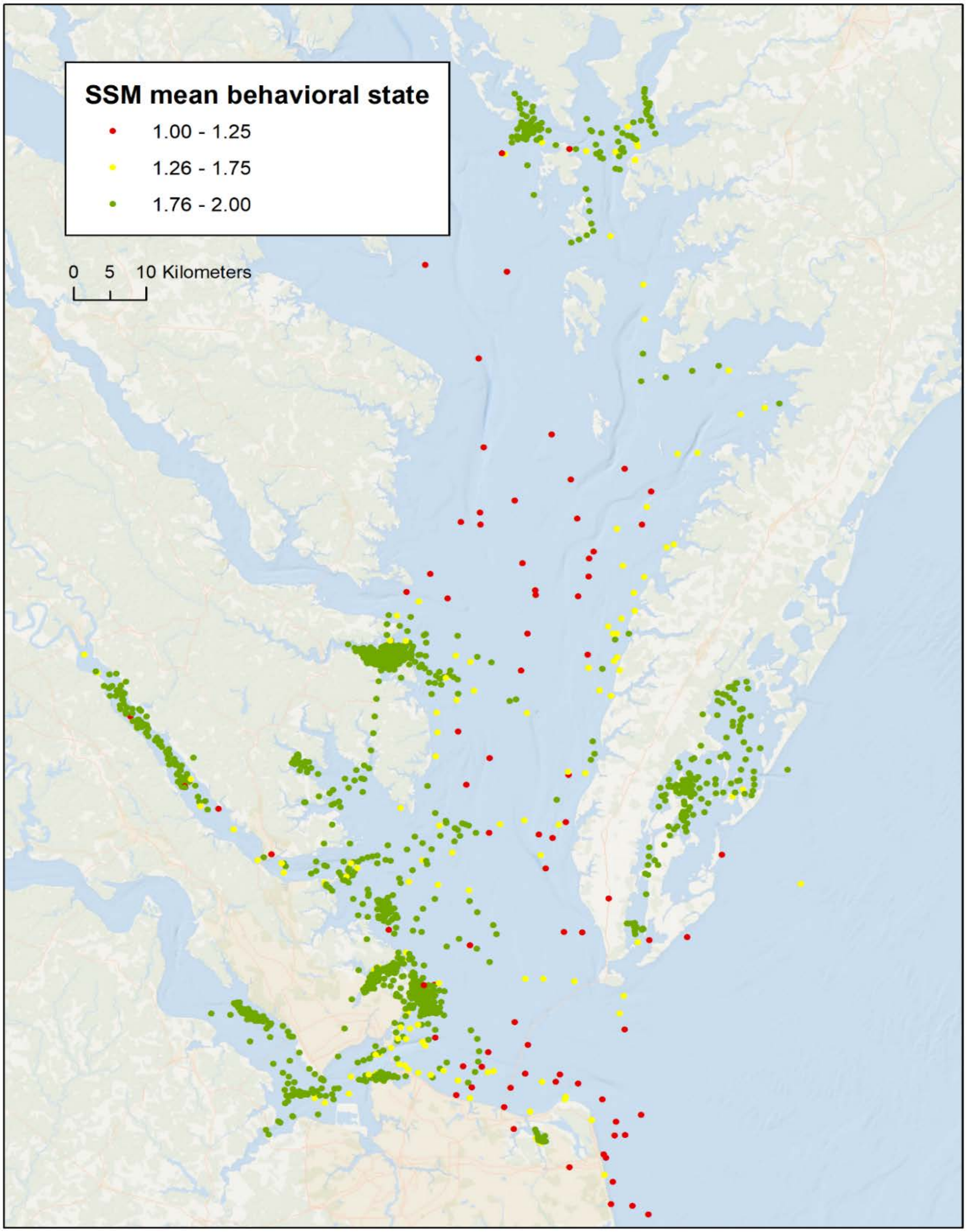

Figure 6: Close-up of Chesapeake Bay and southeast Virginia ocean coast showing SMM analysis output overlaid on filtered ARGOS locations. Green points represent area-restricted search consistent with foraging and red points represent movement, consistent with traveling or migration. Intermediate points in yellow could not clearly be classified as either area-restricted or travel.

These results are preliminary and other models with the full suite of tags will need to be run to see if changes should be made to model parameters. Model outputs still need to be inspected on a tag-by-tag basis, with possible further filtering of modeling results before these outputs are utilized for management decisions or follow-on work. Despite that, the initial output appears to yield valid inference on Kemp's ridley turtle behavior in the Chesapeake Bay and mid-Atlantic coastal ocean.

This preliminary SSM output appears to characterize Kemp's ridley turtle movements and behaviors within Chesapeake Bay and nearshore mid-Atlantic ocean waters, although few animals were tracked outside the Bay and inference there is limited. Generally, animals recruited to shallow inlets and restricted estuarine environments, presumably to forage on their preferred prey, blue crabs, while undertaking short bouts of directed travel between foraging areas. One animal, 138114, traveled south along the Outer Banks, stopping for several presumed foraging bouts along the way (see **Figure 5**). This animal was likely migrating south toward over-wintering areas.

While preliminary, this analysis is a promising first step towards understanding Kemp's ridley turtle foraging habitats in the Chesapeake Bay (and limited inference beyond). The finalized outputs to follow will be valuable inputs into foraging home range, habitat use, and species ensemble models.

4. Sensitivity Analysis on Loggerhead Data

A persistent problem in spatial ecology is how many satellite tags must be deployed to gain meaningful inference on the behavior and movement of a population. The required sample size is influenced by factors such as the size of the population, individual variation in behavior, and the landscape traveled.

No abundance estimate for the Kemp's ridley turtle exists for Chesapeake Bay, and individuals tagged to date have shown selection of different foraging locations within the bay. The intent of conducting a sensitivity analysis is to inform sample sizes required to allow reliable inference. This will be addressed using two methods: 1) using a large existing tagging dataset for loggerheads (51 deployments) and examining how utilization distributions (UDs) change when tags are removed from the analysis and 2) using correlated random walk models to simulate additional tags and examine other areas turtles may utilize that have not been visited by turtles with extant tags..

Method 1 will be addressed using gridded loggerhead foraging UDs to facilitate comparison of UD outputs as tags are removed from the analysis. Gridded UDs are conceptually easy to interpret, can be exactly overlaid, and are regular in shape allowing for the easy generation of comparison statistics. An iteration of this analysis will also be performed truncating the loggerhead tag data to the transmission times of the Kemp's ridley turtle tags.

Method 1 assumes that foraging habitats are comparable between Kemp's ridley and loggerhead turtles. This may not, however, be the case. Based on existing tag data, loggerhead turtles prefer to forage in the open waters of the mainstem Chesapeake Bay and in ocean waters over the continental shelf off the eastern U.S. Kemp's ridley turtles prefer small inlets, embayments, and flats close to shore in the mainstem Chesapeake Bay. Another assumption is that we have tagged enough loggerhead turtles to have sampled that population effectively. Because of these concerns, caution will be taken when interpreting the results. Method 2 will be undertaken for both loggerhead and Kemp's ridley turtles, time allowing. An important metric will be how uncertainty increases in the model outputs as the number of tags is reduced.

To date, most of the work on this task has focused on developing the code base for Method 1. However, some important precursor products have been produced. After exploration of an appropriate cell size for the analysis, gridded UDs for all 51 loggerhead turtle deployments were produced and combined, and summary statistics calculated. This will provide the baseline for comparison as tags are dropped iteratively from the analysis in a bootstrap-like process.

A cell size of 10 km was chosen, as it aggregated the available data well and was able to capture variation with the Chesapeake Bay. Smaller cell sizes did not have enough variation in the number of locations within cells to produce meaningful UDs, and larger cells did not characterize the bay very well. The 10-km grid cells also made area calculations easy to manage. The UD analysis proved to be sensitive to the initial placement of grid cells, but because these UDs are not being used for management purposes this issue will be ignored.

Figure 7 shows the combined 90 percent UD for all 51 loggerhead turtle deployments (restricted to Chesapeake Bay and mid-Atlantic ocean shelf waters). The 90% UD comprises 90 percent of all locations (in this case loggerhead foraging SSM locations). 90% is a common cutoff to exclude outlier locations and represent the animal's 'normal' range. The 50% UD is considered core area for an animal (Table 5). A large percentage of the cells in the 90% UD were identified as foraging by only a single individual. This indicates high variation in individual behavior and suggests that this population may not have been sampled as well as previously thought. **Table 5** shows summary statistics for this analysis that will provide the baseline for future comparisons.

Table 5: Example summary statistics for combined gridded UDs that will serve as the basis for comparison in the sensitivity analysis. The first row is for the raster presented in Figure 5.

UD	Total Area* (cell count)	Number of Clusters (contiguous cells)	Mean Cluster Area	Standard Deviation of Cluster Area	Count of Cells Identified by a Single PTT	Proportion of all Cells Identified by a Single PTT
90	382	13	29.38	65.72	197	0.52
50	140	39	3.59	4.90	111	0.79

[*each cell = 100 km^2; mean cluster area and standard deviation are expressed in # of 100 km^2 cells]]

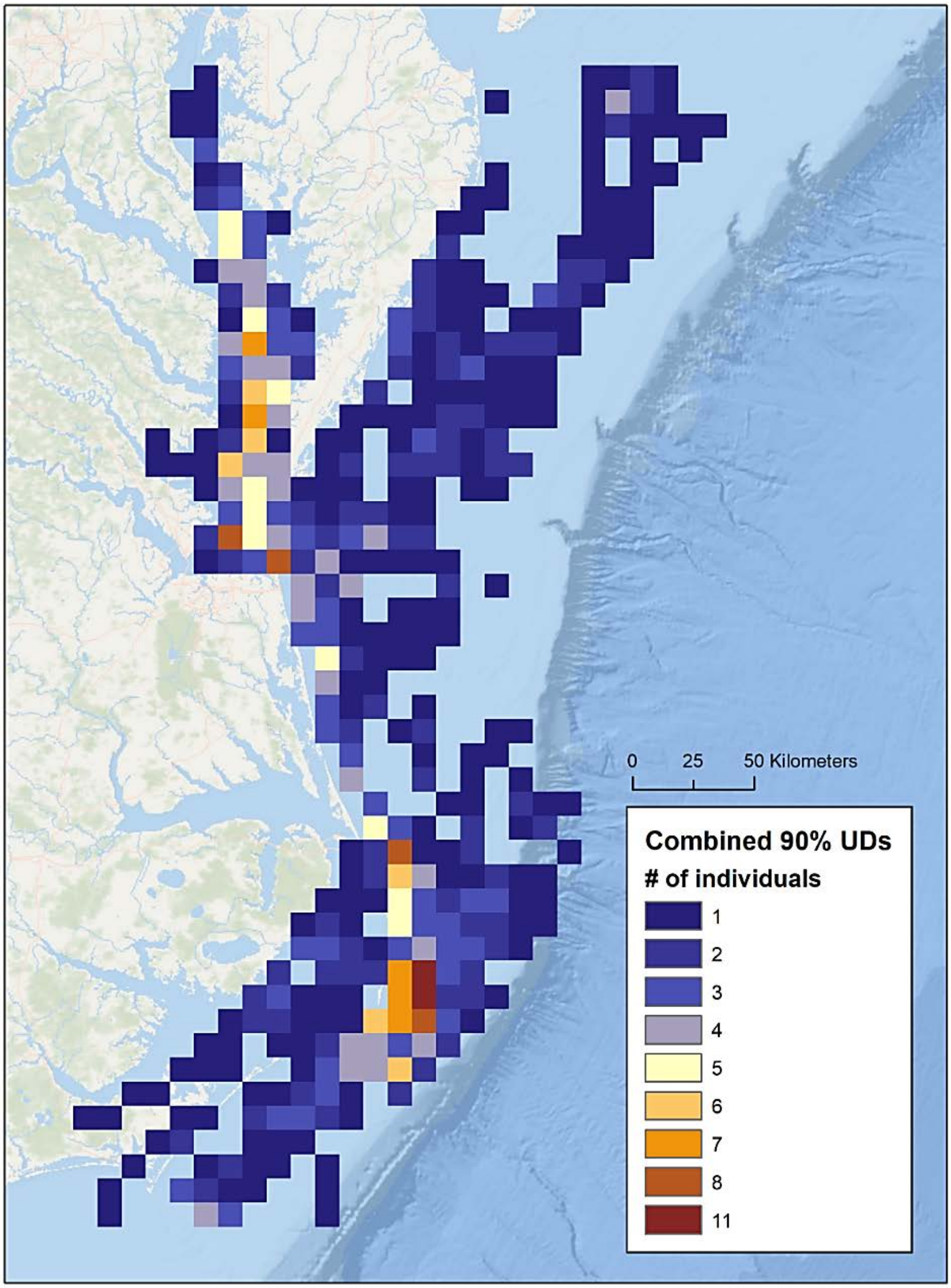

Figure 7: Combined gridded utilization distributions for 51 loggerhead turtle deployments, categorized by the number of turtles with 90% UDs within each grid cell.

5. Summary and Future Work

The satellite and acoustic telemetry data collected for Kemp's ridley and green turtles for this on-going project are beginning to provide important information on the locations of Kemp's ridley turtles in relation to military facilities and training areas. Continued data collection is needed for both turtle species. In 2018, we will continue to deploy satellite and acoustic tags, as well as to refine analyses and further evaluate the amount of data needed to better understand sea turtle behavior and movement in Chesapeake Bay and the greater mid-Atlantic region.

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