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Surface Availability Metrics of Leatherback Turtles (*Dermochelys coriacea*) Tagged off North Carolina and Massachusetts, United States

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Surface Availability Metrics of Leatherback Turtles (*Dermochelys coriacea*) Tagged off North Carolina and Massachusetts, United States

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INTRODUCTION

Understanding the physical and biological characteristics associated with protected species occurrence and distribution is critical for the proper management of the protected species, especially as it faces increasing natural and anthropogenic impacts. The Atlantic Marine Assessment Program for Protected Species (AMAPPS) is a comprehensive, multi-agency research program with overarching goals to 1) assess the abundance, distribution, ecology, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic shelf region, and 2) evaluate these data within an ecosystem context where the results are accessible to managers, scientists, and the public.

The AMAPPS Turtle Ecology program is midway through a 5-year program designed to collect and analyze leatherback sea turtle (*Dermochelys coriacea*) behavioral data. To address immediate needs of U.S. federal agencies for data on leatherback surfacing information, we are providing simple summary statistics from our partially completed project. Because of the imminent need for data in the midst of an ongoing project, we followed the procedural and methodological precedent set in NEFSC (2011). The AMAPPS III Turtle Ecology study plan includes more data collection and more sophisticated data analysis, so this current document is offered as a preliminary product to take advantage of existing data while we continue to pursue the longer term AMAPPS III data collection and analysis goals.

METHODS

Between 2017 and 2019, leatherback turtles (*Dermochelys coriacea*) were caught off the coasts of Massachusetts and North Carolina using a 2-m breakaway hoop net as described in Sasso et al. (2021). Upon a successful capture, turtles were equipped with satellite-linked transmitters (Wildlife Computers MK-10AF) via a tether attached to the caudal peduncle (NMFS SEFSC 2008). In addition to reporting location, these transmitters were programmed to record depth metrics, such as time at depth (TAD), within 6-hour bins. TAD refers to the proportion of time a turtle spent within specific depth bins. For this study, we defined the first 2 depth bins as “TAD2,” which together represent the proportion of time spent in water shallower than 2 m, including time when the sensor was dry at the surface. Thus, 1 observation was defined as the proportion of time an individual spent within the first 2 m of a water column during a 6-hour period.

We removed data that were not relevant to understanding leatherback surfacing behavior in the daytime along the Eastern Coast of the United States and Canada. Advanced Research and Global Observation Satellite (ARGOS) location data were filtered to include only location classes of 1, 2, and 3 (the most accurate). These locations were then plotted in ArcGIS (ESRI, Redlands, CA) and filtered to remove any locations on land or within 1 mile of the shoreline. We filtered data to exclude instances in which a tag prematurely detached from the turtle. Because we used positively buoyant towable tags, when a tag detaches prematurely from a turtle, the tag floats to the surface, causing the TAD2 to equal 100 and the time deeper than 2 m to be 0. We determined premature detachment when the total time at depth deeper than 2 m equaled and stayed equal to 0 for the remainder of the deployment period. In those instances, we kept all data leading up to the tag detachment. The first 24 hours of each deployment were also excluded from analyses to reduce any potential bias in dive data that resulted from the tagging procedure. To filter for diurnal data, we used time bins starting at 8:00 and 14:00 eastern time. We used this filtered dataset for all of the data we present here.

We summed the total TAD2 within the first 2 m for each observation and then recorded the mean and median TAD2 across all individuals per month. In addition to calculating the mean and median, we also recorded the standard deviation, first and third quartiles (consistent with NEFSC [2011]), number of individuals, and number of observations. The mean TAD2 was also calculated for each individual per month.

RESULTS

A total of 29 turtles were tagged, with 11 tags deployed in Massachusetts and 18 in North Carolina (Table 1). Along the East Coast of the United States and Canada, turtles moved as far south as Florida and as far north as Nova Scotia with concentrated movements between North Carolina and Massachusetts (Figure 1). Some turtles moved far off the North American continental shelf as far east as the central Northwest Atlantic Ocean and as far south as Panama (Figure 1). Mean TAD2 appeared to increase from December through May and then decrease from June through November (Table 2). It should be noted that the standard deviation for each month is quite large indicating a high amount of variability in TAD2 across all dives. Median TAD2 demonstrated the same pattern as the mean. However, the median values were much lower for most months (especially October through January) except for months with the highest TAD2 (i.e., February, March, and May).

There was high variability in monthly mean TAD2 across all individuals (Table 3). For most leatherbacks, there was a monthly mean TAD2 of 0 for either the entire deployment or after 1-3 months of mean TAD2 greater than 0.

DISCUSSION

Several issues should be considered before using these data to account for availability bias in the analysis of line transect data to produce density and abundance estimates. First and foremost, there is uncertainty about determining what the best metrics are for summarizing percent surface time and variability. In this study, we presented various summary statistics so that end users can choose the metric that best meets their need. We included both mean and standard deviation, as well as median and quartiles, as estimates for surface availability. Even though the mean and median demonstrated a similar trend across the year, the differences between both metrics were inconsistent, indicating variability in the distribution of TAD2 across all months. The values for the standard deviation were large in comparison to the mean, which could be due to the small sample size. If the variability associated with repeated measures is a concern, interquartile values can be used to assess variability, as was done in NEFSC (2011). Alternatively, end users could calculate average TAD2 from the monthly averages per turtle (Table 3). We provided the monthly mean TAD2 and associated number of observations (Table 4) for each individual turtle so that end users could evaluate and decide how they want to handle zero estimates and sample size issues.

The value of 0 for the median and first quartile TAD2 estimates are also noteworthy. In the winter, at least a quarter of all the observations had 0 values for TAD2. Some tags reported only 0 values for entire months. A strict interpretation of the data would indicate that a 0 value for TAD2 means the tag spent no time within the top 2 m of the water column during that 6-hour interval period. Because of the preliminary nature of this analysis and the significant uncertainties associated with the data, we do not recommend making a strict interpretation of the data. We will explore this issue in more detail in future analysis.

Depth sensors on the satellite-linked transmitters can also introduce uncertainty as the tags used in this study are programmed to withstand much deeper dives, which ultimately results in less accurate readings at and near the surface. Wildlife Computers reports a depth sensor range of 0-2000 m, resolution of 0.5 m, and accuracy of ± 1% of the reading for the SPLASH10-F-323. In field validation experiments, comparing depth estimates from a previous generation Wildlife Computer tag (MK9) and a calibrated Sea-Bird SBE39 time/temperature/ depth probe, the average error reported for the Mk9 was 4.3 m across a 500 m water column profile (Robinson et al 2009; Hill 2006). At some (deeper) depths the MK9 estimates were significantly deeper than the Sea-Bird probe.

Caution should be exercised if using these data summaries as availability corrections to line transect survey analysis. The uncertainties and data caveats associated with this research could make our results unreliable as availability bias corrections. There is also uncertainty as to whether using TAD data from the top 2 m of the water column appropriately corresponds to the visibility from a plane. This is important to consider as visibility from the plane can be influenced by weather conditions, water turbidity, and bathymetry. In cases where surfacing behavior varies spatially or temporally, availability bias corrections associated with line transect surveys will be more accurate if they are calculated from data collected during the same time and area as the survey. We did not use spatial strata in creating the data summaries, but future analysis will more explicitly consider spatial issues.

This study consists of preliminary analyses of a complex dataset that is still being built with additional tag deployments. Thus, in-depth quality assurance and control have not been performed yet. Future studies will be conducted that will aim to estimate surface availability while accounting for location, environmental conditions, and biological factors (i.e., size, sex, and behavioral state). Overall, both additional data collection and analyses are needed to provide more reliable and accurate estimates of leatherback surfacing behavior.

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TABLES AND FIGURES

Table 1: Descriptive data on turtles tagged in Massachusetts and North Carolina between 2017 and 2019.

ID	Sex	CCL (cm)	CCW (cm)	Capture Date	Region Tagged	Capture Latitude	Capture Longitude
MA17.01	Female and/or juvenile	149.7	113	10/13/2017	Massachusetts	41.81	-70.03
MA18.01	Female and/or juvenile	152	112	8/15/2018	Massachusetts	41.84	-70.08
MA19.01	Female and/or juvenile	140.1	120.1	8/23/2019	Massachusetts	41.86	-70.02
MA19.02	Male	152.8	111	8/23/2019	Massachusetts	41.78	-70.1
MA19.03	Male	148.2	105.6	8/24/2019	Massachusetts	41.83	-70.02
MA19.04	Female and/or juvenile	143.6	127	8/24/2019	Massachusetts	41.8	-70.69
MA19.05	Female and/or juvenile	140.6	101.6	8/27/2019	Massachusetts	41.8	-70.04
MA19.06	Female and/or juvenile	130.5	95.1	8/27/2019	Massachusetts	41.79	-70.04
MA19.07	Male	153.2	111.2	8/27/2019	Massachusetts	41.83	-70.02
MA19.08	Male	144.7	107.5	8/28/2019	Massachusetts	41.82	-70.02
MA19.09	Male	144.6	107.2	8/28/2019	Massachusetts	41.84	-70.02
NC18.01	Female and/or juvenile	165	99	5/9/2018	North Carolina	34.64	-76.56
NC18.02	Female and/or juvenile	158.8	108.2	5/10/2018	North Carolina	34.59	-76.54
NC18.03	Female and/or juvenile	141.8	106.8	5/10/2018	North Carolina	34.57	-76.54
NC18.04	Female and/or juvenile	133.2	89.1	5/14/2018	North Carolina	34.62	-76.53
NC18.05	Male	155.2	104.6	5/15/2018	North Carolina	34.61	-76.54
NC18.07	Female and/or juvenile	149.8	104.7	5/16/2018	North Carolina	34.63	-76.54
NC18.06	Male	155.4	118.7	5/16/2018	North Carolina	34.62	-76.53
NC19.02	Female and/or juvenile	140.1	104.1	5/15/2019	North Carolina	34.62	-76.57
NC19.03	Female and/or juvenile	162.8	120.8	5/15/2019	North Carolina	34.6	-76.55
NC19.04	Female and/or juvenile	168.1	119.1	5/18/2019	North Carolina	34.63	-76.54
NC19.06	Female and/or juvenile	158.8	117.7	5/18/2019	North Carolina	34.62	-76.54
NC19.08	Female and/or juvenile	126.4	90.2	5/19/2019	North Carolina	34.61	-76.56
NC19.07	Female and/or juvenile	159.4	129.7	5/19/2019	North Carolina	34.59	-76.54
NC19.09	Female and/or juvenile	139.2	104.4	5/21/2019	North Carolina	34.62	-76.54
NC19.12	Male	151.2	117.7	5/21/2019	North Carolina	34.63	-76.54
NC19.11	Female and/or juvenile	167.2	120.5	5/21/2019	North Carolina	34.64	-76.55
NC19.10	Female and/or juvenile	144.6	106.1	5/21/2019	North Carolina	34.64	-76.55
NC19.13	Female and/or juvenile	139.6	114.9	5/22/2019	North Carolina	34.64	-76.55

Table 2: Monthly summary statistics of time at depth within the first 2 meters of the surface (TAD2) for all leatherback turtles (*Dermochelys coriacea*).

Month	Mean TAD2	SD TAD2	Median TAD2	First Quartile	Third Quartile	Observations	Tags
1	21.686	29.28	0	0	52.675	28	8
2	38.035	30.508	51.5	0	60.1	17	5
3	42.593	37.645	57.7	0	69.6	30	5
4	31.209	36.534	4.55	0	70.125	34	4
5	46.805	37.226	55.3	0.3	76.4	73	12
6	29.629	22.108	24.65	11.4	47.45	114	11
7	21.481	18.506	21.4	0.3	35.325	206	14
8	14.432	14.429	11.3	0.4	22.2	197	23
9	6.563	10.777	1.7	0.2	8.25	291	23
10	9.242	19.28	0	0	9.425	238	23
11	8.54	17.351	0	0	12.425	80	15
12	17.372	26.762	0	0	36.325	50	10

Table 3. Average time at depth within the first 2 meters of the surface (TAD2) for each individual leatherback turtle (*Dermochelys coriacea*) for each month. Blank cells indicate no data.

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MA17.01										67.8	61.63	74.9
MA18.01	0	0	0					34.76	9.1	0.64	0	0
MA19.01								5.7	3.24	0.46		
MA19.02	0								2.73	0.06	0	
MA19.03	61.59	58.78	73.46	75.18	76.32				26.55	53.47	36.82	54.98
MA19.04	0	0							0.24	0	0	0
MA19.05								0.2	0.07	0	0	
MA19.06	0	0	0	0					0.38	0		0
MA19.07	0	0	0	0	0				1.93	0	0	0
MA19.08								4.9	0.48	0.01	0	0
MA19.09	30.8		51.25	20.95	88.89				13.49	15.43	19.5	
NC18.01								25	29.5	5.5		
NC18.02						45.04	42.08					
NC18.03						21.77	2.42	0.45	2.36	0		
NC18.04	22.1					41.28	49.78	38.2		37.5	22.75	28.3
NC18.05						0.52	0.06	0	0	0	0	
NC18.06					46.85	42.66	33.86	37.95	19.74	21.1		
NC18.07					14.6		24.4	30.15	26.52	6.8		
NC19.03					0.25	0						
NC19.04							0	0	0			
NC19.06							0	0	0	0	0	
NC19.07						1.6	0.1	0	0	0	0	0
NC19.08								0.2	0	0		
NC19.09					56.1	25.24	17.06	9.83	4.08	33.78		
NC19.10							10.57	4.04	0.05	0	0	
NC19.11							0.15	0.05	0			
NC19.12					72	23.36	23.42	20.66				
NC19.13							22.37	21.89	26.42	14.38	24.46	11.15

Table 4. Number of monthly observations (i.e., 6-hour time bin) for each individual leatherback turtle (*Dermochelys coriacea*).

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MA17.01										1	3	1
MA18.01	5	1	2					8	11	10	3	2
MA19.01								10	54	14		
MA19.02	1								23	10	1	
MA19.03	9	11	16	13	25				17	25	5	13
MA19.04	3	2							5	10	7	2
MA19.05								1	15	28	13	
MA19.06	1	1	4	3					5	5		4
MA19.07	7	2	6	14	15				27	24	11	7
MA19.08								5	32	33	15	11
MA19.09	1		2	4	7				11	12	5	
NC18.01								5	2	1		
NC18.02						18	29					
NC18.03						10	13	8	5	2		
NC18.04	1					14	17	4		1	2	2
NC18.05						8	29	6	7	8	1	
NC18.06					2	21	24	11	7	2		
NC18.07					1		14	18	8	2		
NC19.03					2	2						
NC19.04							5	4	1			
NC19.06							5	12	4	1	1	
NC19.07						4	6	4	7	12	4	6
NC19.08								1	1	2		
NC19.09					1	9	12	27	22	5		
NC19.10							3	7	4	13	2	
NC19.11							2	11	4			
NC19.12					4	21	31	22				
NC19.13							7	17	13	15	7	2

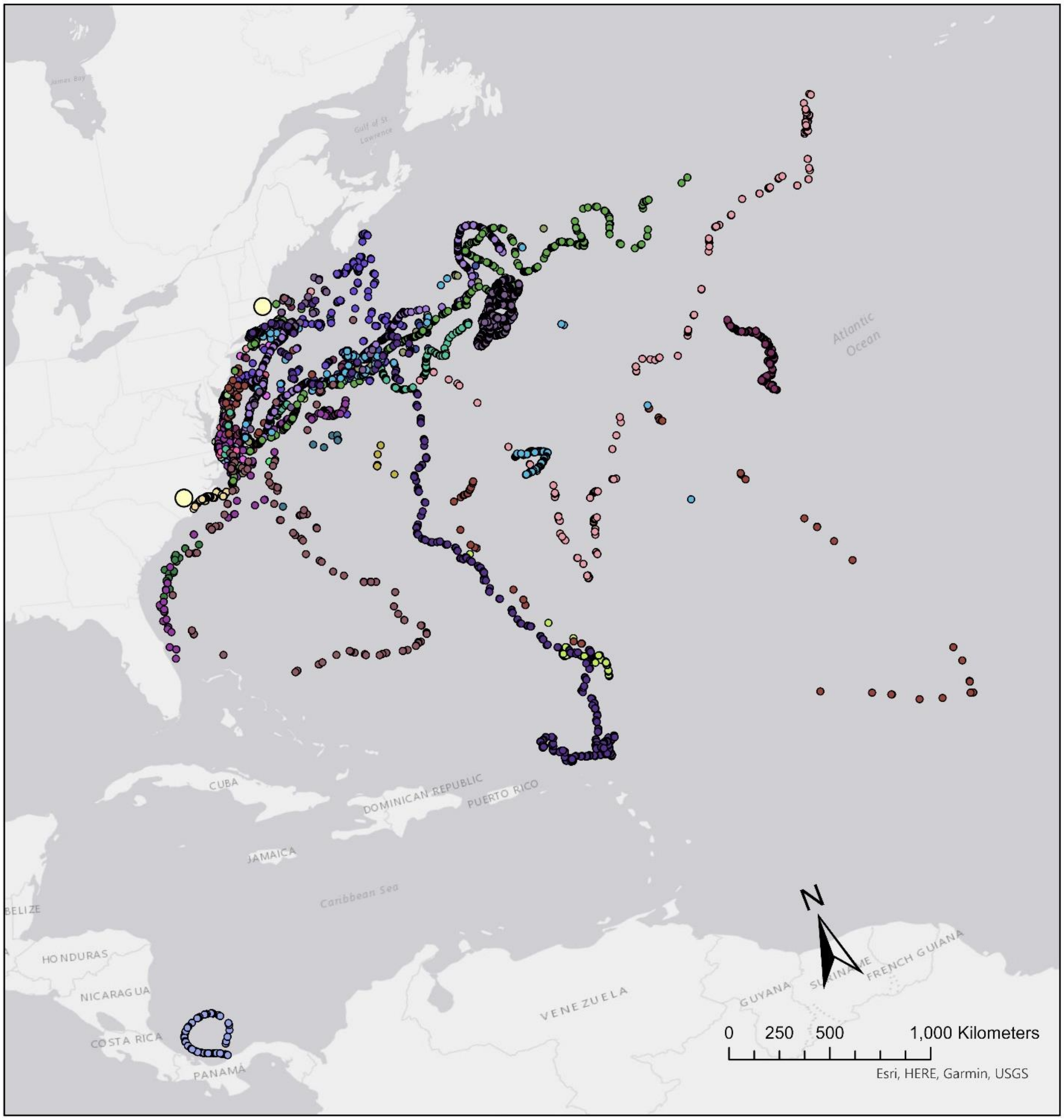

Figure 1. Leatherback turtle (*Dermochelys coriacea*) locations from 2017-2020. Each color represents a single individual. Yellow points represent the 2 locations where turtles were tagged (i.e., North Carolina and Massachusetts).

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