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 Mid-Atlantic Bight (MAB) 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 this project, CFF purchased ten 9000x Satellite Relay Data Loggers (SRDL) with Argos Fastloc GPS tags through the University of St. Andrews's Sea Mammal Research Unit (SMRU). The tags' data relayed through the Argos satellite system provide detailed surfacing locations, pressure/temperature/wet/dry sensors, and individual dive (max depth, shape, time at depth, etc.) and haul-out records which were essential for this project. (Table 1, Figure 1). These data were collected and analyzed to evaluate seasonal distribution, migrational patterns, dive profiles, and foraging sites in conjunction with satellite-derived oceanographic data to identify spatiotemporal "hot spots" on the fishing grounds. Satellite-derived chlorophyll *a* surface concentration and sea surface temperature (SST) data were also accessed via the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua-4km satellite project through NOAA's Goddard Earth Sciences Data and Information Services Center (GES DISC).

There is a high likelihood of interaction between sea turtles and fishing gear within the MAB. Learning more about loggerhead abundance and distribution in this area will inform more effective policies that are sensitive to both the turtles' ecological niche and fisheries. The analysis utilized satellite and oceanographic data to identify where, when, and how loggerhead sea turtles use this area. We also evaluated availability bias and perception bias, which can affect abundance estimates produced from transect surveys.

Tagging efforts in 2013 were shifted earlier in the year (late May) and father south to ensure detection of tagged turtles foraging in the MAB. Through a joint effort between CFF, the Northeast Fisheries Science Center (NEFSC), and the Virginia Aquarium's Marine Science Center, CFF successfully captured and tagged ten juvenile (curved carapace length, CCL, greater than 60 cm) loggerhead sea turtles. 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 were conducted aboard the F/V Kathy Ann.

Introduction

The completed work represents a decade 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. Over the duration of these past projects, this CFF/NMFS collaboration has resulted in the tagging of over eighty loggerheads, which were tracked for over 32,000 days total (Table 2). Our vast set of observational records within our continuously growing database (Table 3) will be used to assess the environmental patterns that drive sea turtle distributions and behavior in the MAB.

Based on past fieldwork, we hypothesize that factors associated with horizontal density gradients, regional currents and water mass fronts such as salinity and chlorophyll-a have equally important influence on turtle foraging in the MAB as SST and bathymetry. In order to accurately develop time-sensitive management strategies, it is imperative to understand relationships between oceanographic conditions and sea turtle behavior (Mansfield et al., 2009).

Availability bias and perception bias can both affect abundance estimates produced from line transect survey data. Perception bias occurs when turtles are available to be seen but are missed by observers. There are well-developed methods that adjust abundance estimates to account for perception bias (Laake and Borchers 2004). Availability bias occurs when turtles are not available to be seen by aerial survey observers (i.e., if sea turtles are diving deep below the surface) and can be a substantial source of bias (Marsh and Sinclair 1989). Telemetry data derived from this project has been used to develop corrections for availability bias in the abundance estimates and to collect additional data on habitat use and life history, residence time, and frequency of use. Further analysis is ongoing.

Due to complications involved with locating and capturing immature turtles on their offshore foraging grounds, relatively little is known about the immature turtles that occupy the offshore shelf-constrained Mid-Atlantic region. In the last decade, incidental takes of turtles by the Mid-Atlantic scallop fisheries, and many other fisheries, have been perceived as a threat to loggerhead populations. As a result, identifying the factors that create overlap between turtles and the scallop fishery has become a higher priority.

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.

In May 2013, ten turtles were satellite-tagged (Tables 4, 5; Figure 2). All data is continuously downloaded into our database from online Argos and SMRU sources (Table 6, Figure 3). In addition to tagging, morphometric measurements as well as blood and genetic samples are taken from each turtle (Tables 7, 8). Two newly designed solar-powered tags were deployed along with eight battery-powered tags (Table 9). According to our production control representative, in theory, solar tags should last indefinitely, although they will be subject to gradual marine fouling and degradation. The solar tags are self-regulated, and are designed to transmit data at a higher or lower rate in relation to the voltage remaining in the charge.

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 hoop 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 juvenile loggerhead sea turtle with the Sea Turtle Species Identification Key (NOAA Technical Memorandum NMFS-SEFSC-579), measured to confirm it was within the size range for this study (60-90 cm) and examined to ensure that its carapace 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. All tagging operations on this project were operated under the terms of the NEFSC (ESA Section 7(a)(1) Permit 1576 and 1295) and CFF ESA Section 10(a)(1)(A) permit 14249. Ronald Smolowitz is a Cooperative Investigator (CI) on this permit and has undergone NMFS training on handling and sampling sea turtles. All sea turtles brought on board that were comatose or inactive were handled in accordance with Sea Turtle Resuscitation Regulations at 50 CFR 223.206(d)(1).

Data Analysis

To evaluate the turtles' main temperature gradient, tag-transmitted temperature profiles greater than two meters depth were exported to and interpreted within Ocean Data View (ODV, Figure 4). These data were compared with month long time-averaged maps of satellite-derived SST data from the MODIS Aqua-4km satellite overlaid with turtle movement paths (Figure 5). Similarly, turtle tracks were overlaid upon monthly time-averaged maps of MODIS surface chlorophyll-a concentration data (Figure 6). For this same time period, turtle kernel density analysis was completed utilizing location data and was compared to bathymetric characteristics (Figures 7-10).

Sea turtles migratory tracks from 2009-2012 (*n*=72) and the 2013 non-transmitting tags (*n*=4) were classified into four groups based on latitudinal movement, according to the migration patterns outlined in Mansfield et al., 2009, which were defined by shelf-constraint and site fidelity (Figure 11). Of the 76 tags, 50 transmitted for over a year and were able to be evaluated for repetitive behavior. We refrained from including the six still-transmitting 2013 tags in case their movements change in the future, although presently they would belong in Group 1. Sea turtle movement was defined by the following groups: (1) The sea turtle remains within the shelf for the duration of the tagging, not displaying site fidelity (*n*=1), (2) the sea turtle travels off of the shelf (> one week), not displaying site fidelity (*n*=6), (3) the sea turtle remains within the shelf, displaying site fidelity (*n*=29), and (4) The sea turtle travels off of the shelf (> one week), displaying site fidelity (*n*=14). A fifth category, (0, *n*=26) represents the sea turtles with tags that ceased transmissions before spatial changes could be observed.

In addition to site fidelity, turtle dive behavior was evaluated. The SMRU tags are programmed to check their wet/dry sensors every four seconds. A designated dive begins once the sensors are wet and below 1.5 meters for longer than 20 seconds, and ends when they are dry or above 1.5 meters. Dive shapes are communicated as five points using a broken-stick algorithm. Identification of loggerhead activity at the surface as well as deeper depth usage can indicate when and where interactions with scallop vessels and gear are most likely to occur.

Dive profiles of the turtles were created, and all individual dives were grouped into six categories previously defined by Minamikawa et al 1997, Hochscheid et al 1999, Hays et al 2000, and Houghton et al 2002 (Figure 12). Type 1(a) and 1(b) (n=88; depth range=22-58m; duration range=9-330 min) reference "U" shaped dives, which are mainly resting dives, and are characterized by a steep descent, distinct bottom phase, and steep ascent. The bottom phase of type 1(a) was a consistent depth, while the 1(b) bottom phase displays a more sporadic pattern, which might indicate foraging. Type 2 (n=96; depth range=2-62m; duration range=1-319 min) represents "V" shaped dives, which are marked by a steep descent and immediate ascent once the maximum depth is reached. The immediate ascension indicates minimal activity at maximum depth. Type 3 (n=125; depth range=4-70; duration range=2-180 min) are "S" shaped dives, which include a steep descent followed by a gradual ascent from maximum depths. Past studies (Hochscheid et al 1999) suggest the gradual ascent is a form of energy-saving locomotion achieved by diving to neutral buoyancy depth with a specific lung volume of air and passively floating back to the surface by gaining positive buoyancy. Type 4(a) and 4(b) (n=107; depth range=2-5m; duration range= <1-40 min) indicate "subsurface dives" (SSD); dives completed in the upper 5 meters of the water column. Type 4(a) is a shallow, smooth dive pattern where the turtle creates a gradual arc similar to type 1(a). Type 4(b) is shallow as well, yet the turtle makes more sporadic vertical movements. Dive duration and dive depth comparisons for the dive types are shown in Figure 13.

Results

At-sea Sampling and Tagging Developments

Figure 14 depicts an example of the IDEXX blood chemistry results from a turtle tagged in 2011. Due to corrosion problems plaguing the lab responsible for processing 2012 and 2013 samples, we are still waiting for the results from those project years. We aim to continue our stable isotope analyses among other data interpretations once we acquire this information.

At the start of the project, we were hopeful that the solar tags might help to provide longer sampling periods with stronger GPS generated positions. Unfortunately, one solar tag was in fact the first tag to cease transmission (11/19/13), and the second solar tag stopped transmitting on 1/8/14. The two tags reported for 182 and 242 days respectively, both lower total transmission days compared to the 402 average transmission days of our past tags.

Physical Oceanography

According to the ODV data, the minimum temperature experienced by a turtle was 11.4ºC in June 2013, and the maximum temperature was 28.3ºC in July 2013, which reflects the MODIS data range from 15ºC (June) and 30ºC (July). We have found, as the months progress, that two of the ten satellite tags appear to be transmitting temperatures that are multiple degrees lower than surrounding tags during the same period. The turtles maintained a range of chlorophyll-a concentration from 0.03-30 mg m^{-3} during these months. The four months showed a consistent aligning with the -40 m bathymetric contour, consistent with previously observed higher rate of observable fishery/turtle interactions around 40-60m depth (Murray 2011).

The turtles maintained a range of chlorophyll-a concentration from 0.03-30 mg m^{-3} during the foraging months, which is slightly broader than the range that Mansfield et al 2009 observed during this time (0.18-29.74 mg m^{-3}), though expected due to her assertion that neretic turtles experience a broader range of chlorophyll concentrations during this season.

Turtle Behavior

Preliminary analysis has indicated that loggerheads show repetitive, accurate targeting of foraging areas across multiple years and similar individual latitudinal migratory paths. Twenty-seven turtles from previous tagging years were observed occupying similar migratory routes post-foraging and post-overwintering (Figure 15).

Due to the large amount of data, preliminary dive profile analyses encompass three turtles (PTT numbers 129783, 129775, 129776) for six successive days of each month from June through February (54 days total). Of the 548 dive shapes transmitted during the 54 days, 416 were greater than two meters and were classified into the six groups. Further analysis of all turtles and data points will be continued. As expected, preliminary results show that the frequency of each general dive type (U, V, S, SSD) and number of dives completed shifts between the summer and winter months. From June-September, over 60% of the dives completed are SSD and S (Figure 16). This could be attributed to the high epipelagic gelatinous zooplankton biomass located around the Chesapeake Bay, a common food source for loggerheads (Lilley et al 2011, Polovina et al 2000). The greatest jump between the two phases is the proportion of U dives, which increases from 12% in the summer to 39% in the winter. This observation is consistent with previous studies (Broderick et al 2007) and suggests characteristic reduction in movement and potential hibernation during this time. Further analysis that integrates these data is presently being conducted.

The seven turtles that are still transmitting from the late-November 2013 through the last sampling date of this project (February 28, 2014) consistently remained in two small, distinct groups in the coastal waters off of North Carolina (Figure 17). The turtles appear to roughly be grouped by carapace size; the average CCL of the more northern turtles is 75.9 cm, and the average CCL of the southern turtles is 95.5 cm. However, tail length and tagging location do not appear to be associated with the grouping strategies.

Discussion

We believe that fluctuating hydrographic properties associated with the distinct water masses and frontal zones in the MAB shelf and slope regions influence loggerhead distributions. Additionally, prior attempts to parameterize turtle distributions in the northwest Atlantic have indicated strong correlation with SST and bathymetry (Hawkes et al., 2007).

Pelagic-stage loggerheads will actively seek out such frontal zones, which frequently entrain Sargassum into windrows that can be up to several miles long, for foraging and for protection (Carr 1986; Conston-Clements et al. 1991). We find it imperative to focus on the role of Sargassum as critical habitat found in the MAB scallop areas in future research. There has been no direct study of sea turtles within the Sargassum community of the MAB thus far. Since Sargassum is being considered for a Critical Habitat designation as far north as 40 degrees, it is important for the scallop industry to understand the potential ramifications. Knowledge of what importance Sargassum has to loggerheads this far north is essential for managers to develop appropriate protections.

In their juvenile to adult stages, loggerhead turtles are known to migrate annually into the Mid-Atlantic shelf region to forage between June and November when sea surface temperatures (SST) exceed 20°C (Figure 18; Mansfield et al., 2009; Hawkes et al., 2007; Shoop and Kenney, 1992). From 2009 through 2012, our tagging trips took place in early June and again in late summer in the northern half of the MAB, close to New Jersey and Delaware. Past results suggest strong site fidelity to the specific areas where turtles were tagged for the duration of the foraging period. The goal was to observe site fidelity in the summer of tagging and again a year later (Figure 19).

To further explore site fidelity, we tagged loggerheads earlier in the season (late May) in 2013 and farther south (off of Virginia and North Carolina) prior to their migration northwards for foraging months. This fidelity lasted throughout the duration of the foraging season, and certain turtles displayed an interannual loyalty to these sites, returning at the same time each year.

Through the years of tagging, we have consistently observed loggerheads overwintering in close proximity to the waters from Cape Hatteras to Onslow Bay, North Carolina. Their foraging behavior was observed as more sporadic and with smaller "hotspots" (Figure 20) than the larger, yet more consistent summer foraging grounds. Although smaller foraging areas are expected during this time, the consistency of location and grouping observed in 2013 is markedly different from past years. We believe that the first step to analyzing this unique foraging pattern is establishing the sex of the animals in the two groups. Although total tail length of the animals does not appear to be an indicator (Casale et al 2005) the two tail measurements that we take (plastron to tip of tail and vent to tip of tail) do not show a strong difference in sex ratio estimates.

Improving our ability to model the highly influential availability bias would directly improve our ability to produce more accurate, spatially explicit loggerhead abundance estimates. One major hurdle in assessing the relationship between surface behavior and bottom temperature is the difficulty in obtaining accurate bottom temperatures in the U.S. Mid-Atlantic Bight (MAB).

Outreach

We are currently working on a number of peer-reviewed papers on prior ROV work and its relationship to the interpretation of tagging data. Additionally, we are working to complete a paper about complementary ROV operational methodology and satellite data interpretation. Our satellite-tagging database is one of the largest loggerhead sea turtle datasets and documents interannual variability in loggerhead movements, behaviors, and habitat characteristics (Table 12). The extensive data collected in the tagging component of this study, continues to be used by both researchers and resource managers (Addendum A). We will continue to present our data at upcoming conferences. Most recently, we were invited to give an oral presentation at the 2014 American Fisheries Society Annual Meeting in Québec City.

Previous work by CFF has led to the development of the Turtle Deflector Dredge (TDD) and chain mats, both of which greatly reduce the risk of injury and mortality to loggerhead sea turtles in scallop dredges by virtually eliminating their capture (Murray, 2011; Smolowitz et al., 2012; Smolowitz et al., 2010; Milliken et al., 2007; Dupaul et al., 2004). As of May 1, 2013, TDDs must be used in all waters west of 71º W longitude during the TDD season (May 1 through October 31) by all scallop fishing vessels, with the exemption of Limited Access General Category vessels which use a dredge less than 10’6’’ in width. (USGPO 1996).

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Table 1. Technical specifications of SMRU's SRDL with Argos Fastloc GPS tag.

Specification	Description	Details
Performance	Transmitter	0.5 W Argos transmitter
Characteristics	Size	10.5 cm x 7 cm x 4 cm
	Weight	370 grams
Sensors	Depth	2000 meter depth transducer
	Resolution	0.5 meter resolution
	Temperature	Accurate to 0.1º C
Power	Battery	Lithium "D" size cell
	Data	85000 full Argos transmissions
	Longevity	Approximately one year

Table 2. Summary data for all tracked CFF/NEFSC sea turtles including overall turtle number, turtle ID, deploy date, date of last transmission, and total number of days the tag was transmitting, as of 2/17/14. Blue text indicates an active tag.

Turtle #	Turtle ID	Deploy Date	Date Last Trans.	Days
1	2009-1	8/24/09	9/28/10	401
2	2009-2	8/24/09	7/30/10	341
3	2010-1	8/7/10	11/9/10	94
4	2010-2	8/6/10	12/20/10	136
5	2010-3	8/5/10	11/7/11	460
6	2010-4	7/9/10	1/4/12	545
7	2010-5	7/9/10	9/23/12	808
8	2010-6	8/6/10	9/5/11	395
9	2010-7	9/8/10	3/27/12	567
10	2010-8	8/9/10	9/27/11	414
11	2010-9	9/9/10	11/21/11	438
12	2010-10	9/11/10	9/10/11	364
13	2010-11	8/6/10	7/2/11	331
14	2010-12	9/9/10	11/1/11	421
15	2010-13	8/5/10	10/29/11	451
16	2010-14	9/11/10	9/23/11	378
17	2010-15	9/10/10	11/11/11	428
18	2011-1	6/2/11	3/27/13	665
19	2011-2	6/4/11	11/29/11	179
20	2011-3	6/6/11	8/18/12	440
21	2011-4	6/6/11	10/15/11	132
22	2011-5	6/3/11	11/11/12	572
23	2011-6	6/5/11	6/22/12	384
24	2011-7	6/6/11	11/17/12	531
25	2011-8	6/4/11	6/15/12	377
26	2011-9	6/3/11	4/23/13	691
27	2011-10	6/3/11	2/1/13	610
28	2011-11	6/2/11	7/12/12	406

29	2011-12	6/3/11	6/29/12	393
30	2011-13	6/3/11	7/10/12	404
31	2011-14	6/3/11	8/18/12	443
32	2011-15	6/4/11	5/17/12	349
33	2011-16	6/3/11	11/11/12	528
34	2011-17	6/4/11	5/9/13	706
35	2011-18	6/4/11	9/24/12	479
36	2011-19	6/6/11	9/18/12	471
37	2011-20	6/3/11	12/20/12	567
38	2011-21	6/7/11	9/2/12	457
39	2011-22	6/6/11	10/10/12	493
40	2011-23	6/6/11	6/21/12	381
41	2011-24	6/6/11	4/9/13	674
42	2011-25	6/7/11	7/23/12	412
43	2012-1	6/1/12	10/17/13	504
44	2012-2	5/31/12	7/14/13	410
45	2012-3	6/1/12	8/31/13	456
46	2012-4	6/1/12	2/28/14	637
47	2012-5	6/2/12	7/22/13	415
48	2012-6	6/2/12	3/20/13	291
49	2012-7	6/3/12	2/22/14	630
50	2012-8	6/2/12	8/28/12	452
51	2012-9	6/2/12	10/30/12	134
52	2012-10	6/2/12	10/11/13	497
53	2012-11	6/3/12	10/17/13	502
54	2012-12	6/2/12	12/27/12	208
55	2012-13	6/3/12	2/28/14	636
56	2012-14	6/2/12	9/29/12	119
57	2012-15	6/3/12	11/11/13	527
58	2012-16	6/1/12	10/13/13	501
59	2012-17	6/1/12	8/21/13	448
60	2012-18	6/1/12	10/21/13	508
61	2012-19	5/31/12	9/14/12	106
62	2012-20	6/1/12	6/22/13	387
63	2012-21	6/3/12	5/27/13	361
64	2012-22	6/1/12	5/24/13	358
65	2012-23	6/2/12	9/4/13	460
66	2012-24	6/3/12	11/8/12	159
67	2012-25	6/2/12	2/26/13	269
68	2012-26	6/2/12	10/29/12	149
69	2012-27	6/3/12	7/16/13	408
70	2012-28	6/1/12	8/31/13	455
71	2012-29	6/3/12	10/4/13	489
72	2012-30	6/3/12	5/28/13	359
73	2013-1	5/22/13	2/28/14	283
74	2013-2	5/21/13	8/16/13	84
75	2013-3	5/21/13	2/28/14	283

76	2013-4	5/21/13	2/28/14	283
77	2013-5	5/22/13	11/24/13	181
78	2013-6	5/21/13	2/28/14	283
79	2013-7	5/22/13	2/28/14	283
80	2013-8	5/21/13	2/28/14	283
81	2013-9	5/22/13	11/19/13	182
82	2013-10	5/22/13	1/8/14	242
			Total Days	**32938**
			Average Days	**402**

Table 3. Number of data points from the Northeast Sea Turtle Collaborative tags

Data Type	**Total Data points**
Locations	534,000
Dive profiles	167,000
Depth use	79,000
Surface behavior	82,000
TAD	290,000

Table 4. Take Summary for the Kathy Ann 2013-1 trip, specific to the time spent tagging the CFF turtles. Missed takes are turtles sighted but not successfully captured.

Trip	**Takes**
Kathy Ann 2013-1	10 tagged
	4 missed
	14 total

Table 5. Tagging trip turtle take events, Kathy Ann 2013-1.

#	Tag Date	Time	Capture Lat	Capture Long	SST	SatTag Body #	LRear FlipTag #	RRear FlipTag #	PIT Tag #
1	5/21/13	9:15	37º 46'	74º 56'	16.5	12811	BBR961	BBR962	4348505462
2	5/21/13	10:38	37º 44'	74º 50'	16.5	12809	BBR964	BBR963	43494F017C
3	5/21/13	12:35	37º 44'	74º 52'	16.9	12806	BBR965	BBR966	436A171A69
4	5/21/13	13:34	37º 44'	74º 52'	17.1	12814	BBR967	BBR968	43676F0C46
5	5/21/13	14:00	37º 43'	74º 51'	17.0	12808	BBR969	BBR970	43674D3D68
6	5/22/13	7:53	36º 39'	74º 51'	18.7	12810	BBR971	BBR972	434B717552
7	5/22/13	8:45	36º 38'	74º 52'	18.9	12812	BBR976	BBR977	4368024405
8	5/22/13	11:28	36º 40'	74º 58'	19.9	12517	BBR978	BBR979	4369274F3F
9	5/22/13	11:55	36º 40'	74º 58'	19.9	12813	BBR980	BBR981	436A354476
10	5/22/13	11:57	36º 40'	74º 58'	19.9	12805	BBR982	UUC426	43694F6810

Table 6. The dates and time of the most recent uplink and GPS location transmission for each satellite tag according to the SMRU website. (Feb 25, 2014)

Reference	Latest uplink	Latest location	PTT	Body	Parameters
tu80-R517-13	23-Feb-2014 14:32	17-Oct-2013 15:24	129782	12517	FA_13A
tu80-R806-13	16-Aug-2013 19:21	10-Aug-2013 09:29	129777	12806	FA_13A
tu80-R808-13	25-Feb-2014 15:00	19-Oct-2013 17:38	129779	12808	FA_13A
tu80-R809-13	25-Feb-2014 13:58	19-Oct-2013 05:18	129776	12809	FA_13A
tu80-R810-13	24-Nov-2013 01:27	18-Oct-2013 07:01	129780	12810	FA_13A
tu80-R811-13	25-Feb-2014 08:55	19-Oct-2013 08:12	129775	12811	FA_13A
tu80-R812-13	25-Feb-2014 15:49	20-Oct-2013 08:59	129781	12812	FA_13A
tu80-R814-13	25-Feb-2014 15:49	19-Oct-2013 14:59	129778	12814	FA_13A
tu80-Rs805-13	19-Nov-2013 22:29	18-Nov-2013 00:00	129784	12805	FA_13SOL
tu80-Rs813-13	08-Jan-2014 19:00	20-Oct-2013 06:25	129783	12813	FA_13SOL

Table 7. Tagging trip turtle take measurements, Kathy Ann 2013-1. All measurements are in centimeters unless otherwise noted.

NotNot CCL=Notch to notch curved carapace length; NotTip CCL=notch to tip CCL; NotNot SCL=notch to notch straight carapace length; NotTip SCL=notch to tip SCL; WCCL=width CCL; WSCL=width SCL; TotTail=total tail (plastron to tip) length; VenTail=vent to tip of tail length; BDepth=body depth; weight=weight of turtle.

#	NotNot CCL	NotTip CCL	NotNot SCL	NotTip SCL	WCCL	WSCL	TotTail	VenTail	BDepth	Weight (kg)
1	83	85	77	78.3	81	66.5	17.5	3.5	29.5	74.4
2	74	75.3	69.5	70.7	72	58	11.9	3.8	28	51.4
3	80	81	74	75	75	63	13.8	4	39.5	65.4
4	77	79	71	73	75	62	17.7	3.3	32	57.4
5	79	80	72.5	74	77	63.2	19.9	5.8	33.4	68.8
6	80	82	75	77	80	64	17.2	4.6	34	63.4
7	108.5	111	99.5*	100.75*	99	78.5	9	3	32.4*	156.9
8	72	73.4	66.5	67.7	71.8	58.8	13.2	3.9	30.2	50.4
9	103.5	106	94.4	95.5	99.5	71	7.7	4	34.2*	117.4
10	67.1	68.8	62	64	68.2	55	11.2	2.7	26.5	42.4

*Estimated length

Table 8. Tagging trip turtle take biological data, Kathy Ann 2013-1

#	IntTemp ºC	Bld CCs	# Stabs	HRper Min	BiopRear SI	BiopRear Genetic	Epibiont Samp
1	15.2	12	1	16	Y	Y	Y
2	12.3	12	1	24	Y	Y	Y
3	16.7	12	1	20	Y	Y	Y
4	16.3	12	1	24	Y	Y	Y
5	16.7	12	3	20	Y	Y	Y
6	16.8	12	1	20	Y	Y	Y
7	17.2	12	1	nd	Y	Y	Y
8	18.8	12	1	20	Y	Y	Y
9	17.9	12	2	16	Y	Y	Y
10	19.4	9	3	20	Y	Y	Y

nd = no data

Table 9. Product specifications for the solar SRDL with Argos Fastloc GPS tags.

Specification	Description	Details
Solar Power	Battery	2Ah solar rechargeable battery
	Data	4x as many transmissions as D cell
Transmission Allowance	< 3500 mV	0
	3500-3800 mV	72
	3800-3900 mV	144
	3900-4000 mV	288
	> 4000 mV	Maximum

Table 10. Capture location, CCL, and Total tail length (cm) of the seven overwintering grouped turtles. Colors correspond to Figure 20.

PTT	Capture Lat (N)	Capture Long (W)	CCL	TotTail
129776	37º 44.00	74º 50.00	75.3	17.7
129778	37º 43.43	74º 51.70	79	13.2
129782	36º 40.10	74º 58.11	73.4	17.5
129781	36º 38.00	74º 52.00	111	9
129779	37º 43.00	74º 51.00	80	13.8
129775	37º 45.75	74º 56.16	85	17.2
129783	36º 40.00	74º 58.00	106	11.2

Table 11. Preliminary estimated adjusted abundance of only positively identified loggerheads within the northwest Atlantic continental shelf study area when accounting for perception bias (*g(0)*<1). Adapted from Table 8 of NEFSC SEFSC 2011.

Strata	**Abundance, not adjusted for availability bias**	**Correction factor for availability bias**	**Abundance, adjusted for availability bias**
South Atlantic	38,974	14.29	556,771
Mid-Atlantic South	17,376	1.49	25,896
Mid-Atlantic North	3,873	1.49	5,772

Table 12. Comparison of other publications to CFF/NEFSC in number of satellite tags and total number of transmission days accumulated, as of 2/28/14.

Paper	**Study Year(s)**	**# Tags**	**Species**	**Days**
Cardona et al 2005	2002	5	Loggerhead	424
Mansfield et al. 2012	2009	7	Loggerhead	491
Bentivegna 2002	1995-1999	4	Loggerhead	995
Varo-Cruz et al. 2013	1999-2007	5	Loggerhead	1104
Polovina et al. 2000	1997-1998	9	Loggerhead	1161
Zbinden et al. 2011	2004-2007	18	Loggerhead	2210
Eckert et al. 2008	2004-2005	19	Loggerhead	2705
Arendt et al. 2011	2006	29	Loggerhead	3837
Hayes et al. 2010	2004-2009	17	Loggerhead	4152
Mansfield et al. 2009	1986-2007	23	Loggerhead	4968
Hawkes et al. 2011	1998-2008	68	Loggerhead	
Polovina et al. 2006	2000-2004	43	Loggerhead	5710
Marcovaldi et al. 2010	2006	10	Loggerhead	8748
CFF/NEFSC	2009-2013	82	Loggerhead	32938*

*tags still transmitting

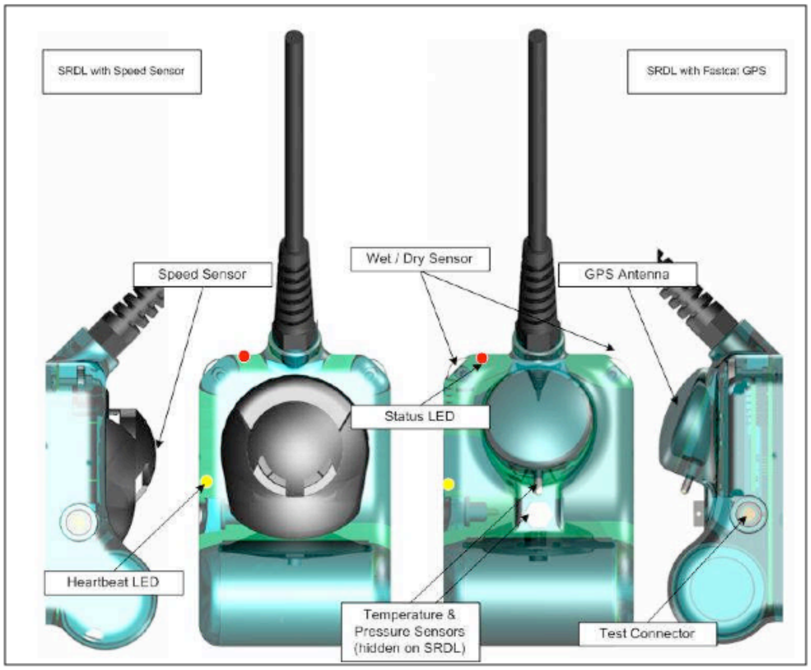


Figure 1. SRDL with Argos Fastloc GPS satellite tag used within this project, (http://www.smru.st-and.ac.uk/Instrumentation/SRDL/).

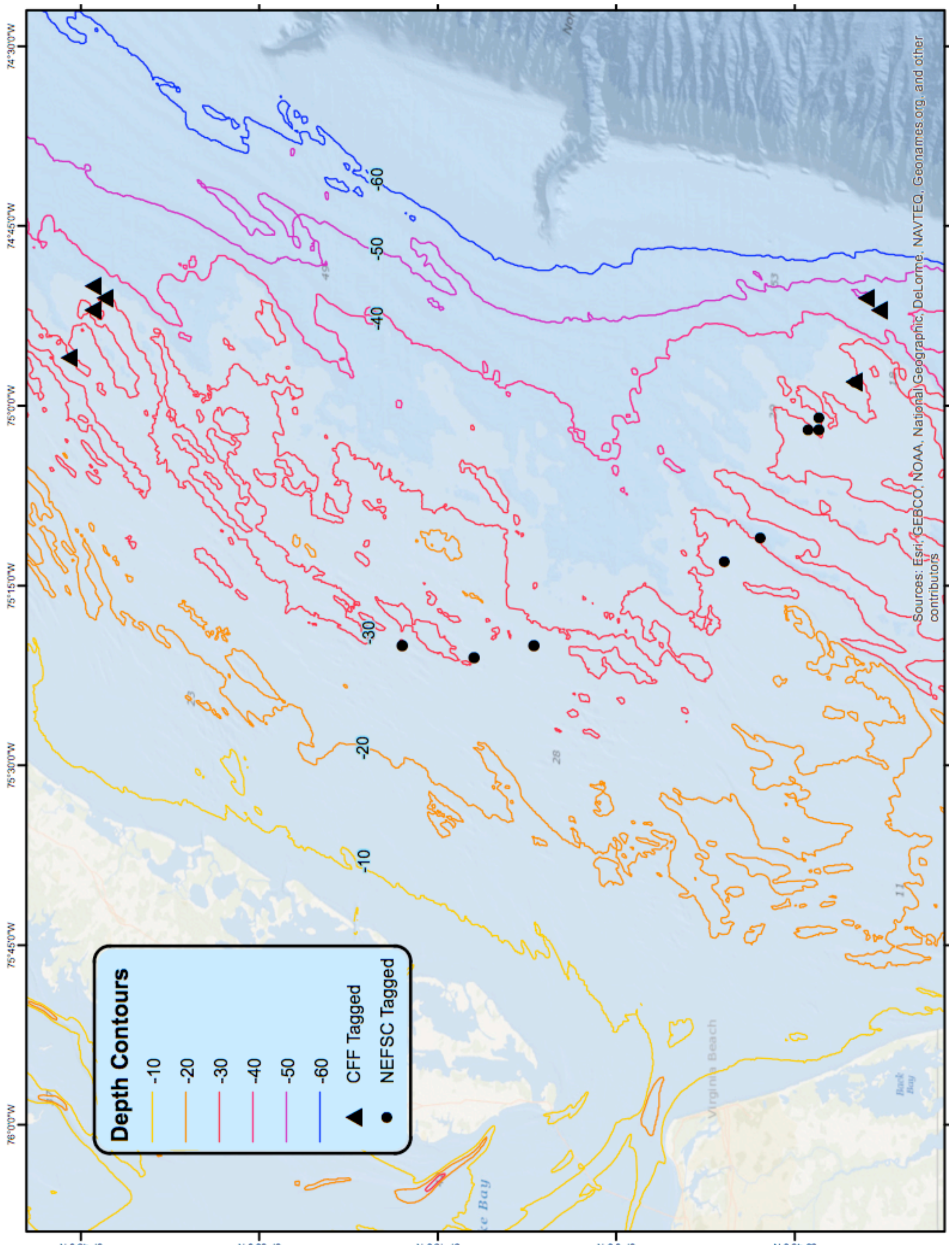


Figure 2. Map of tagging locations of the 2013 CFF tagging location sites (triangles) and our partners' tagging location sites (circles), with depth contours included. Some locations host multiple tagging events yet may appear as one.

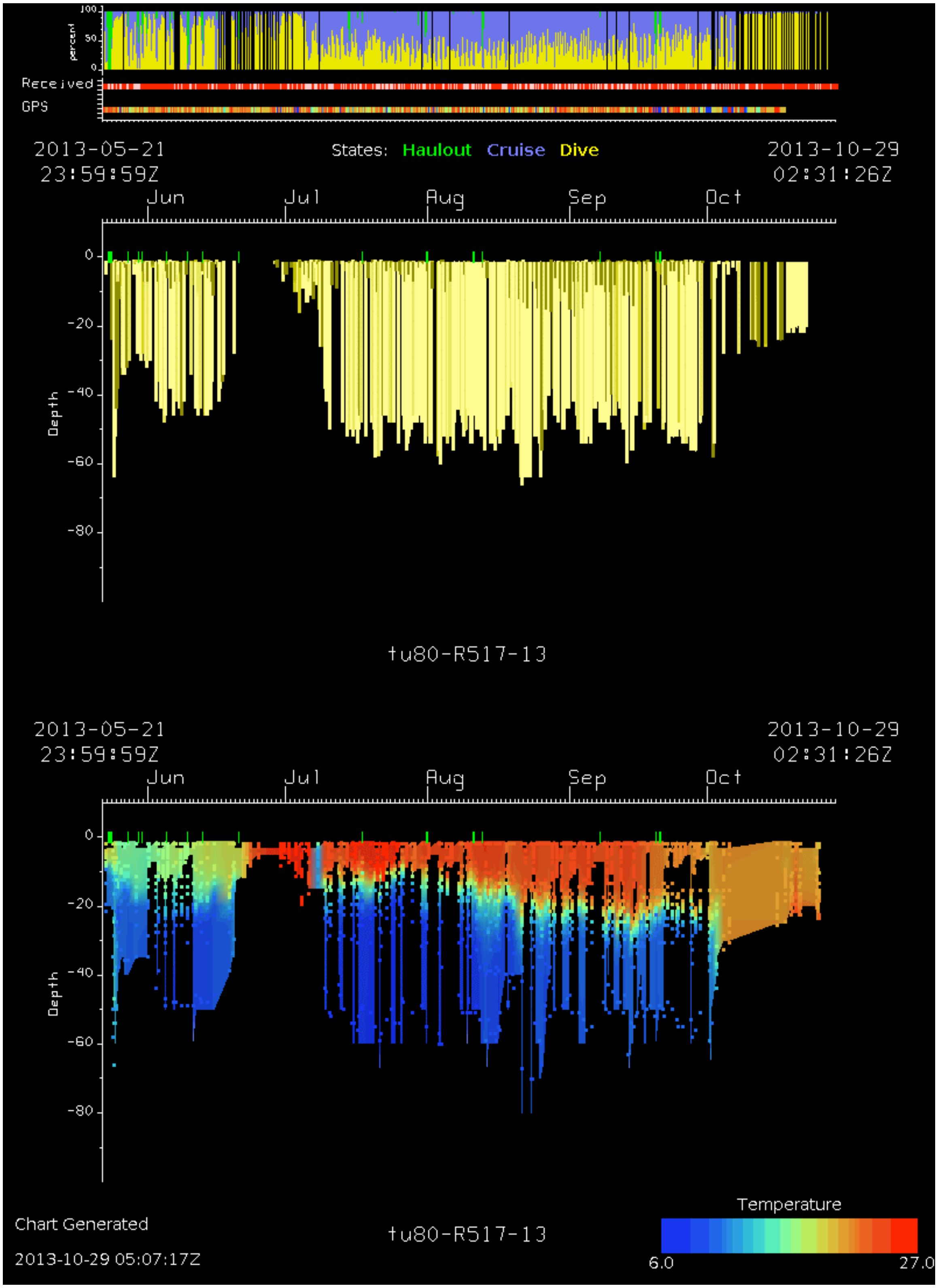


Figure 3. An example of a typical chart dataset provided for an individual tag. Haulout, cruise, and dive states, depth of dives, and temperature during dives are presented here.

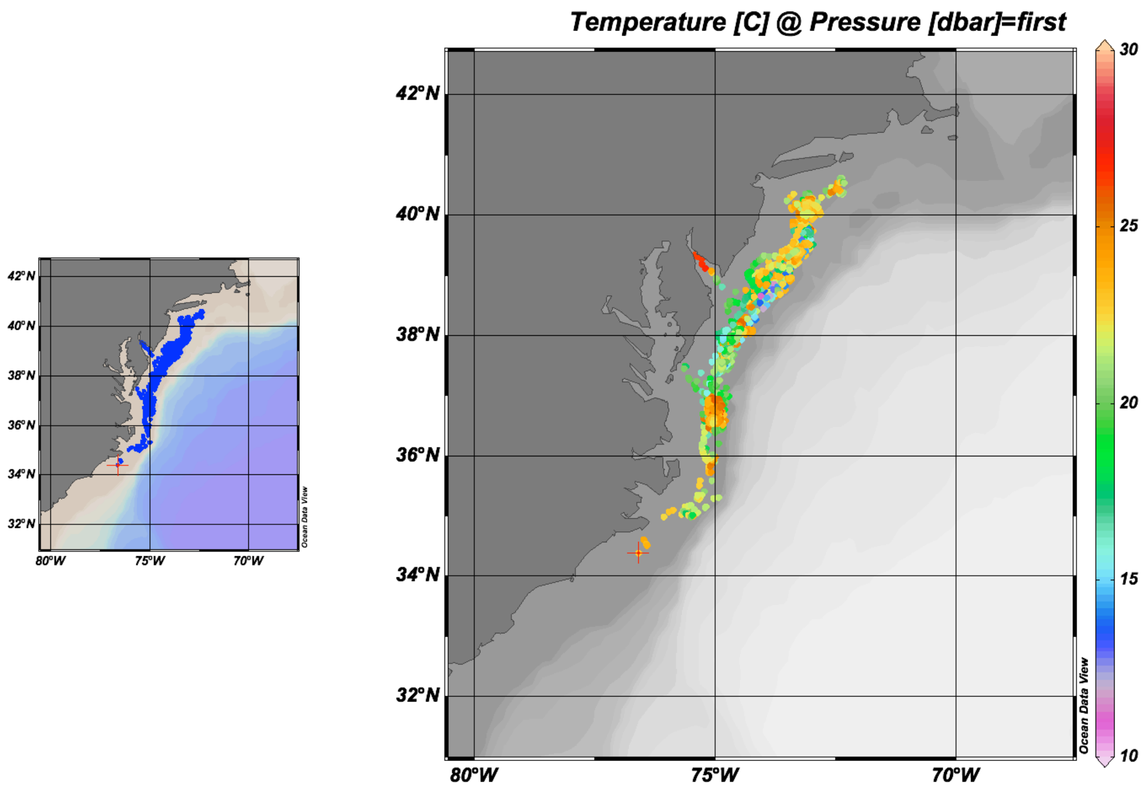


Figure 4. Temperature profile as viewed within the ODV program from all 10 turtles from date of tagging in May through 2/28/14. The smaller figure to the left shows all data points relayed from the SRDL, the larger figure on the right represents the temperature at each data point.

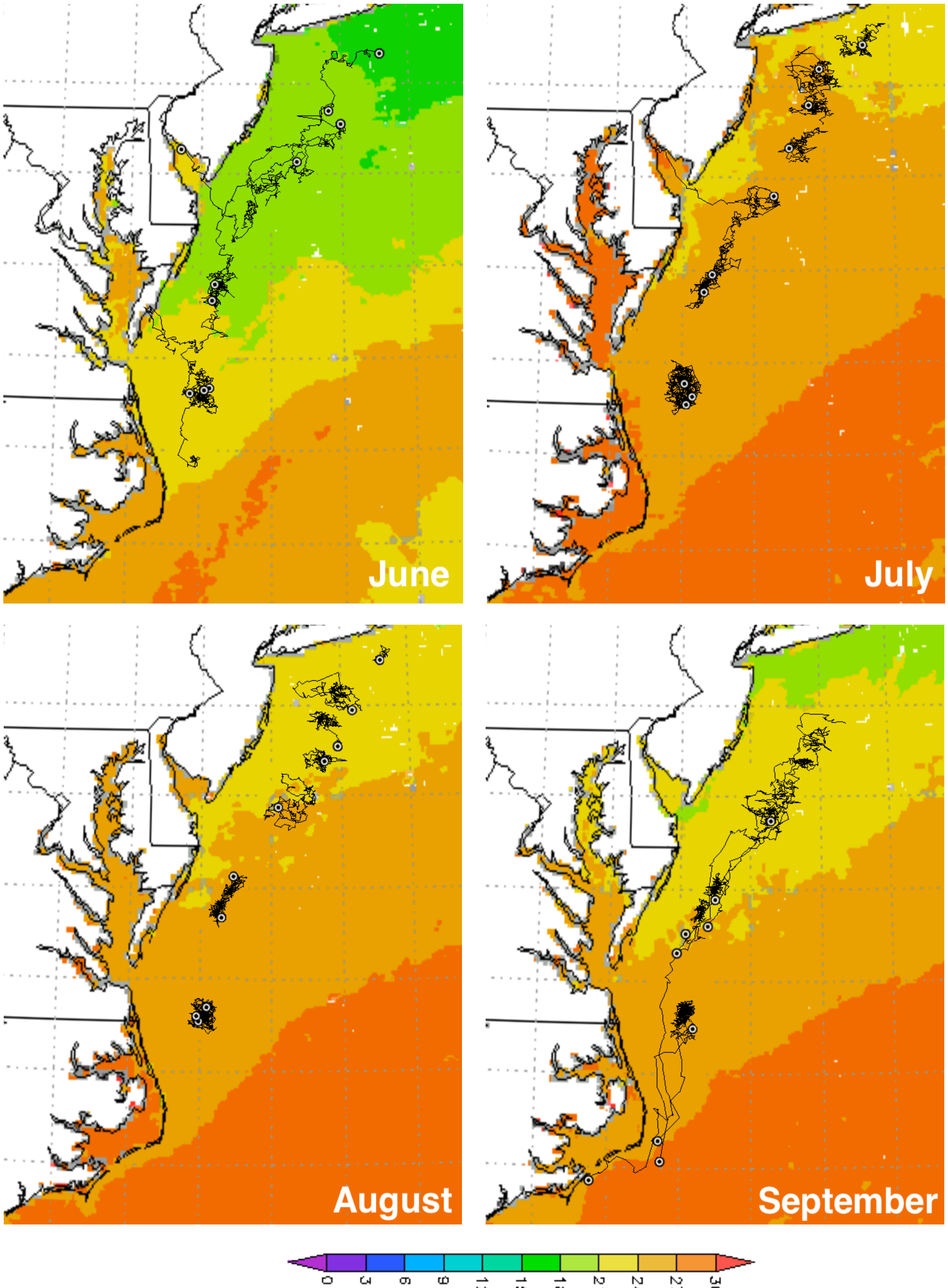


Figure 5. Tracks of transmitting turtles for the months of June – September 2013 overlaid upon month long time-averaged SST (ºC) from MODIS 4km data.

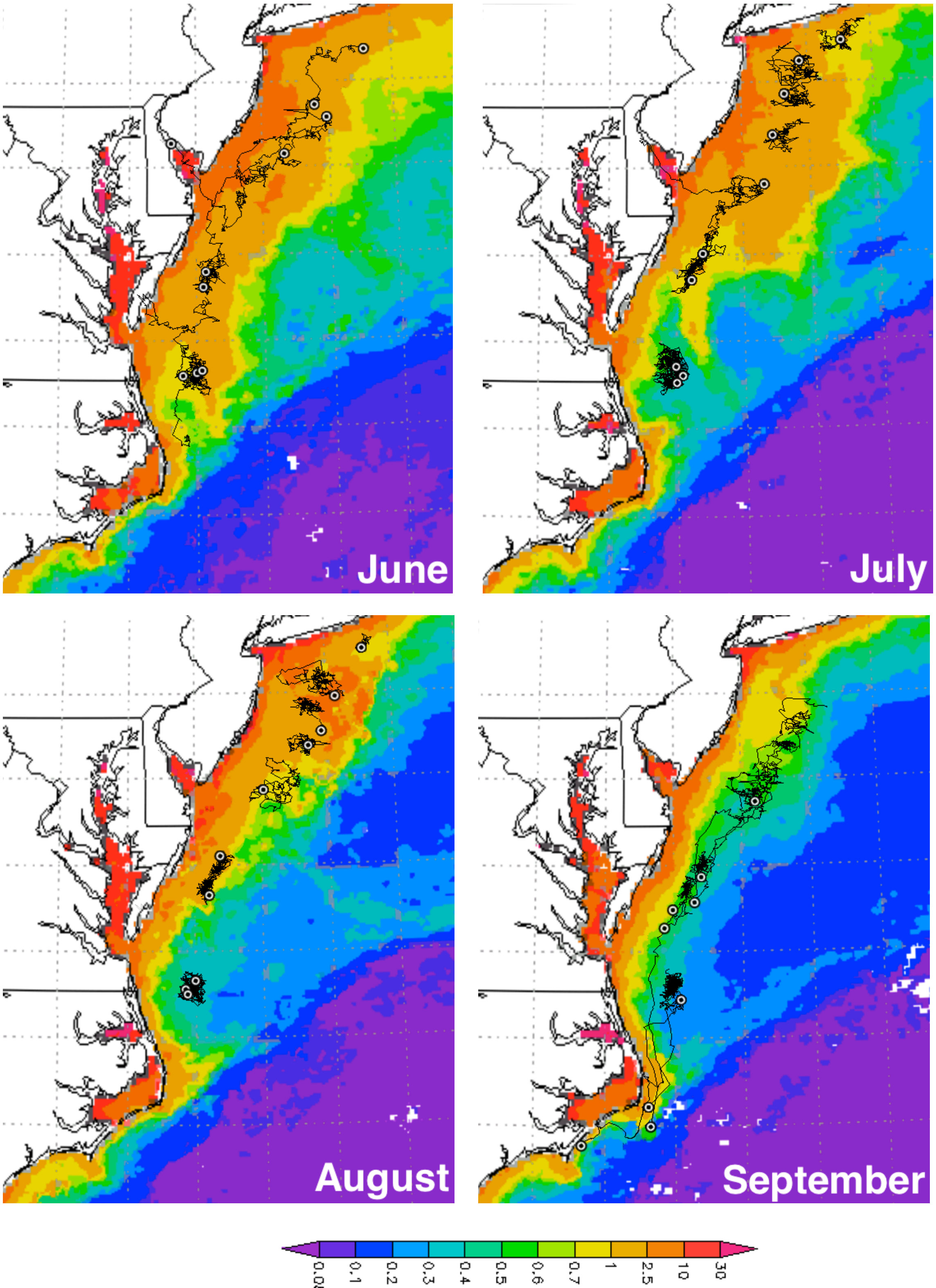


Figure 6. Tracks of transmitting turtles for the months of June – September 2013 overlaid upon month long time-averaged chlorophyll-a (mg m^{-3}) from MODIS 4km data.

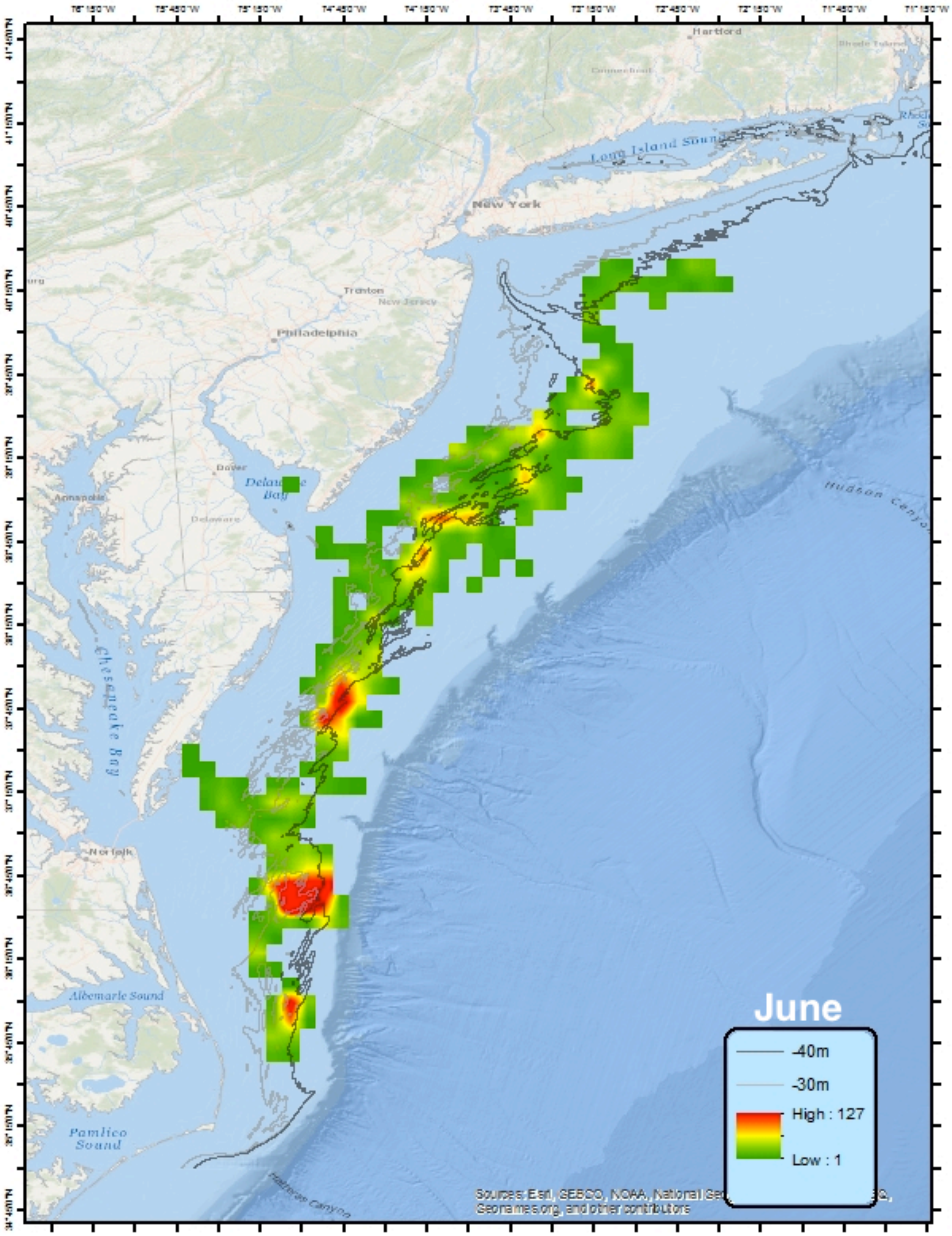


Figure 7. Kernel density analysis of turtle locations during June 2013 closely aligned with the -40 meter bathymetry contour. The “high” and “low” points represent the number of location data points in that location during the time period.

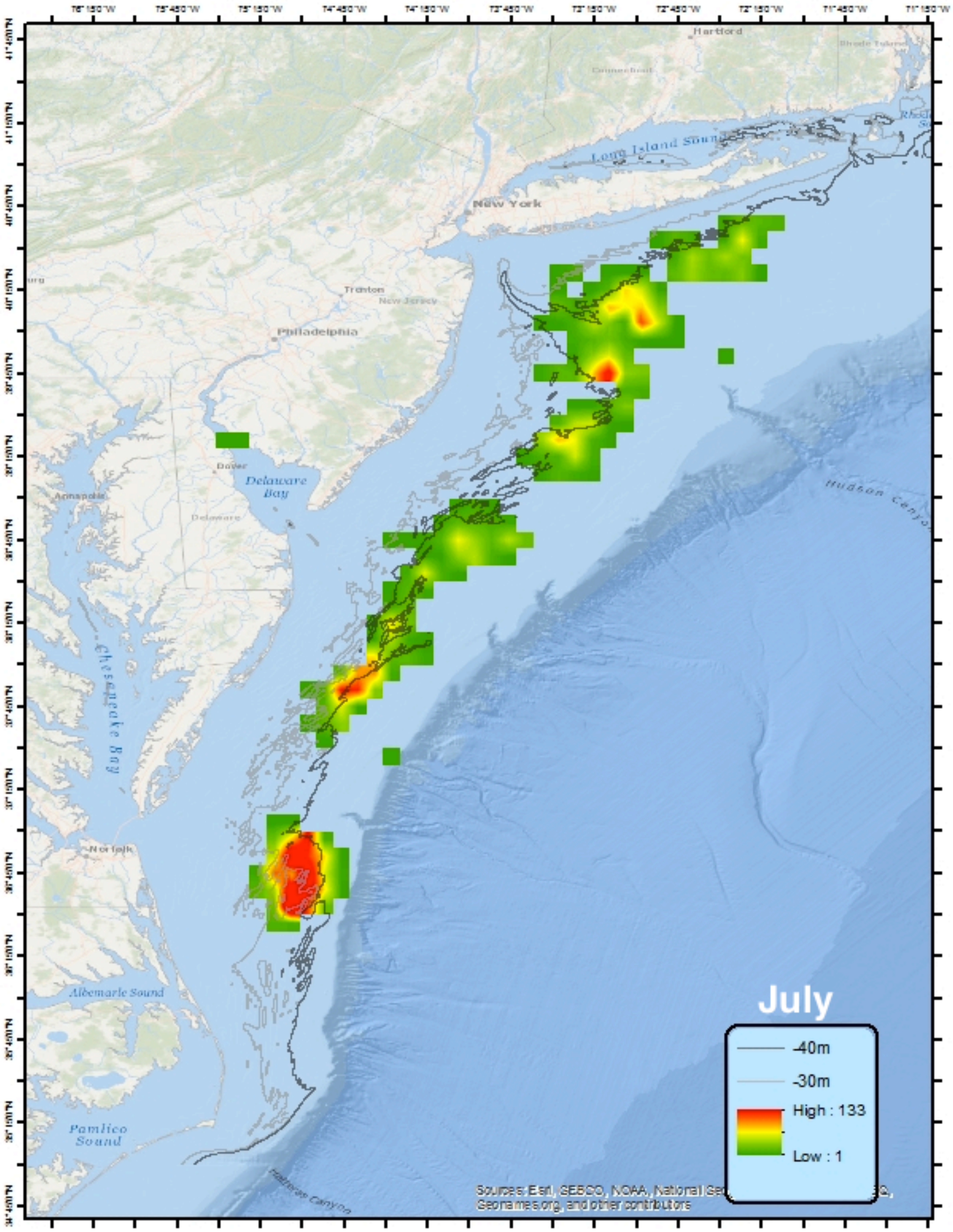


Figure 8. Kernel density analysis of turtle locations during July 2013 closely aligned with the -40 meter bathymetric contour. The “high” and “low” points represent the number of location data points in that location during the time period.

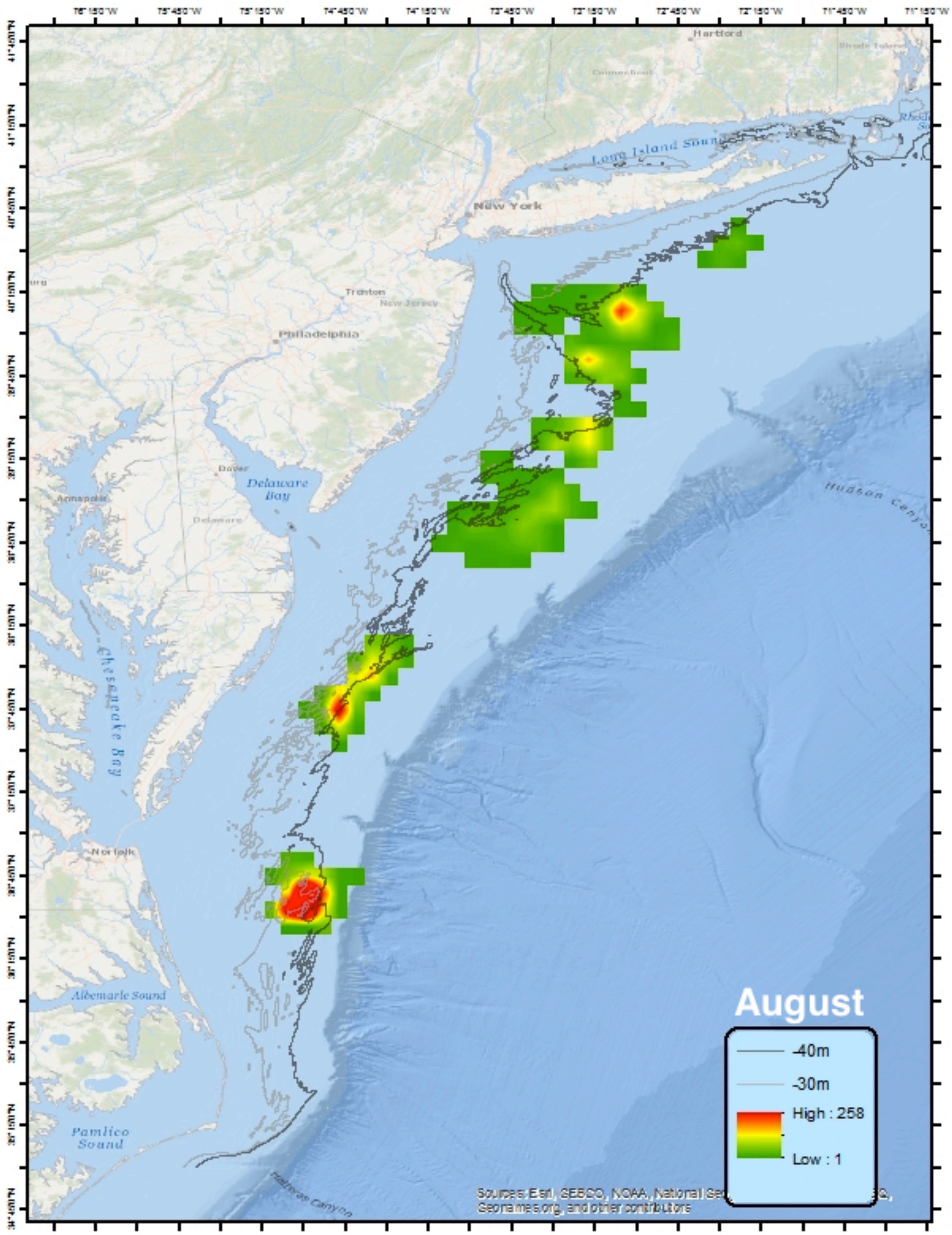


Figure 9. Kernel density analysis of turtle locations during August 2013 closely aligned with the -40 meter bathymetry depth. The "high" and "low" points represent the number of location data points in that location during the time period.

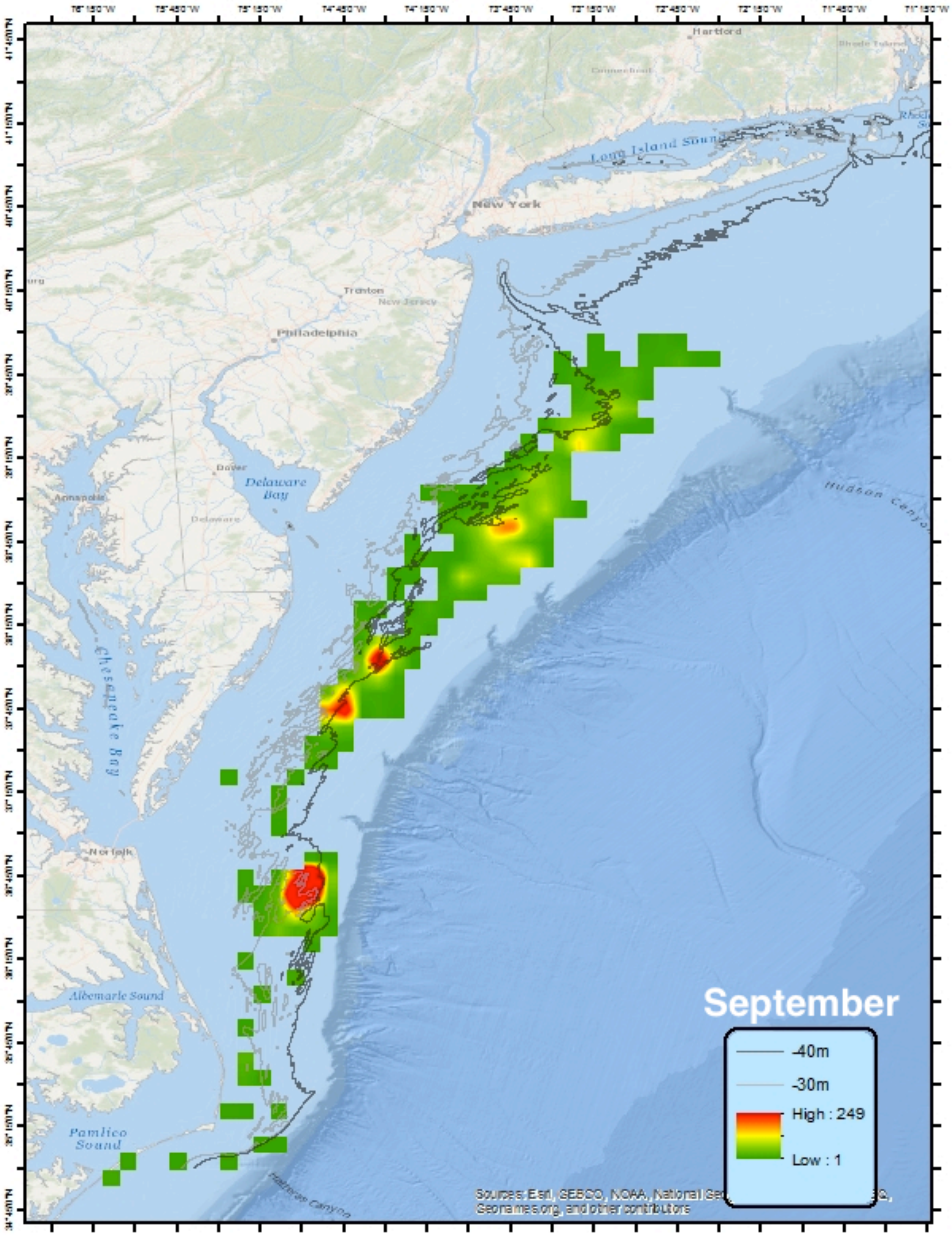


Figure 10. Kernel density analysis of turtle locations during September 2013 closely aligned with the -40 meter bathymetry depth. The “high” and “low” points represent the number of location data points in that location during the time period.

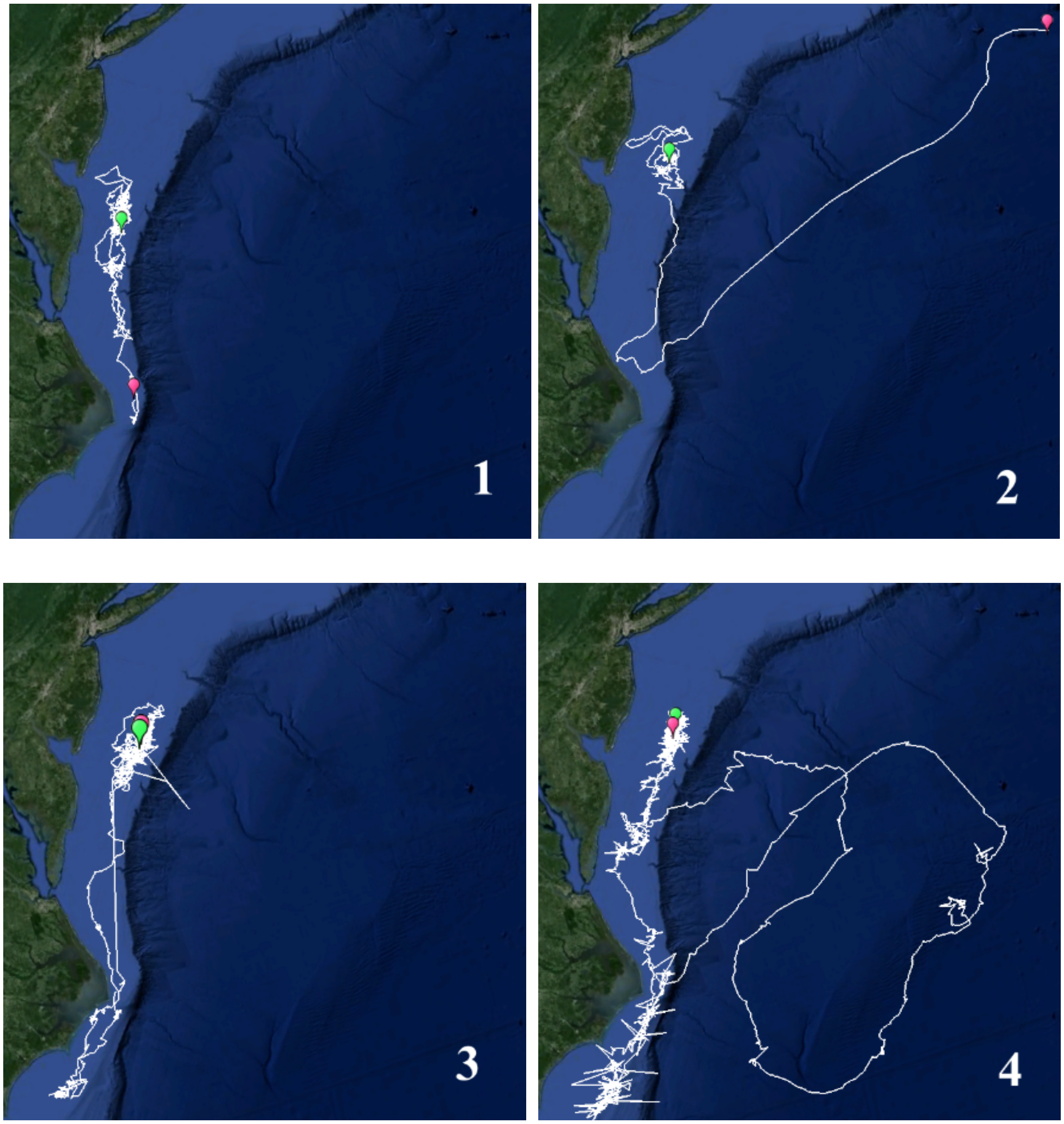


Figure 11. Four examples of individual tagged loggerhead turtles displaying the four different north-south migratory pattern classifications. The green marker represents the initial tagging location, and the pink marker represents the position of the last transmission. (1) The sea turtle remains within the shelf for the duration of the tagging, not displaying site fidelity, (2) the sea turtle travels off of the shelf (> one week), not displaying site fidelity, (3) the sea turtle remains within the shelf, displaying site fidelity, and (4) The sea turtle travels off of the shelf (> one week), displaying site fidelity.

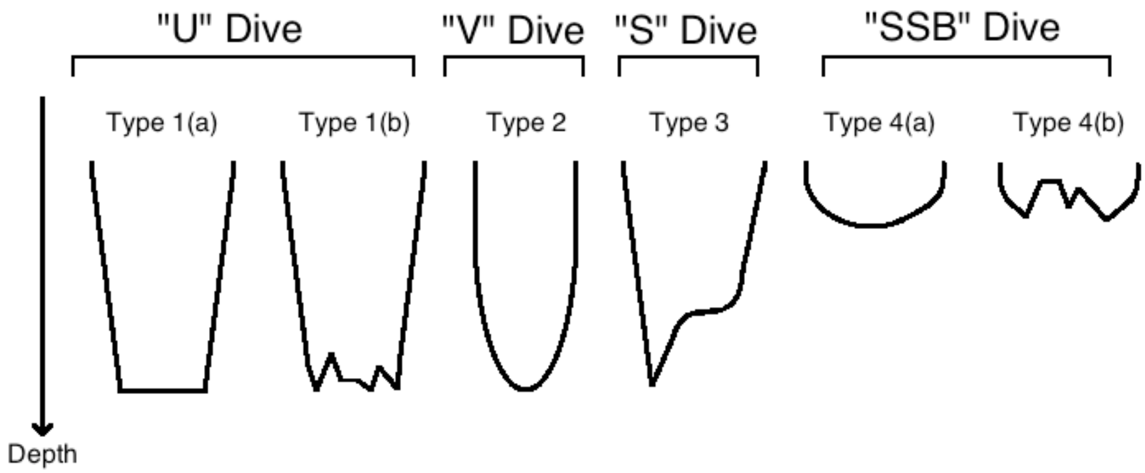


Figure 12. General model of the six dive classifications and four overarching dive types.

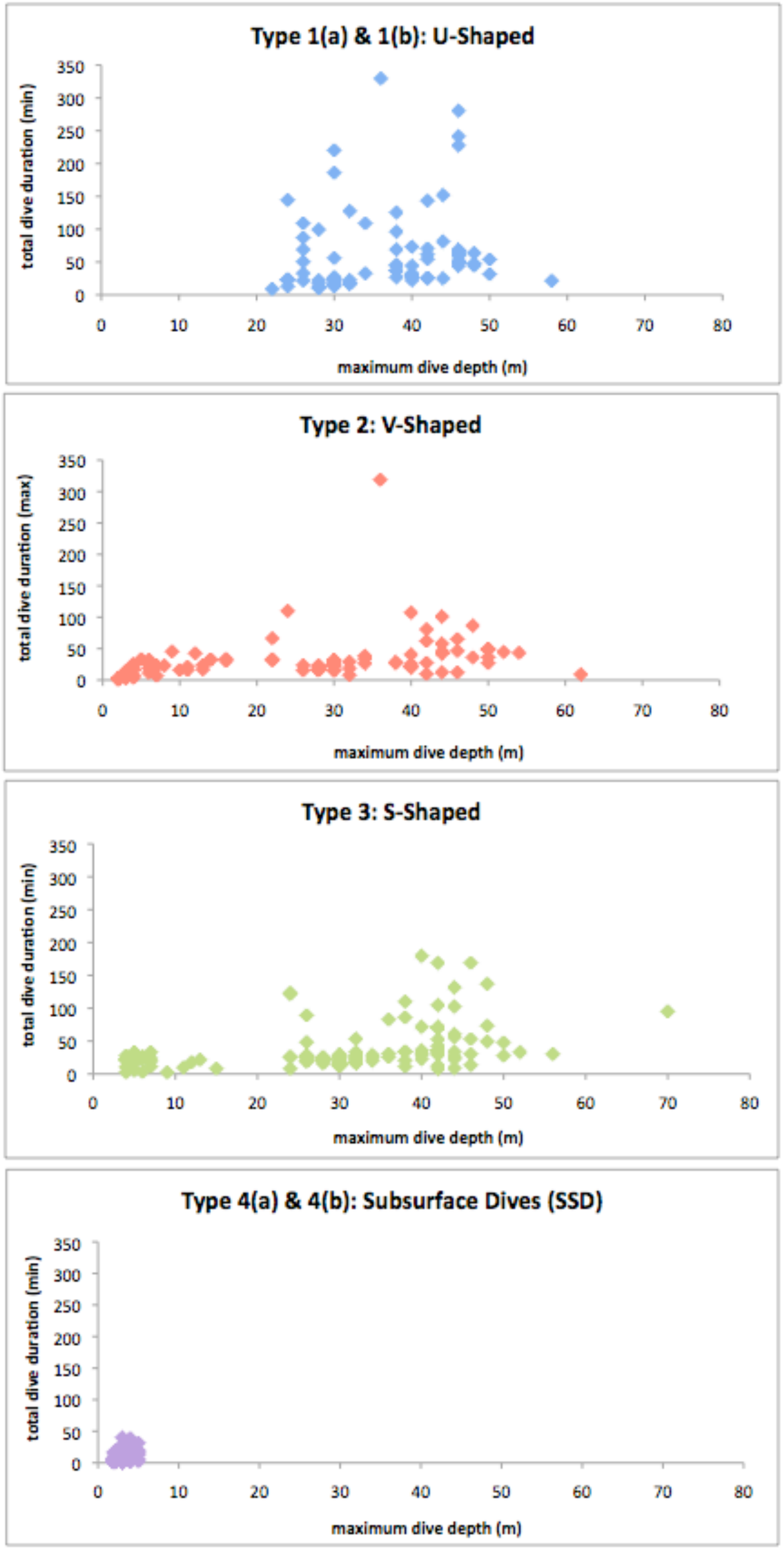


Figure 13. Correlation between total dive duration and maximum dive depth for each general dive type (n=3).

REPTILIAN PROFILE #1 : REPTILIAN PANEL #1

Test	Result	Reference Range	Low	Normal	High
ALK. PHOSPHATASE	24	U/L			
ALT (SGPT)	24	U/L			
AST (SGOT)	354	U/L			
CK	1137	U/L			
LDH	54	IU/L			
ALBUMIN	1.0 [1]	g/dL			
TOTAL PROTEIN	3.6	g/dL			
GLOBULIN	2.6	g/dL			
CHOLESTEROL	73	mg/dL			
GLUCOSE	86	mg/dL			
CALCIUM	7.3	mg/dL			
PHOSPHORUS	4.8	mg/dL			
POTASSIUM	3.6	mEq/L			
SODIUM	154	mEq/L			
A/G RATIO	0.4				
URIC ACID	1.7	mg/dL			

Comments:

1. RESULT VERIFIED BY REPEAT ANALYSIS

REPTILIAN PROFILE #1 : AVIAN/EXOTIC CBC AND PLASMA PROTEIN

Test	Result	Reference Range	Low	Normal	High
WBC-EST	4.2-6.2	THOUS.			
WBC COUNT	5.2 [1]	THOUS.			
HCT	40.0	%			
HETEROPHILS	67	%			
LYMPHOCYTES	30	%			
AZUROPHIL	3	%			
ABSOLUTE HETEROPHIL	3484	/uL			
ABSOLUTE LYMPHOCYTE	1560	/uL			
ABSOLUTE AZUROPHIL	156	/uL			
THROMBOCYTES	ADEQUATE				
BLOOD PARASITES	NO PARASITES SEEN				
REMARKS	SLIDE REVIEWED MICROSCOPICALLY.				
PLASMA PROTEIN	3.8				

Figure 14. Example of previously processed IDEXX blood chemistry results.

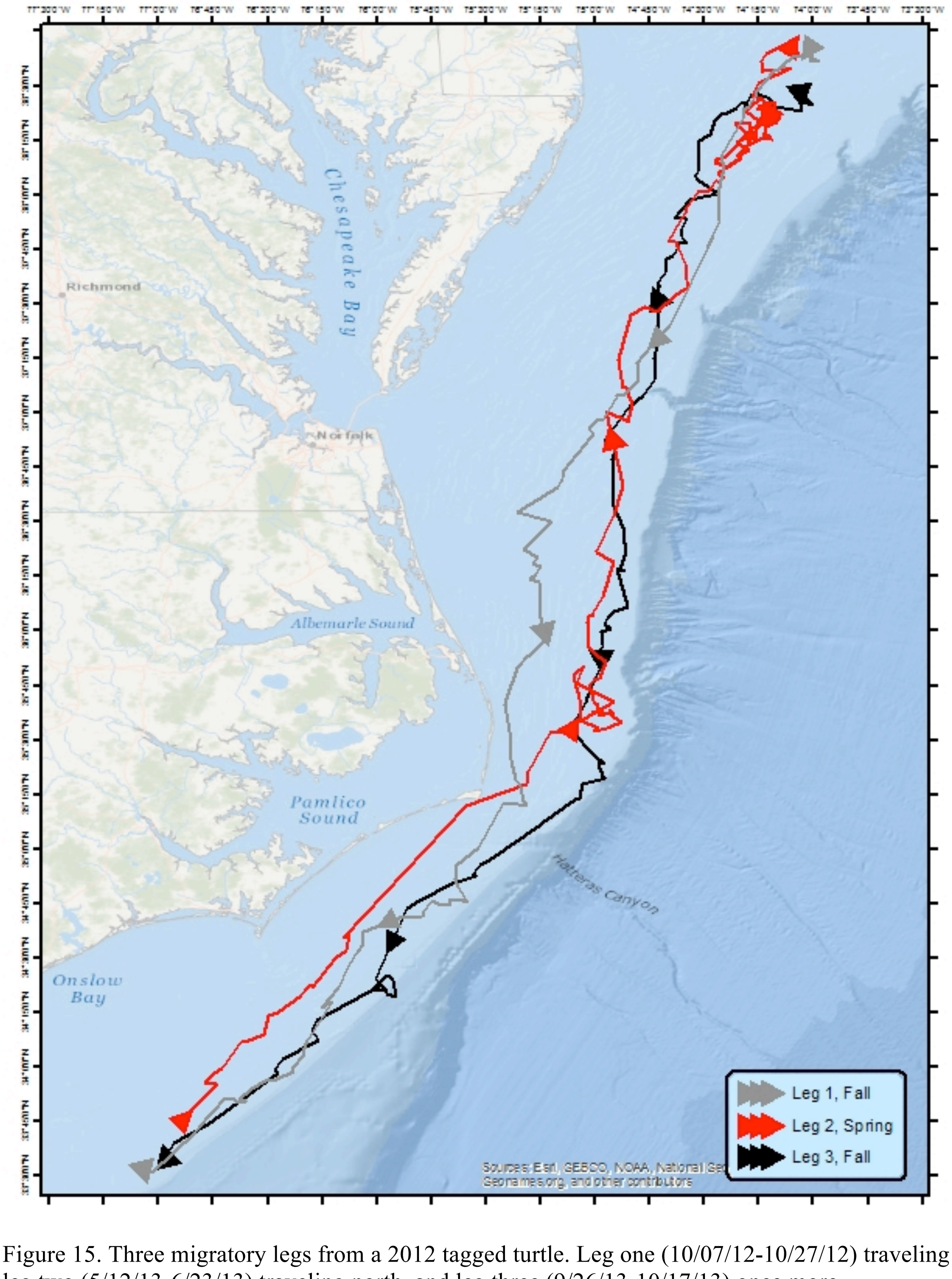
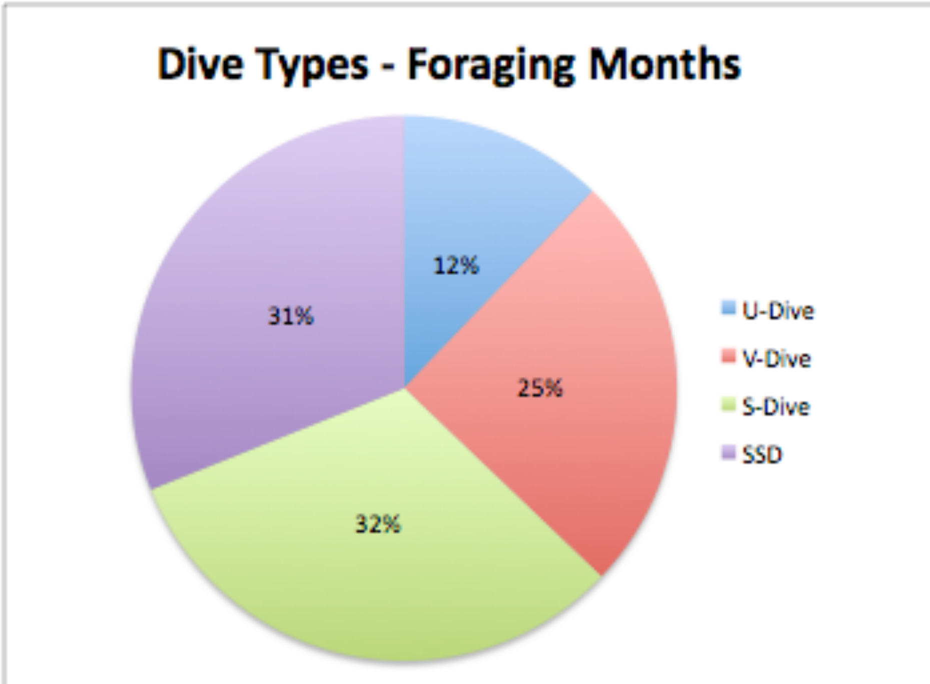


Figure 15. Three migratory legs from a 2012 tagged turtle. Leg one (10/07/12-10/27/12) traveling south, leg two (5/12/13-6/23/13) traveling north, and leg three (9/26/13-10/17/13) once more.



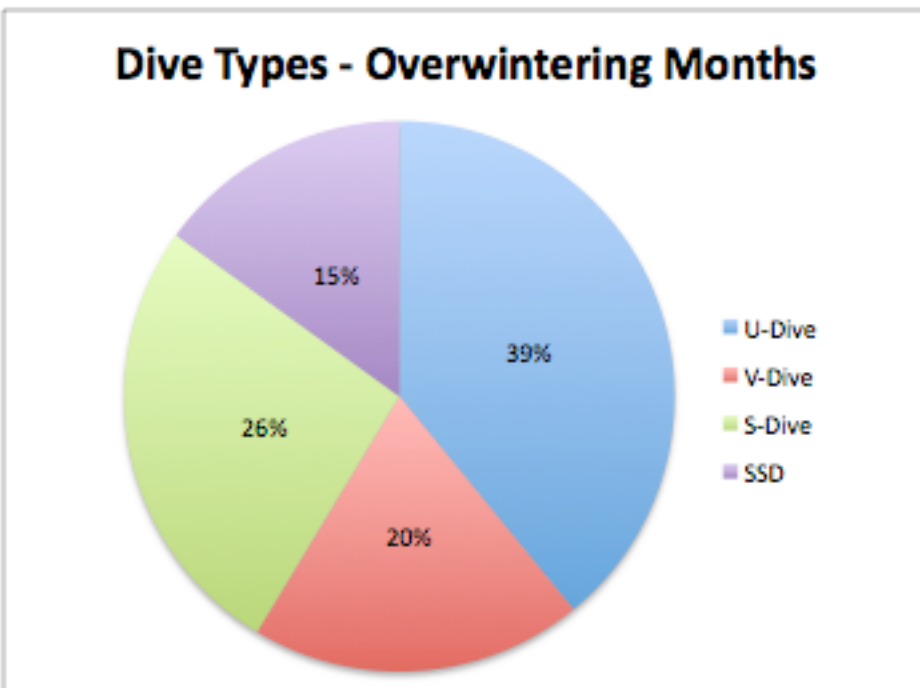


Figure 16. Proportion of type of dives completed during the summer foraging months (*n*=283) and overwintering months (*n*=133).

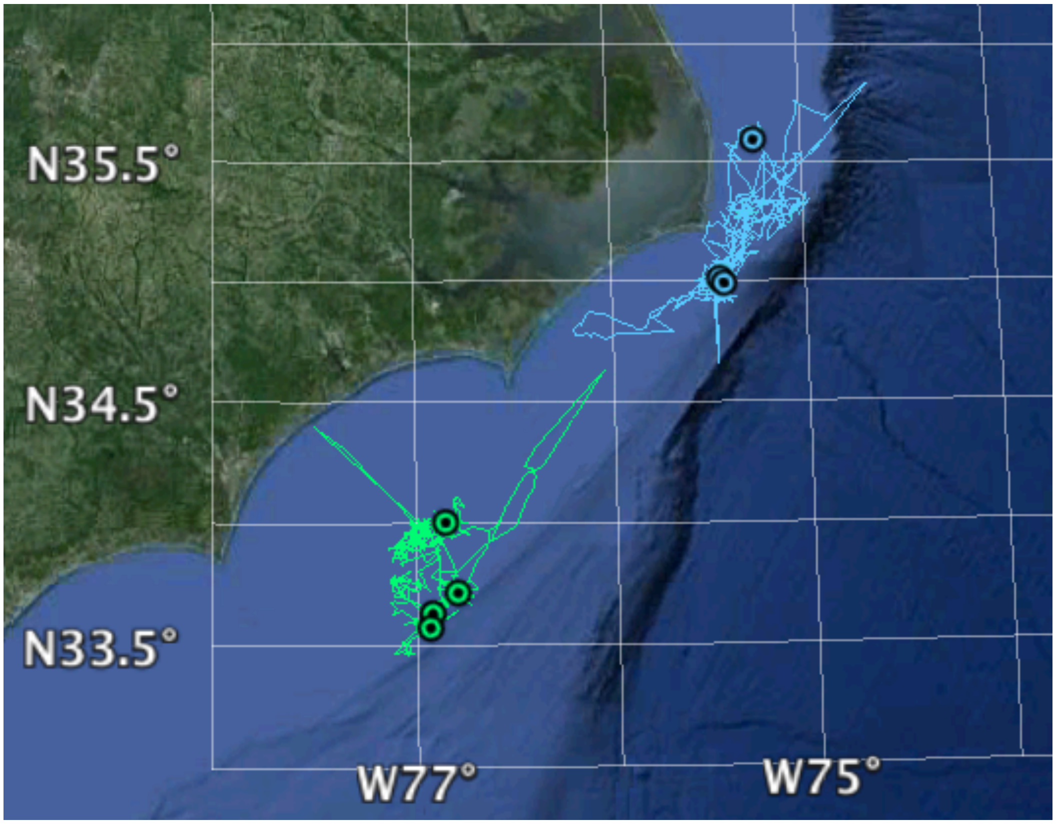


Figure 17. Tracks during 11/21/13-2/28/14 of the two distinct groups of tagged turtles (*n=7)*.

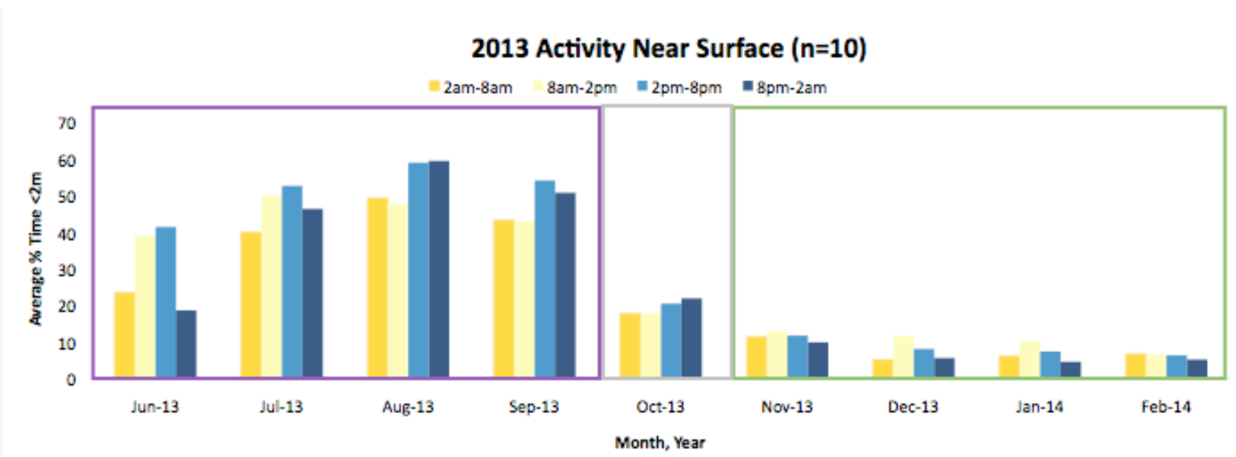


Figure 18. Average time spent by sea turtles in the Mid-Atlantic near the surface during six time periods (2am-8am, 8am-2pm, 2pm-8pm, 8pm-2am) separated by month, with a clear peak between the summer and late fall. The purple box (June-September) designates the general foraging months, the grey box (October) designates the general migratory period, and the green box (November-February) designates the overwintering time.

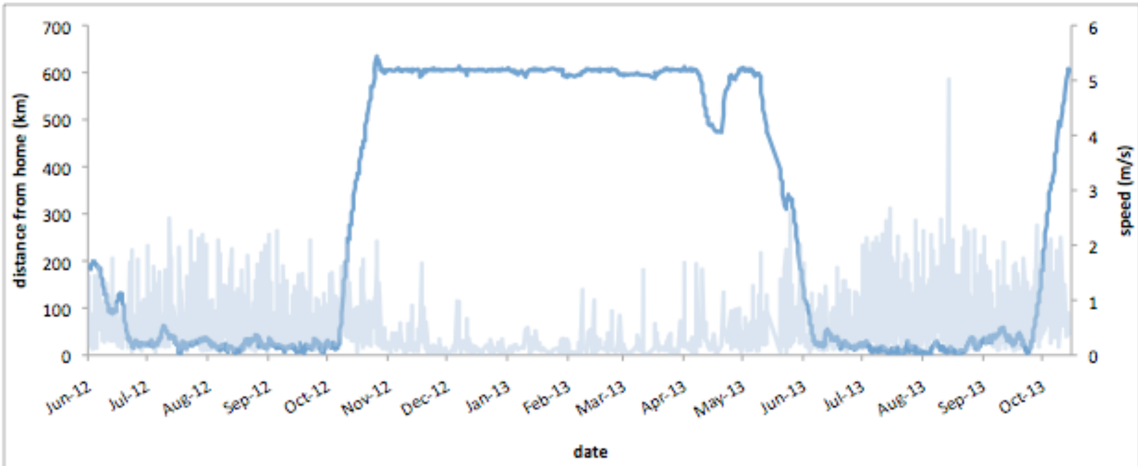


Figure 19. Distance from home range over 1.5 years of a previous tag (2012). Summer months indicate close proximity to "home" – foraging grounds – to a greater distance during the overwintering months, as well as a return to the home foraging sites.

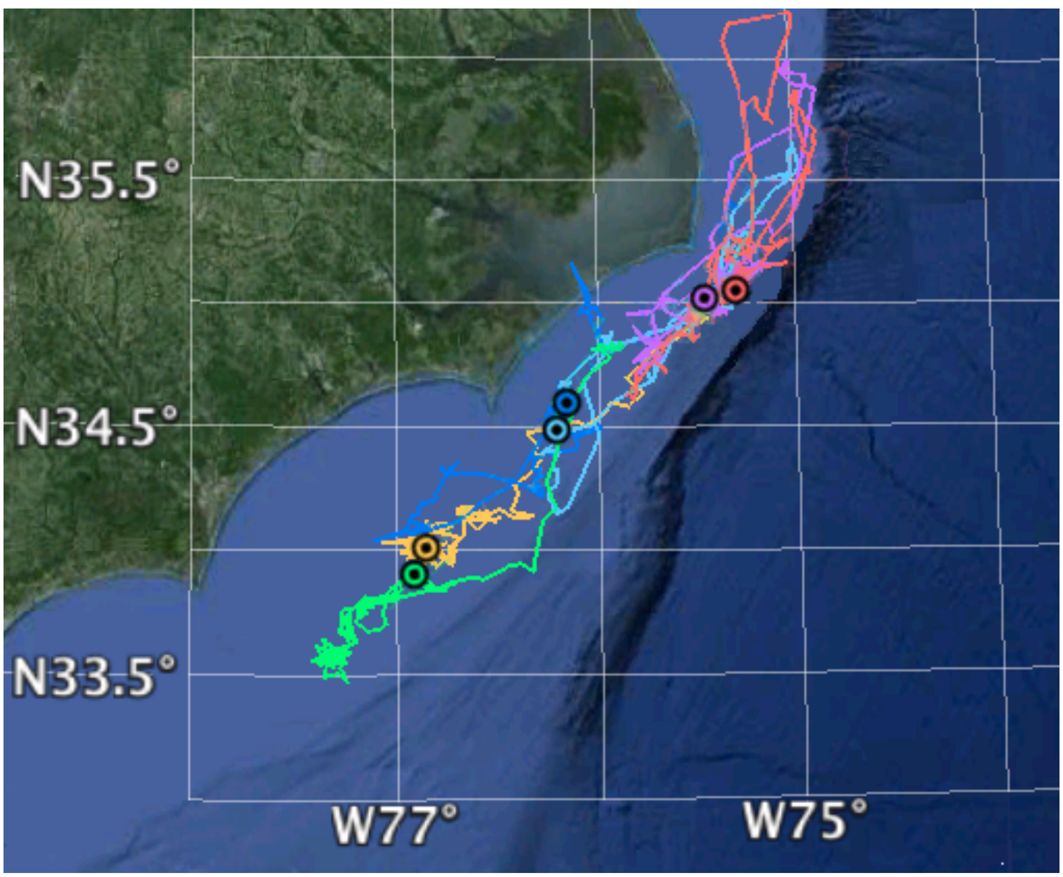
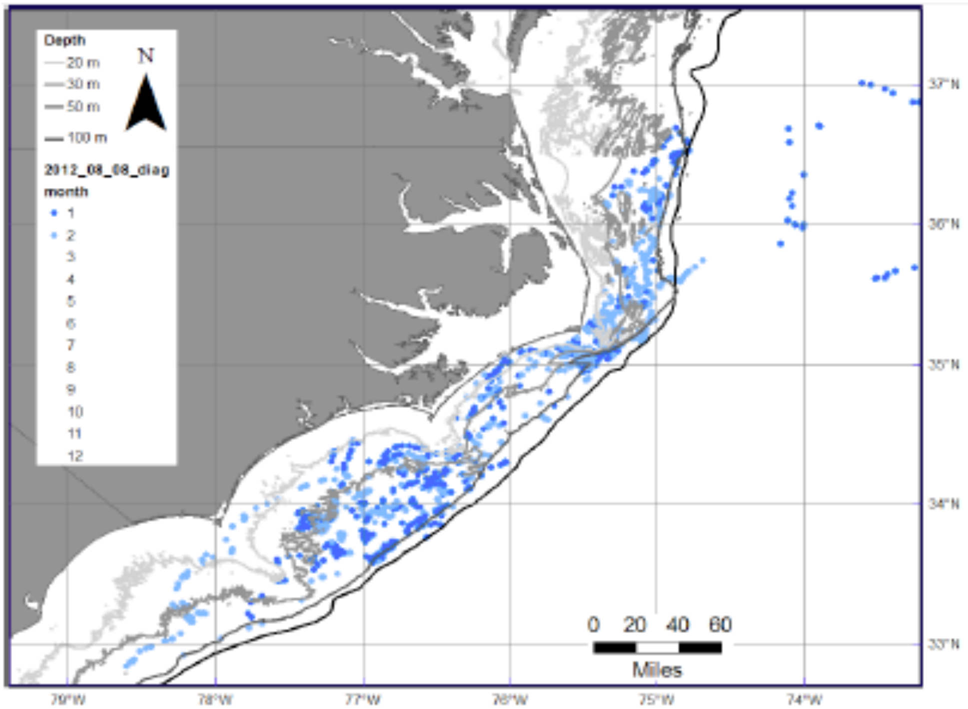
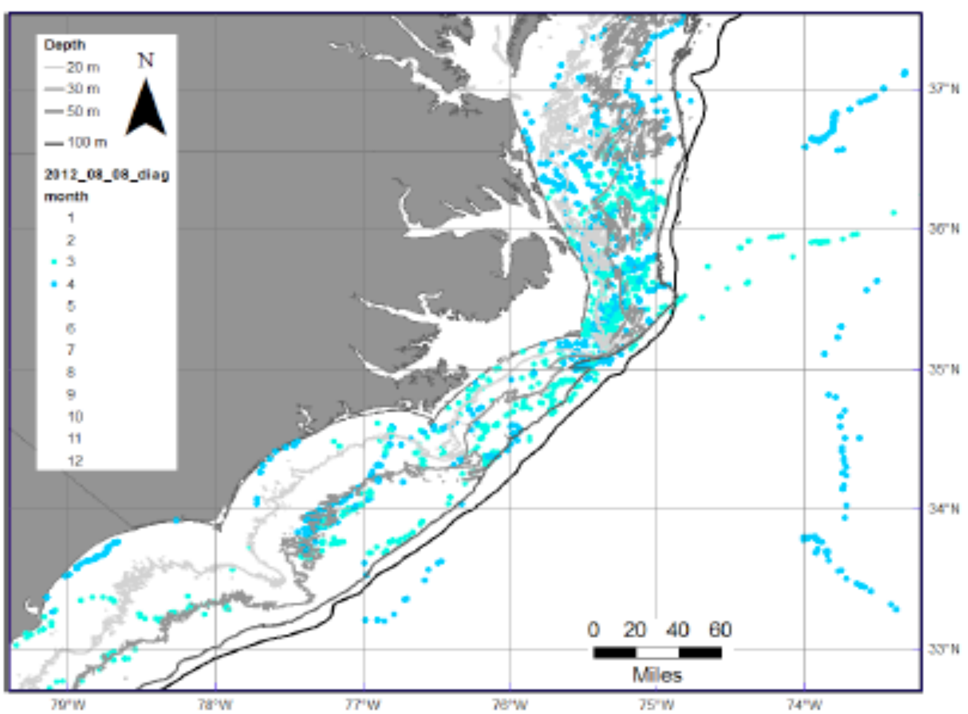
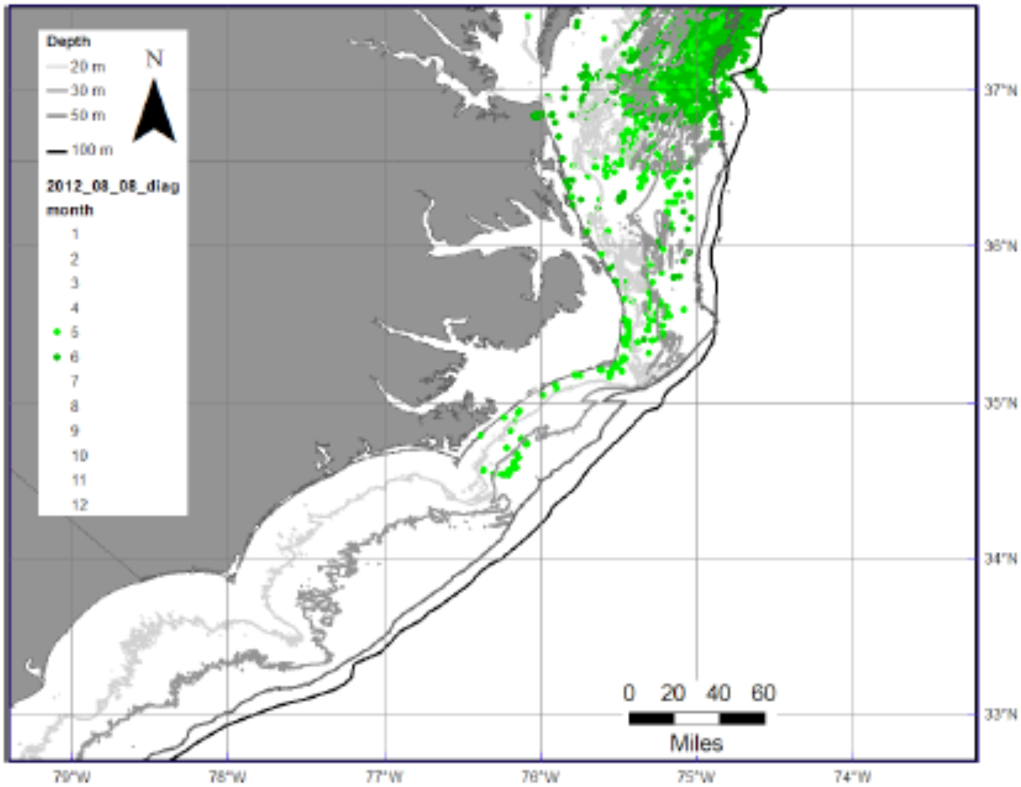


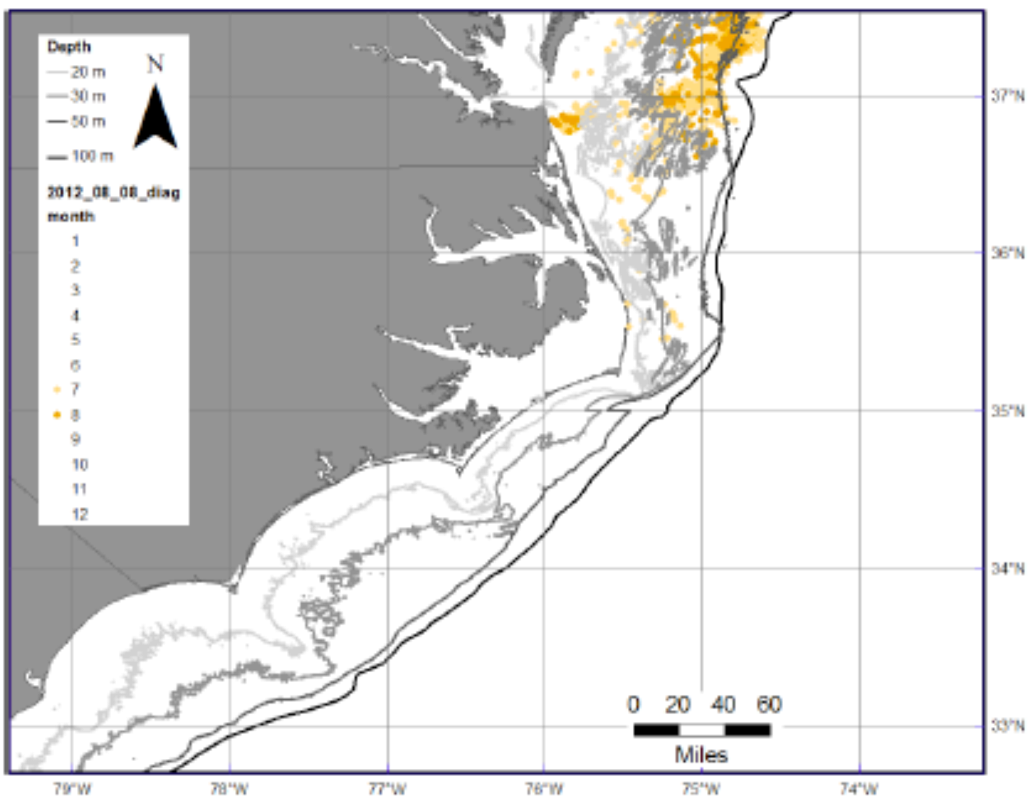
Figure 20. Tagged turtles' more sporadic overwintering foraging grounds (November-February 2012)(*n*=6)

Addendum A: The use of our dataset from this project has been applied to the Scallop Framework Actions, and assisted in determining critical habitat of loggerheads (January – December 2012)






Depth
20 m
30 m
50 m
100 m
N
2012_08_08_diag
month
1
2
3
4
5
6
7
8
9
10
11
12
0 20 40 60
Miles
37°N
36°N
35°N
34°N
33°N
79°W
78°W
77°W
76°W
75°W
74°W


Depth
20 m
30 m
50 m
100 m
N
2012_08_08_diag
month
1
2
3
4
5
6
7
8
9
10
11
12
0 20 40 60
Miles
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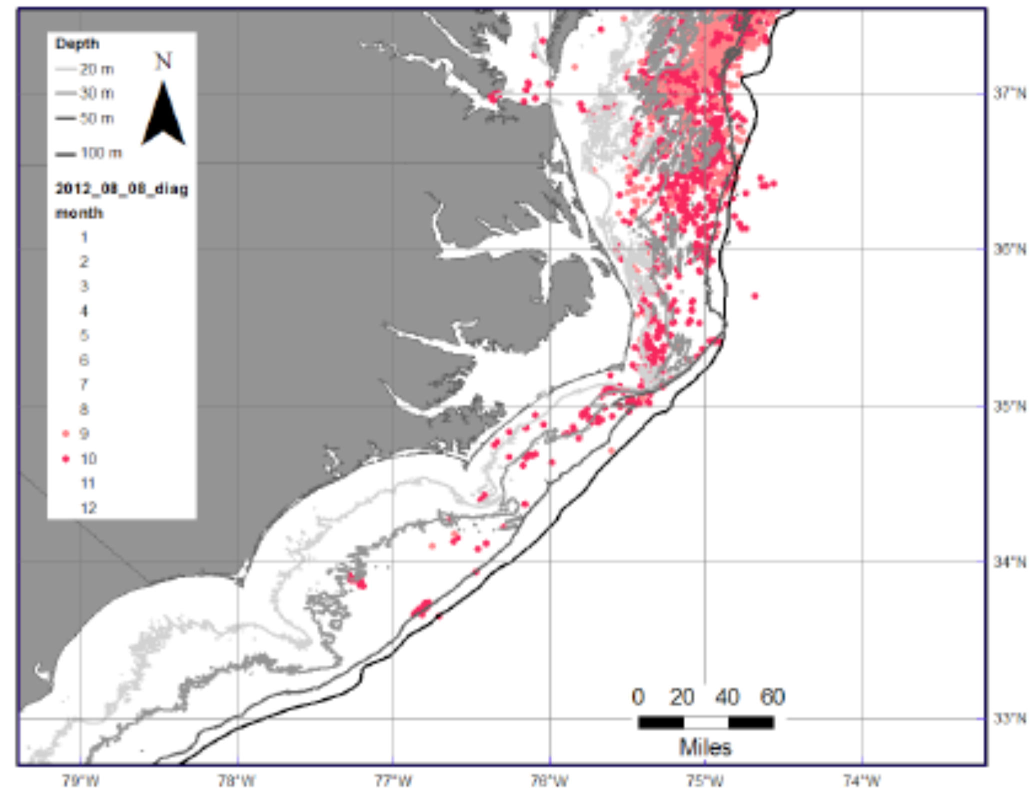
76°W
75°W
74°W


Depth
20 m
30 m
50 m
100 m
N
2012_08_08_diag
month
1
2
3
4
5
6
7
8
9
10
11
12
0 20 40 60
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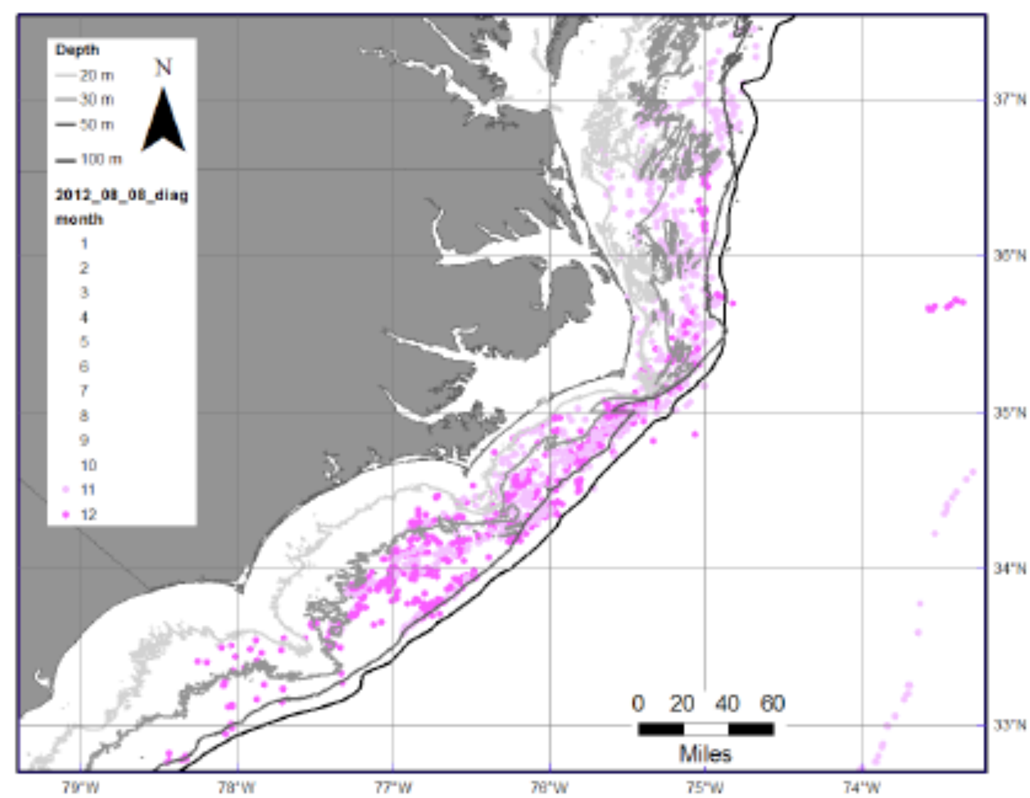
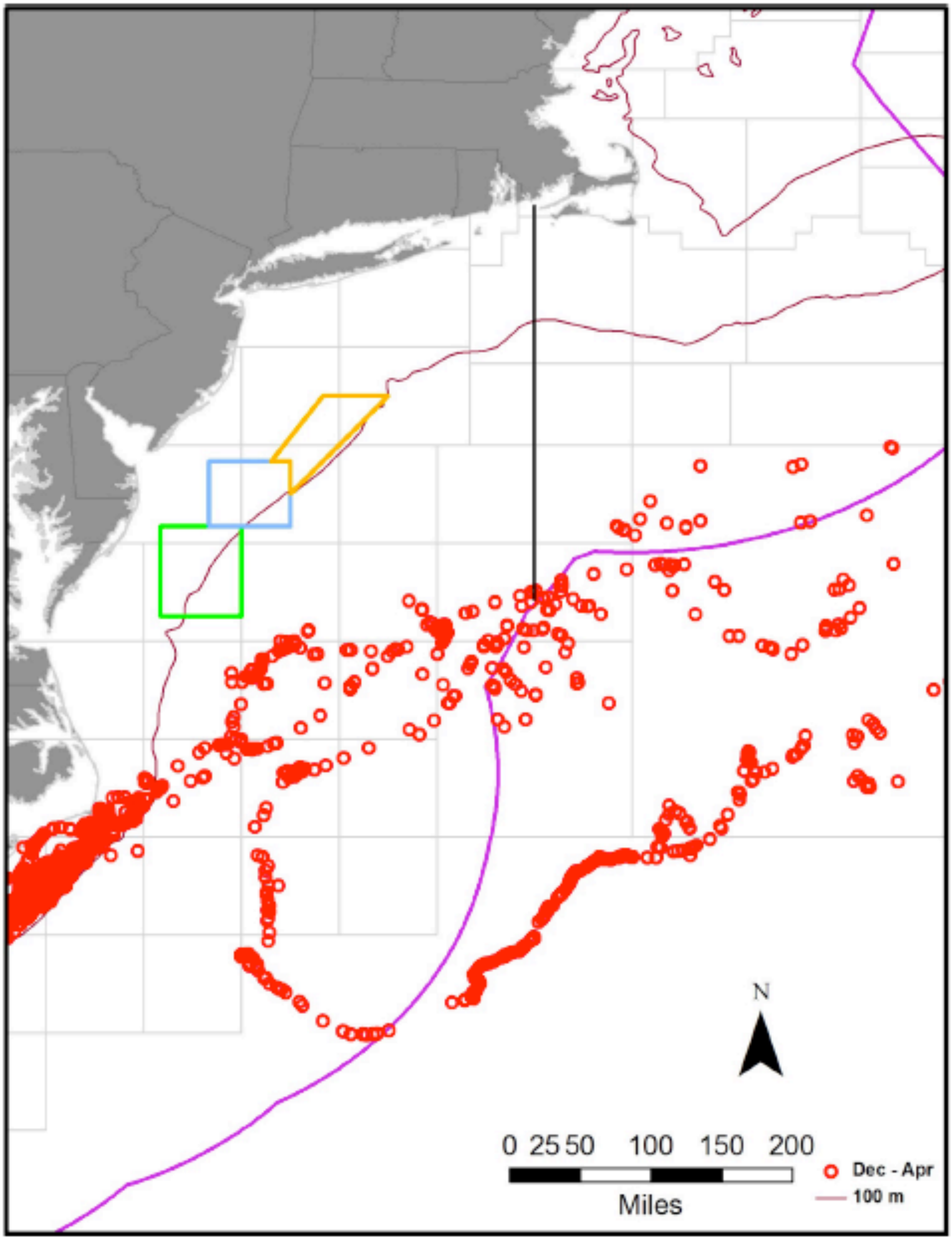
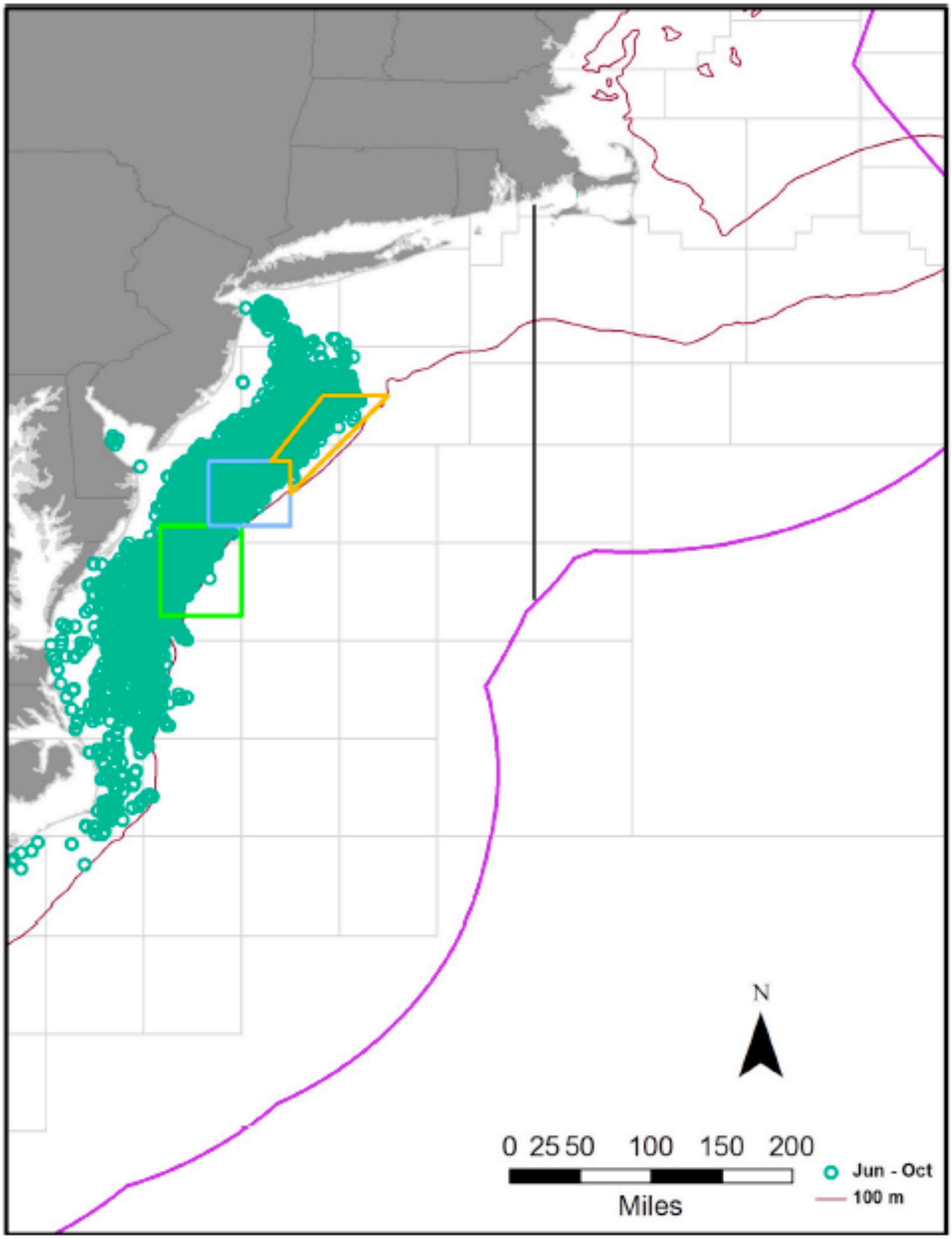
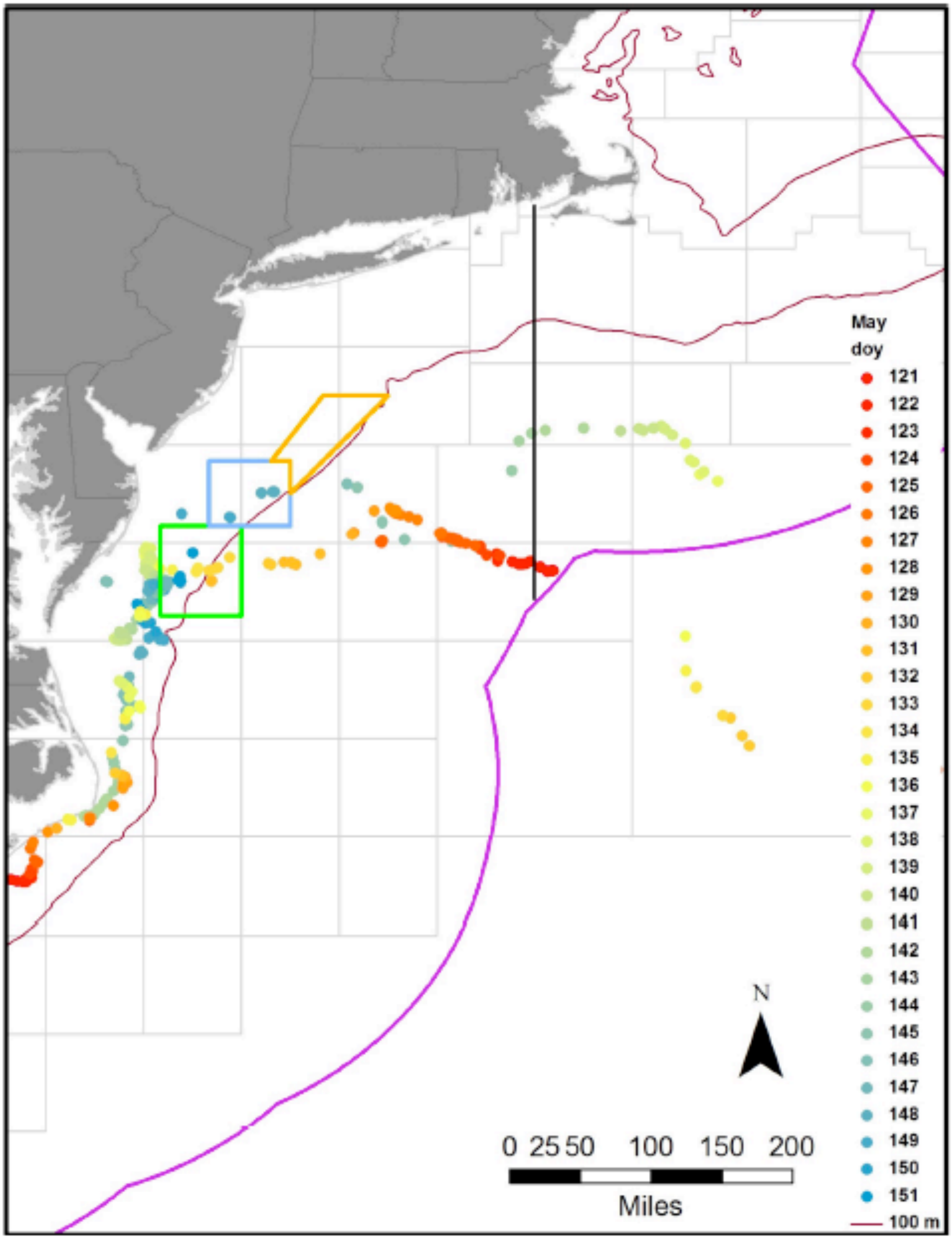
76°W
75°W
74°W


Depth
20 m
30 m
50 m
100 m
N
2012_08_08_diag
month
1
2
3
4
5
6
7
8
9
10
11
12
0 20 40 60
Miles
37°N
36°N
35°N
34°N
33°N
79°W
78°W
77°W
76°W
75°W
74°W

Addendum B: The use of data from this project to define area and seasons for the CFTDD. Hudson Canyon, DelMarVa, and Elephant Trunk Scallop Access Areas are depicted within each map.




N
0 25 50 100 150 200
Miles
Jun - Oct
100 m



May
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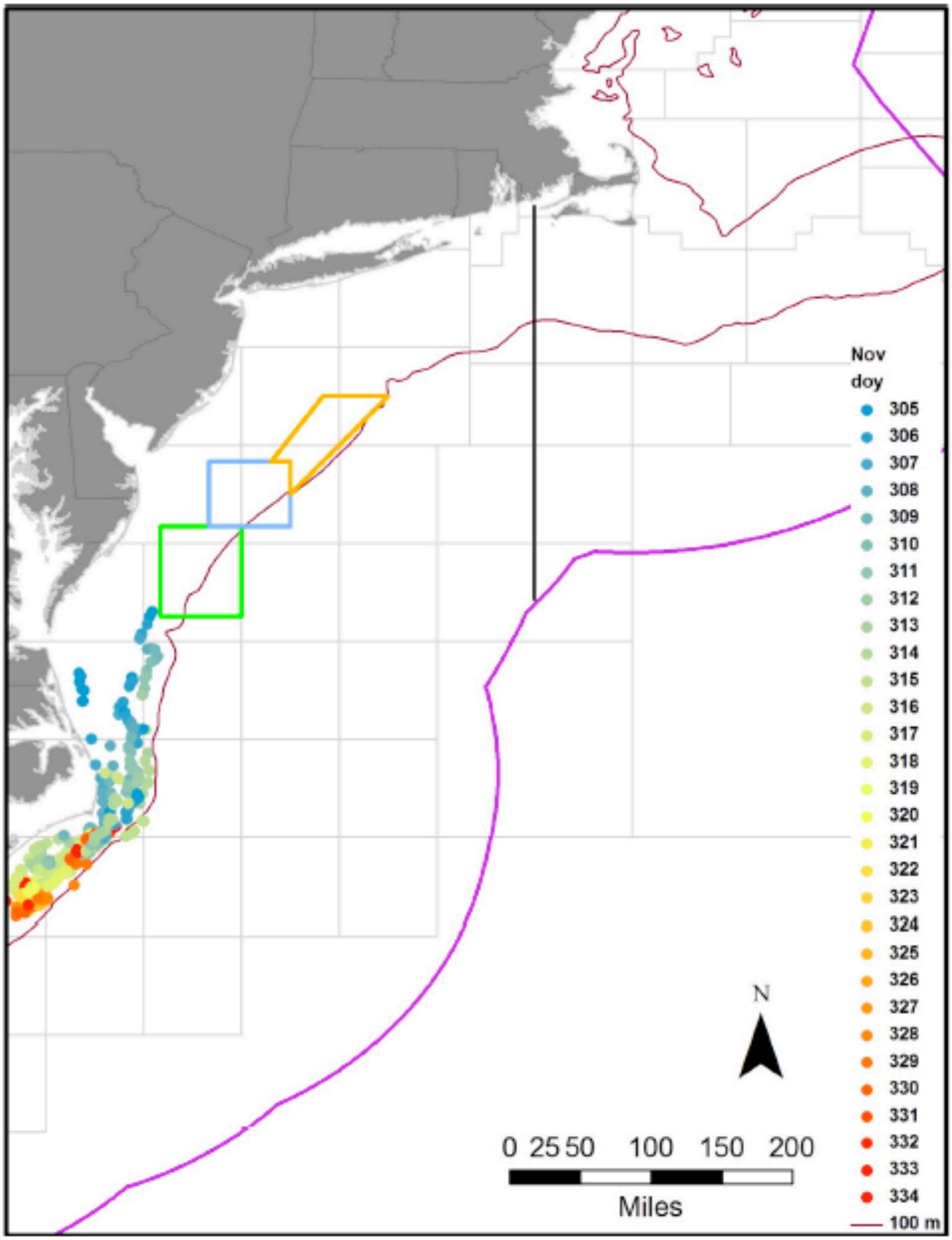
148
149
150
151
100 m
N
0 25 50 100 150 200
Miles


Nov
doy
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332
333
334
100 m
N
0 25 50 100 150 200
Miles