LOGGERHEAD SEA TURTLE DIVING BEHAVIOR

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By:

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INTRODUCTION:

The U.S. Army Corps of Engineers (ACOE), Norfolk Division has utilized hopper dredges off the coast of Virginia to obtain sand for placement on oceanfront beaches along Virginia Beach, Virginia. Hopper dredging and beach nourishment are activities which have the potential to adversely affect sea turtles, either directly by encounters with dredging equipment or indirectly by alteration of nesting habitat (Coston-Clements and Hoss, 1983). In 2001 and 2002, ACOE dredging operations in Thimble Shoals Channel exceeded the National Marine Fisheries Service sea turtle incidental take limits for loggerhead turtles (*Caretta caretta*) and Kemp's ridley sea turtles (*Lepidochelys kempi*), resulting in a temporary cessation of operations and the need for relocation trawling. The threat to Virginia's sea turtles can be minimized by gathering life history data on the sea turtles inhabiting Virginia's waters during the time that dredging operations are in effect. Examining sea turtle diving patterns will help determine their vulnerability to different fishing/commercial gears, aiding the development of management plans that may reduce the number of incidental turtle takes in near-shore fisheries and dredging activities.

Each year, between 200 and 400 sea turtle stranding deaths are recorded within Virginia's waters. The vast majority of these strandings are juvenile loggerhead and Kemp's ridley sea turtles. These sea turtle mortalities may be attributed to a variety of fishing and commercial operations found within State waters. In recent years, the number of annual sea turtle deaths has been on the rise. This increase may be due to either intensified fishing/commercial pressure, or to an increase in the sea turtle population over time.

The distribution, biology and behavior of sea turtles are strongly linked to the thermal regimes of a turtle's environment (Spotila et al., 1997). Temperatures within any given environment can vary geographically, seasonally, or by depth. With the exception of leatherbacks, sea turtles are not efficient thermoregulators (Zug et al., 2001). Loggerhead sea turtles can only exceed ambient water temperatures by 1° or 2° C (Zug et al., 2001), and therefore must compensate for their inability to thermoregulate via other mechanisms, including habitat selection and temporal/seasonal changes in activity (Zug et al., 2001). Virginia's estuarine and coastal waters are subject to a large range of temperature regimes over the course of four seasons. Temperatures in winter get as low as 1º C, while summer Bay temperatures may reach 30º C. Sea turtles are resident in Virginia waters between May and November (Lutcavage, 1981, Musick et al., 1984), with a few strandings occurring as early as mid-April or as late as December. Analysis of sea surface temperatures during residency seasons indicate that turtles first migrate into Virginia's waters when sea temperatures warm to approximately 18º C (Bellmund et al., 1987; Byles, 1988; Keinath et al., 1987; Musick, 1988; Keinath, 1993; Coles, 1999). When sea surface temperatures drop in the fall, turtles will begin their southern migration out of the Bay and coastal waters, over-wintering in waters ranging from North Carolina south to Georgia, Florida and the Gulf of Mexico (Keinath, 1993; Mansfield et al., 2001). Prolonged exposure to temperatures lower than 8° to 10° C may result in cold stunning, or a disruption in the turtle's metabolic pathways, resulting in loss of buoyancy and inability to dive or swim (Spotila et al., 1997).

The VIMS Sea Turtle Research Program has used aerial surveys to determine relative abundance and seasonal distribution of animals found in Chesapeake Bay and coastal waters (Byles, 1988; Keinath, et al., 1987; Keinath and Musick, 1987). Aerial surveys conducted between 1982 and 1985 and 1991 to 1992 indicated that 6,500 to 9,700 turtles are found in Virginia's waters within any given season (Byles, 1988; Musick et al., 1984; Keinath et al.,

1987). These estimates were based on the number of aerially observed sea turtles extrapolated to account for the entire Chesapeake Bay. The largest numbers of sea turtles were observed during the spring of the year, implying that the greatest sea turtle abundances occurred within the spring. Sea turtle population estimates for the Chesapeake Bay were not consistently quantified for over ten years due to lack of available funding. Surveys were reinstated during the 2001 and 2002 seasons. The distribution of sea turtles aerially observed in 2001 and 2002 were consistent with the distribution of sea turtles observed during VIMS turtle surveys in the 1980's (Mansfield et al., 2002a; 2002b). However, questions remain concerning sea turtle surfacing behavior during these early months.

Byles' radio and sonic tracking work in the 1980's indicates that sea turtles spend 5.3% of their time at the surface while foraging in the Bay during the summer months (Byles, 1988). When migrating long distances, loggerhead sea turtles spend 10 to 20% of their time at the surface due to the metabolic costs of migration requiring increased oxygen intake (Byles, 1988). These data were collected by tracking sea turtles with sonic and radio transmitters (Byles, 1988; Keinath, 1993; Musick and Limpus, 1997) during the summer and fall in Chesapeake Bay and coastal waters. However, surfacing behavior may vary with season (Keinath, 1993), particularly early in the residency season when sea temperatures are lower and waters are more stratified—cooler temperatures layered below a shallower warm water layer. To date, no data have been available to describe sea turtle surfacing behavior in the spring when the animals first enter Chesapeake Bay, a time period when aerial density estimates are higher, and strandings rates are highest.

To improve estimates of regional abundance from surface densities, more data are needed on the amount of time turtles are visible on the sea surface throughout their residency in Virginia waters. If it is found that turtles spend significantly more time above the thermocline in the spring, then the likelihood of turtle takes by hopper dredges is reduced during that season. Thus, the window for turtle safe dredging activities may broaden based on thermocline location, bottom temperature and associated sea turtle diving behavior. This report describes the at-sea movements of the turtles tracked over a period of time up to 24 hours post-release, including an analysis of seasonal sea turtle diving/surfacing behavior. These data will be related to the potential interaction of sea turtles with dredging operations and beach replenishment.

METHODS:

Between May 22 and July 17, 2002 seven sea turtles were outfitted with both VHF radio (Lotek RMMT_3) and acoustic (Lotek CAFT16_3) transmitters to track their at-sea movements. Two of these turtles also received UHF satellite transmitters (Wildlife Computers, Inc. SPOT2 and SDR-T16). Two radio frequencies were used for the radio transmitters: 148.380 MHz and 149.800 MHz. Each radio tag had a three second pulse rate and was encoded with a unique number in order to identify individual turtles while tracking. Sonic tags were set at a frequency of 150.066 MHz (or 65.5 KHz) with a three second pulse rate. Sonic tags were also encoded with a unique number matching those of the radio tags. Due to permitting constraints, only incidentally caught turtles captured by cooperative poundnet fishermen and cold stun rehabilitated turtles that had over-wintered at the Virginia Marine Science Museum (VMSM) were available to track during the spring months of 2002. Of the turtles tracked, six were loggerheads and one was a Kemp's ridley. One of the loggerheads was an adult female, the remaining four were juveniles. The Kemp's ridley was close to adult sized and one of the largest live specimens recorded in Virginia. Two of the juvenile loggerheads were cold-stunned

strandings in 2001. These turtles were rehabilitated during the winter of 2001-2002 by VMSM. VIMS veterinarian Dr. R. George declared these turtles healthy and ready for release in the Spring of 2002.

Prior to tag application, turtles were measured, flipper tagged, and the turtles' scutes were lightly sanded with 100 grit sandpaper and cleaned with acetone. Radio and satellite transmitters were placed on the turtles' carapace at the second vertebral scute. This location provided optimum transmission when the turtles surfaced to breathe. Quick setting Power-Fast™ marine epoxy resin, amine hardener and Fibre Hair Body Filler™ fiberglass resin were used to attach the transmitter to the turtle. Acoustic (sonic) transmitters were placed along the ninth and tenth marginal scute, typically along the left side of the turtle. These transmitters were secured into place using quick setting marine epoxy and fiberglass resin.

A Lotek hydrophone and receiver (SRX 400) were used to monitor the respiratory behavior of the sea turtles through direct observation of radio/sonic signals onboard the tracking vessel. The first turtle was tracked with a polarized 150 MHz H antenna. Due to the limited range of this antenna, later turtles were tracked with a three-element Yagi antenna. Approximately one turtle was tracked each week. With the exception of one loggerhead juvenile (the first turtle tracked) and the adult loggerhead, all turtles were released in the Bay mouth just outside the Chesapeake Bay Bridge Tunnel (CBBT) within the Thimble Shoal or Chesapeake Channel. The first turtle tracked and the adult loggerhead were released at the mouth of or approximately five miles up the York River at the VIMS beach. Turtles were tracked continuously for eight to 24 hours post-release. Tracking time was heavily dependent upon weather and sea state. When turtles surfaced to breathe, the radio tags emit a coded signal, based on time intervals of a three second pulse, to the receiver located onboard the tracking vessel (Pemberton, 2000). Radio transmissions cease when the turtle is sub-surface. Prior to tracking, a series of range tests were conducted to determine relative distances of tags from the tracking vessel based on received signal strength. The locations of the turtles were estimated from GPS locations of the tracking vessel and the relative strength and direction of radio and sonic signals relative to the tracking vessel (Pemberton, 2000). Turtles could be tracked when below the surface via acoustic signals emitted by the sonic tags, ensuring that the tracking vessel remain within the signaling range of the turtles' radio transmissions.

The UHF satellite transmitters (SPOT 2 and SDR-T16) were also used to remotely track the long-term movements of two sea turtles in the spring. Position data were transmitted to NOAA Tiros Satellites when the turtles surfaced to breathe. Tags were programmed with a duty cycle of one day on, one day off, resulting in location and data transmissions occurring every other day. Position data were determined via Doppler shift. The shift in frequency in each signal received by the satellite "indicates the satellite's speed relative to the tag. A tag's bearing is computed based on the ratio of this speed to the satellite's ground speed" (Kenward, 2001). At least two such bearings are needed in order for tag position to be estimated. The accuracy of these positions was determined by the number of bearings (or satellite passes) available per transmission. All position data were sorted based on accuracy codes received with each data transmission. All data were transferred from the NOAA satellites to the ARGOS data processing system, which in turn sent the data in email format to VIMS.

All location (radio/sonic and satellite) data were imported into either ArcView 3.2 (Mercator projection) or Captain Voyager Version 5 and plotted. Kernel analyses for home range were performed on the long-term satellite tracks using the Spatial Analyst and Animal Movement extensions (Hooge et al., 2001). Kernel analyses use "locations of an individual to

generate a probability density" (Millspaugh and Marzluff, 2001) based on the frequency distribution of location data over time. Kernel outputs are calculated using the estimated value of the distribution per location point (Millspaugh and Marzluff, 2001). Kernel output contours were set at 95% and 50% confidence levels. The 95% contour is typically used to determine the area the animal actually inhabits or uses, and the 50% contour is used to determine the "core area of activity" (Hooge and Eichenlaub, 1997).

Temperature profiles of the water column were taken at the time of release for each turtle using an YSI 600XL Sonde with temperature and conductivity sensors. Differences between surface and bottom temperatures at time of release for each turtle were determined by regression using Minitab v12. A paired t-test was used to determine whether there was a significant difference between the temperature profiles among tracking events (May 23-July 18, 2002). One-way analyses of variance (ANOVA) were used to test for differences in surface and dive times among individuals.

RESULTS:

A summary of data for the seven turtles tracked within the Chesapeake Bay may be found on Table 1. All turtles were tracked approximately one week apart beginning May 23, 2002, and ending July 18, 2002.

Radio/Sonic Tag #198; Satellite Tag #04936; Loggerhead (juvenile)

Turtle #198 was released May 23, 2002 in 31 feet of water in the York River Entrance Channel near the mouth of the York River. The curved carapace length of this turtle was 53.4 cm, indicating that it was a juvenile. The turtle was released on an ebb tide and swam with the current, along the York River Channel, adjacent to Poquoson Flats (Figure 1). With the change in tide after sunset, the turtle remained within the flats until track was broken. Tracking was aborted approximately eight hours after release due to high seas and winds. Follow-up tracking the next two days for this turtle was unsuccessful.

At the time of release, surface temperatures were approximately 18.3º C, and bottom temperatures were approximately 17.9º C (Figure 2). The analysis of variance indicated that there was a significant difference between surface and bottom temperatures ($p=0.000$; $R^2=28.1\%$, the low R^2 value was possibly due to a dip in temperature mid-depth) (Figure 3). This turtle was tracked with an H antenna, which proved inadequate for receiving consistent surfacing data, therefore respiratory behavior could not be quantified. Further, the Wildlife Computers SPOT2 satellite tag transmitted data for three days while the turtle was held in VIMS turtle facilities, however upon release, the tag ceased transmitting.

Radio/Sonic Tag #199; Loggerhead (juvenile, cold-stun rehabilitated turtle)

Turtle #199 was released May 28, 2002 within the Chesapeake Channel on the ocean side of the CBBT. The turtle was released into 32 feet of water. The curved carapace length of turtle #199 was 61.5 cm, indicating that it was a juvenile. This turtle swam in a large circuit that after approximately 10 hours of tracking, brought it back in the same vicinity of its release location (Figure 4). Track was broken due to high seas and winds. When last observed, the turtle was heading towards the CBBT and into the Bay.

When Turtle #199 was released, surface temperatures were approximately 22.5º C, and bottom temperatures were approximately 19.1º C (Figure 5). The analysis of variance indicated that there was a significant difference between surface and bottom temperatures (p=0.000; R^2=83.3%) (Figure 3). Peak surfacing times occurred between 19:00 and 21:00 (Figure 6). The mean time spent at the surface was 32 seconds (stdev. +/- 0:00:51) during the day and 57 seconds (+/- 0:00:39) at night. Mean dive time was 0:06:57 (+/- 0:07:32) during the day and 0:04:15 (+/- 0:02:52) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:06:00 during the day, 0:01:50 at night. Minimum dive times were 14 seconds during the day, 15 seconds at night. Maximum dive times were 0:40:23 during the day and 0:08:00 at night (Tables 2 and 3). This turtle, however was only tracked for a few hours after sunset, so the sample size for nighttime respiratory behavior is small.

Radio/Sonic Tag #192; Satellite Tag #01234; Kemp's ridley (possible adult)

Turtle #192 was released June 4, 2002 in 24 feet of water on the ocean side of the CBBT, mouth if the Bay. The curved carapace measurement of this turtle was 58.6 cm, indicating that it was either a large juvenile or adult sized. Shortly after release, seas picked up to 3-4 feet and approximately two hours after release, track was broken with turtle in order to secure a calm anchorage for radio monitoring in the lee of the CBBT near the Thimble Shoal channel. The turtle was picked up by radio receiver three hours later, indicating that the turtle was slowly moving up the shipping channel and through the CBBT channel opening, against an ebbing tide. Surfacing events were monitored continuously for approximately three hours until weather and tidal conditions required that the tracking trip be aborted. The long-term movements of this turtle were monitored remotely via satellite transmitter. The week following release, the turtle swam northwest to Mobjack Bay where it remained until mid-July, foraging along the shoreline near the mouths of the Ware, North and Severn rivers (Figure 7). Mid-July through the end of August when transmissions ceased, this turtle remained in the center of the Bay adjacent to Smith and South Marsh Islands (Figure 7).

At the time this turtle was released, surface temperatures were approximately 22.1º C, and bottom temperatures were approximately 20.0º C (Figure 8). The analysis of variance indicated that there was a significant difference between surface and bottom temperatures (p=0.000; R^2=92.3%) (Figure 3). No nighttime respiratory data are available for this turtle due to the shortened sampling period. Mean surface time during the day was 0:01:26 (+/-0:01:49), and mean daytime dive time was 0:03:08 (+/-0:03:05), with an increase in surfacing events during the time that the turtle was tracked passing through the CBBT (Figure 9). Minimum surface and dive times were six and ten seconds respectively; maximum surface and dive times were 0:07:34 and 0:12:47 (Tables 2 and 3). Maximum surfacing time occurred while this turtle was passing through the CBBT.

Kernel home range analysis of this turtle indicated that the primary home range for this turtle was in the waters adjacent to Smith's island as represented by the 50% Kernel probability contour (Figure 10). The 50% Kernel represented an area of 226.30 square kilometers. The area within which this turtle was likely to be found (95% probability Kernel contour) included Mobjack Bay as well as near the Bay mouth within a couple of days post-release (Figure 10). This included an area spanning 1,754.73 square kilometers. The region near the Bay mouth may be somewhat biased due to the period during which the turtle was being transported via boat to the release site and the salt-water switch on the satellite tag was exposed to air.

Radio/Sonic Tag #142; Loggerhead (juvenile, cold-stun rehabilitated turtle)

Turtle #142 was released June 11, 2002 south of the Chesapeake Channel and just north of the Thimble Shoals Channel on the ocean side of the CBBT. The turtle was released into 24 feet of water. The curved carapace length of turtle #142 was 59.6 cm, indicating that it was a juvenile. This turtle was released with an ebb tide. It swam southeast within the Thimble Shoals Channel, past Cape Henry, then almost directly south later in the day with a flood tide (Figure 11). Track was broken due to high seas and winds. The turtle was last observed east of Rudee Inlet, heading slightly offshore and to the southeast.

At the time of release, sea surface temperatures were 22.8º C. Bottom temperatures ranged between 20.9º and 21.0º C (Figure 12). There was a significant difference (p=0.000; R^2=91.2%) between surface and bottom temperatures (Figure 3). Peak surfacing events occurred between 17:00 and 18:00, 20:00 to 21:00 and 22:00 to 23:00 (Figure 13). The mean time spent at the surface was 23 seconds (+/- 0:00:23) during the day and 53 seconds (+/- 0:00:35) at night. Mean dive time was 0:03:01 (+/- 0:02:41) during the day and 0:04:30 (+/-0:02:33) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:02:15 during the day, 0:02:28 at night. Minimum dive times were 14 seconds during the day, eight seconds at night. Maximum dive times were 0:16:33 during the day and 0:11:55 at night (Tables 2 and 3). This turtle, however was only tracked for a few hours after sunset, so the sample size for nighttime respiratory behavior is small.

Radio/Sonic Tag #165; Loggerhead (juvenile)

Turtle #165 was released June 17, 2002 just south of the Chesapeake Channel on the ocean side of the CBBT. The turtle was released into 28 feet of water. Its curved carapace length was 68.7 cm, indicating that it was a juvenile. This turtle was released with an ebbing tide and swam south until the tide turned, after which it swam north along the Chesapeake Channel, under the CBBT and into the Bay. Once under the CBBT, with the tide ebbing, the turtle swam southeast and east until the tide flooded again when it began moving northward again (Figure 14). Track was broken on June 18, 24 hours after release of the turtle.

At the time of turtle release, surface temperatures were approximately 23.2º C, and bottom temperatures were approximately 22.9º C (Figure 15). The analysis of variance indicated that there was a significant difference between surface and bottom temperatures (p=0.000; R^2=69.3%) (Figure 3). Peak surfacing events occurred between 16:00 to 17:00 and 04:00 to 06:00 (Figure 16). The mean time spent at the surface was 24 seconds (+/- 0:00:30) during the day and 54 seconds (+/- 0:01:12) at night. Mean dive time was 0:03:17 (+/- 0:04:14) during the day and 0:05:30 (+/-0:08:10) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:04:44 during the day, 0:07:50 at night. Minimum dive times were six seconds during the day and night. Maximum dive times were 0:26:05 during the day and 0:28:15 at night (Tables 2 and 3). This turtle was tracked for over 24 hours.

Radio/Sonic Tag #167; Loggerhead (juvenile)

Turtle #167 was released June 24, 2002 just north of Thimble Shoals Channel on the ocean side of the CBBT. The turtle had a curved carapace length of 76.5 cm, indicating that it was a juvenile. It was released into 25 feet of water with a flood tide. This turtle immediately

swam east under the CBBT along the northern edge of the Channel (Figure 17). During the nighttime hours and an ebb tide, the turtle remained relatively stationary until the tide changed and morning arrived, after which it continued swimming north to northeast (Figure 17). Track was broken on June 25, 24 hours after release of the turtle.

Surface temperatures at the time that turtle #167 was released were approximately 25.4º C, and bottom temperatures were approximately 24.8º C (Figure 18). The analysis of variance indicated that there was a significant difference between surface and bottom temperatures ($p=0.019$; $R^2=40.8\%$) (Figure 3). Peak surfacing time occurred between 05:00 and 06:00 (Figure 19). The mean time spent at the surface was 29 seconds (+/- 0:00:39) during the day and 56 seconds (+/- 0:00:55) at night. Mean dive time was 0:06:50 (+/- 0:08:27) during the day and 0:08:33 (+/-0:07:40) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:03:12 during the day, 0:05:23 at night. Minimum dive times were six seconds during the day and night. Maximum dive times were 0:39:31 during the day and 0:29:39 at night (Tables 2 and 3). This turtle was tracked for approximately 18 hours.

Radio/Sonic Tag #211; Loggerhead (adult)

Turtle #211 was released from the VIMS beach on July 16, 2002. The curved carapace length of this turtle was 99.7 cm, indicating that it was an adult sized female. Ultrasound tests of this turtle confirmed its gender. This turtle's weight and size prohibited safe transfer to and from the tracking vessel for an in-water release. Thus the turtle was released from the VIMS beach upriver from the Coleman Bridge in the York River. This turtle initially swam with the ebbing tide under the Coleman Bridge until the tide turned and she swam with the flooding tide back under the Bridge towards the US Naval Weapons Station (Figure 20). When the tide turned again, she followed the ebbing tide out under the Bridge a third time, along the York River Channel. With the nighttime flood tide, she remained in the middle of the River, within the Channel until the tide changed again in the early morning and she followed it down river. Track was broken July 17, 24 hours post-release. The turtle was last seen swimming against a flood tide towards the mouth of the York River. This turtle was recaptured in the mouth of the Potomac River ten days later within the same poundnet that she was captured in originally. Follow-up tracking 14 days after her 24-hour track was unsuccessful. She was captured one more time within the same poundnet late summer.

When Turtle #211 was released, surface temperatures were approximately 25.4º C, and bottom temperatures were approximately 26.6º C near the VIMS beach adjacent to the Coleman Bridge (Figure 21). It is important to note that these temperatures increased with depth, unlike all other profiles taken in 2002. For greater comparison with the profiles from the first turtle tracked in 2002, profiles from the end of turtle #211's track in the mouth of the York River were used for temperature analyses. The analysis of variance indicated that there was a significant difference between surface and bottom temperatures ($p=0.007$; $R^2=42.9\%$) (Figure 3), however, temperatures also increased with depth (25.0º C to 27.3º C, Figure 22), unlike all other profiles earlier in the season where temperature decreased with depth (Figure 3).

Peak surfacing events occurred when the turtle was first released (09:00) and between 21:00 to 24:00 and 01:00 to 02:00 (Figure 23). The mean time spent at the surface was 8 seconds (+/- 0:00:07) during the day and 19 seconds (+/- 0:00:31) at night. Mean dive time was 0:04:53 (+/- 0:05:46) during the day and 0:09:55 (+/-0:09:00) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum

transmissions were 0:01:17 during the day, 0:03:07 at night. Minimum dive times were six seconds during the day, seven seconds at night. Maximum dive times were 0:38:05 during the day and 0:32:49 at night (Tables 2 and 3). This turtle was tracked for approximately 24 hours.

The paired t-test analysis comparing mean temperatures by depth among the water profiles at the time of turtle release (May 23 through July 18, 2002), indicated that there were significant differences (p=0.000) in temperature profiles among the days tracked. The loggerhead turtles tracked during the spring months in 2002 exhibited a mean daytime surfacing time of 23 seconds (+/- 0:00:09) and a mean daytime dive duration of 0:05:00 (+/-0:01:52). Excluding the adult turtle, the juveniles exhibited a mean daytime surfacing time of 27 seconds (+/- 0:00:04) and a mean daytime dive duration of 0:05:01 (+/-0:02:10). Due to small nighttime sample sizes among three of the turtles tracked and the age distribution of the remaining three turtles, nighttime respiratory patterns were not calculated. Differences among individual juvenile sea turtle were found in the daytime surface times (ANOVA, p=0.000; F=54.95), as well in the surfacing times between the rehabilitated turtles and wild-caught turtles (ANOVA, p=0.000; F=29.26). Differences were also found among individual juvenile sea turtle were found in the daytime surface times (ANOVA, p=0.000; F=15.97), however, no significant differences were found in the surfacing times between the rehabilitated turtles and wild-caught turtles (ANOVA, p=0.588; F=0.29). The mean ratio of surface to submergence time among the juvenile loggerheads was 9.91% (+/-2.95% stdev.). These ratios ranged from 7.07% to 12.7%. The adult turtle (#211) exhibited a mean surface to submergence ratio of 2.73%. There were not enough samples to test for significant differences among individuals for mean surface times.

DISCUSSION:

Sea turtles are seasonal visitors to Virginia's waters. Due to large fluctuations in temperature between seasons, turtles cannot inhabit Virginia's Bay and coastal waters in the winter as well as early spring or late fall (Coles, 1999). Aerial population and stranding data collected by VIMS in the last 24 years indicate that turtles will not migrate into state waters until sea temperatures reach approximately 18º C in the spring and will migrate south, out of state waters when temperatures drop again in the fall (Coles, 1999). When sea turtles first enter state waters in the spring and during their first few weeks of residency in Virginia, aerial observations indicate that most of the turtles are found in the lower Bay, near the Bay mouth (Byles, 1988; Mansfield et al., 2002a, 2002b). During these first few weeks, stranding counts are historically high, with at least 50% of the annual strandings occurring within a two to three week period between mid-May and mid-June depending upon sea temperatures (Coles, 1999; Mansfield et al. 2002a, 2002b). In the fall, as temperatures drop and sea turtles begin their migration out of state waters, a secondary peak in strandings is often observed, typically beginning mid-September through early to mid-October depending upon sea temperatures (Coles, 1999).

Incidental dredge take data provided to the VIMS stranding program courtesy of C. Slay of Coastwise Consulting indicate that 2002 dredge takes correspond to the 2002 peaks in sea turtle strandings and spring peak in lower Bay sea turtle observations (Figures 24-25). It is our recommendation that future dredging activities either cease during the critical two to three week period when sea turtles are migrating into Virginia's waters in the spring, or at the very least, observer coverage be increased to 24-hour coverage during this time. This period may be identified through aerial observation of sea turtles, the observed rate of sea turtle strandings

found along Virginia's shorelines and by the monitoring of sea temperatures. The Virginia Institute of Marine Science sea turtle program conducts weekly aerial population surveys within Bay waters, closely monitors sea temperatures, is responsible for providing real-time stranding data to state and federal management agencies often on a daily basis. Communications between VIMS and the ACOE dredge operators could easily be established in order to identify the critical period within which sea turtles would be most likely to be taken incidentally by dredge in the spring of the year.

Stranding data for the fall of the year do not indicate as great of a stranding peak as in the spring nor do aerial data indicate as large of a concentration of sea turtles in the Bay mouth (Mansfield et al., 2002a; 2002b). However, as turtles move from their Bay foraging grounds out through the Bay mouth, they are at greater risk of encountering dredge operations. One option would be to cease dredge operations once sea temperatures drop below 18º C until aerial surveys conducted by VIMS indicate that most sea turtles have migrated out of state waters. At the very least, it is recommended that between September 1 and November 1 of any year, endangered species observer coverage be increased to 24-hour coverage.

Turtles tracked early in the season from the Bay mouth exhibited directed movement—either south (turtle # 142) or back into the Bay (turtles #199, 192, 165, 167). Tracking work conducted in the 1980's resulted in observations of two types of foraging movements: either long term circular paths within a turtles' home range or up and down tidal channels with different tidal fluctuations (Byles, 1988). In 2002, the degree of movements often corresponded to or may have been influenced by tidal flow, however only one turtle, turtle #211, exhibited the back and forth tidal foraging movements described by Byles, 1988. This turtle was caught later in the season within her known foraging grounds. It is probable that she had already established her seasonal foraging patterns that she in turn exhibited upon release in the York River. Turtles captured and released earlier in the season from the mouth of the Bay may have been attempting to return to their foraging sites, exhibiting a more directed swimming behavior. More turtles need to be tracked in the spring of the year within their known foraging areas to determine whether there is a difference in the respiratory behavior and movements of turtles as they enter the Bay en route to their foraging areas, and the respiratory behavior of turtles established in their foraging areas in the early spring.

Turtle #211 also spent far less time at the surface per respiratory event than the other turtles tracked. This is most likely due to the size and age of the turtle, resulting in greater lung capacity, lower metabolic rates and therefore fewer respiratory events than the juvenile turtles tracked this season. Ideally, more adult turtles should be tracked to increase the sample size of the older age class in order to better test for differences between adults and juveniles. Byles (1988) determined that foraging loggerheads during the summer and fall months averaged 1.4 minutes per surfacing event and 18.9 minutes per dive. The loggerhead turtles tracked during the spring months in 2002 exhibited a mean daytime surfacing time of 23 seconds (+/- 0:00:09) and a mean daytime dive duration of 0:05:00 (+/-0:01:52). These times are shorter in duration than those times observed by Byles. This may be due to the turtles not yet exhibiting the same swimming behavior as the turtles Byles observed or due to differences in temperature regimes between the turtles observed in the spring of 2002 and the later season foragers tracked by Byles. In the spring of the year, turtles are migrating into Bay waters in order to reach their summer foraging grounds. It is possible that the turtles tracked in 2002 were exhibiting migration behavior, or directed swimming movements from the point of release to their foraging grounds in the Bay or points south (turtle # 142). It is also possible that these turtles may have been

exhibiting a different pattern of respiratory behavior due to sea temperatures. More data are needed on respiratory patters from springtime foragers already established in their foraging grounds, as well as dive depth and temperature data to determine whether turtles are preferentially staying within warmer surface waters.

Two of the juveniles tracked exhibited a similar ratio (7.07% and 7.67%) as the 7.3% mean recorded in the 1980's. However, two turtles had larger surface to submergence ratios: 12.18% and 12.71%, bringing the mean for juvenile surface to submergence time ratio up to 9.91%. These data would suggest that turtles spend more time at the surface in the spring vs. later in the summer, however, more turtles need to be tracked in the spring of the year in order to better understand whether the mean ratio of surface to submergence time for the loggerhead juveniles are significantly different from those turtles tracked in the 1980's. If turtles are spending more time at the surface in the spring of the year, then historic population estimates based on aerial survey data have been over estimated.

It is critical that this research continue in order to increase our sample size of both different species (loggerhead and Kemp's ridley) and different age classes. Increasing our sample size will strengthen our ability to statistically determine the seasonal or temperature based influences on sea turtle diving and respiratory behavior in Virginia. These data would increase the accuracy of population estimates of turtles in Virginia's waters, resulting in refined take limits per fishery or dredge activity. During the 2002 season, turtles were obtained from cooperative poundnetters within the Chesapeake Bay. VIMS' in-water take permit is in the process of being amended to allow tracking of turtles captured by relocation trawler. This addendum should be in place by the start of the 2003 season and would allow VIMS to track turtles caught in the vicinity of dredging activities. Depending upon weather, track times will be extended next season to 24-48 hours post-release to increase the day/night sample sizes.

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TABLES

Table 1. **Summary data for seven sea turtles tracked in the Chesapeake Bay, 2002. Tag # represents primary flipper tag number; CC= loggerhead, LK= Kemp's ridley. N represents sample size of respiratory events recorded during track time**

Turtle #	Species	Tag #	Release Date	Release Location	Hours Tracked	N
198	CC	XXF794	5/23/02	37.324N; -76.301W	12	n/a*
199	CC	XXT521	5/28/02	37.020N; -76.112W	8.5	64
192	LK	XXF767	6/4/02	36.983N; -76.063W	8	43**
142	CC	XXT523	6/11/02	36.989N; -76.079W	12	175
165	CC	XXF775	6/17/02	37.006N; -76.080W	24.5	325
167	CC	XXF771	6/24/02	36.983N; -76.078W	18	125
211	CC	SSB919	7/17/02	37.247N; -76.507W	24	222

* Insufficient data due to small antenna

**Turtle not tracked continuously for entire eight hours due to weather/seas

Tables 2-3 . Summary of surface and submergence activity from turtles radio tracked in the Chesapeake Bay, 2002. Day/Night determined by time of sunset or sunrise. NOTE: turtles #199 and 142 were only tracked for two to four hours post-sunset.

Turtle #	Time	Mean Surface Time	St. Dev.-SURF	Mean Dive Time	St. Dev.-DIVE	Range: Surf. Time	Range: Dive Time
199	**Day**	0:00:32	0:00:51	0:06:57	0:07:32	Min: 0:00:06	Min:0:00:14
						Max: 0:06:00	Max: 0:40:23
192	**Day**	0:01:26	0:01:49	0:03:08	0:03:05	Min: 0:00:06	Min: 0:00:10
						Max: 0:07:34	Max: 0:12:47
142	**Day**	0:00:23	0:00:23	0:03:01	0:02:41	Min: 0:00:06	Min: 0:00:14
						Max: 0:02:15	Max: 0:16:33
165	**Day**	0:00:24	0:00:30	0:03:17	0:04:14	Min: 0:00:06	Min: 0:00:06
						Max: 0:04:44	Max: 0:26:05
167	**Day**	0:00:29	0:00:39	0:06:50	0:08:27	Min: 0:00:06	Min: 0:00:06
						Max: 0:03:12	Max: 0:39:31
211	**Day**	0:00:08	0:00:07	0:04:53	0:05:46	Min: 0:00:06	Min: 0:00:06
						Max: 0:01:17	Max: 0:38:05
TOTAL-All Turtles		**0:00:34**	**0:00:27**	**0:04:41**	**0:01:50**		
Turtle #	**Time**	**Mean Surface Time**	**St. Dev.-SURF**	**Mean Dive Time**	**St. Dev Dive**	**Range Surf. Time**	**Range Dive Time**
199	**Night**	0:00:57	0:00:39	0:04:15	0:02:52	Min: 0:00:06	Min:0:00:15
						Max: 0:01:50	Max: 0:08:00
192	**Night**	n/a	n/a	n/a	n/a	n/a	n/a
142	**Night**	0:00:53	0:00:35	0:04:30	0:02:33	Min: 0:00:06	Min: 0:00:8
						Max: 0:02:28	Max: 0:11:55
165	**Night**	0:00:54	0:01:12	0:05:40	0:08:10	Min: 0:00:06	Min: 0:00:06
						Max: 0:07:50	Max: 0:28:15
167	**Night**	0:00:56	0:00:55	0:08:33	0:07:40	Min: 0:00:06	Min: 0:00:06
						Max: 0:05:23	Max: 0:29:39
211	**Night**	0:00:19	0:00:31	0:09:55	0:09:00	Min: 0:00:06	Min: 0:00:07
						Max: 0:03:07	Max: 0:32:49
TOTAL-All Turtles		**0:00:46**	**0:00:18**	**0:07:09**	**0:02:30**		
TOTAL-24 Hr tracks only		**0:00:43**	**0:00:21**	**0:08:03**	**0:02:10**		

FIGURES

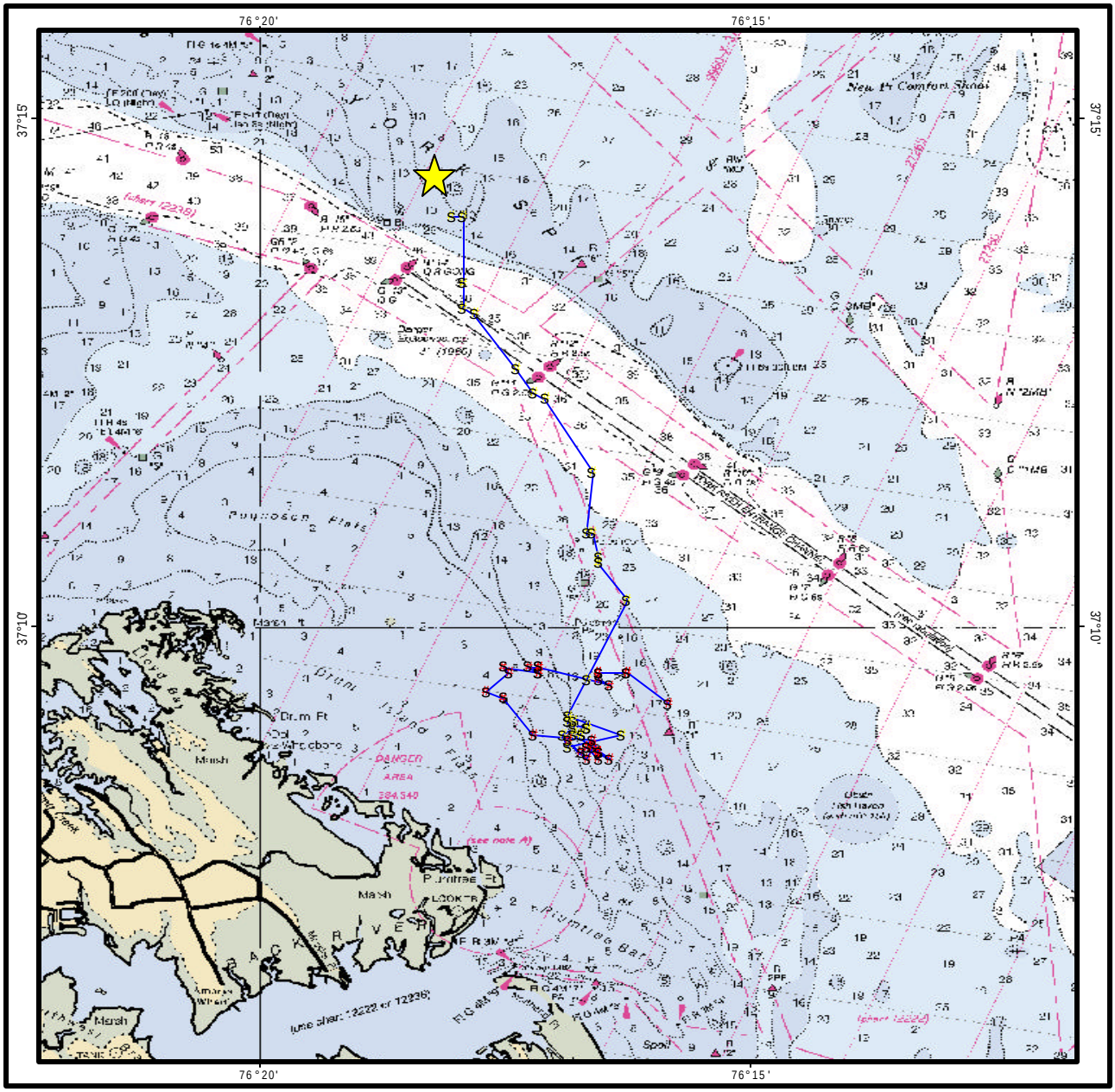


Figure 1 . **Turtle #198 tracked from the mouth of the York River, May 23, 2002. NOAA Chart 12221_1.**

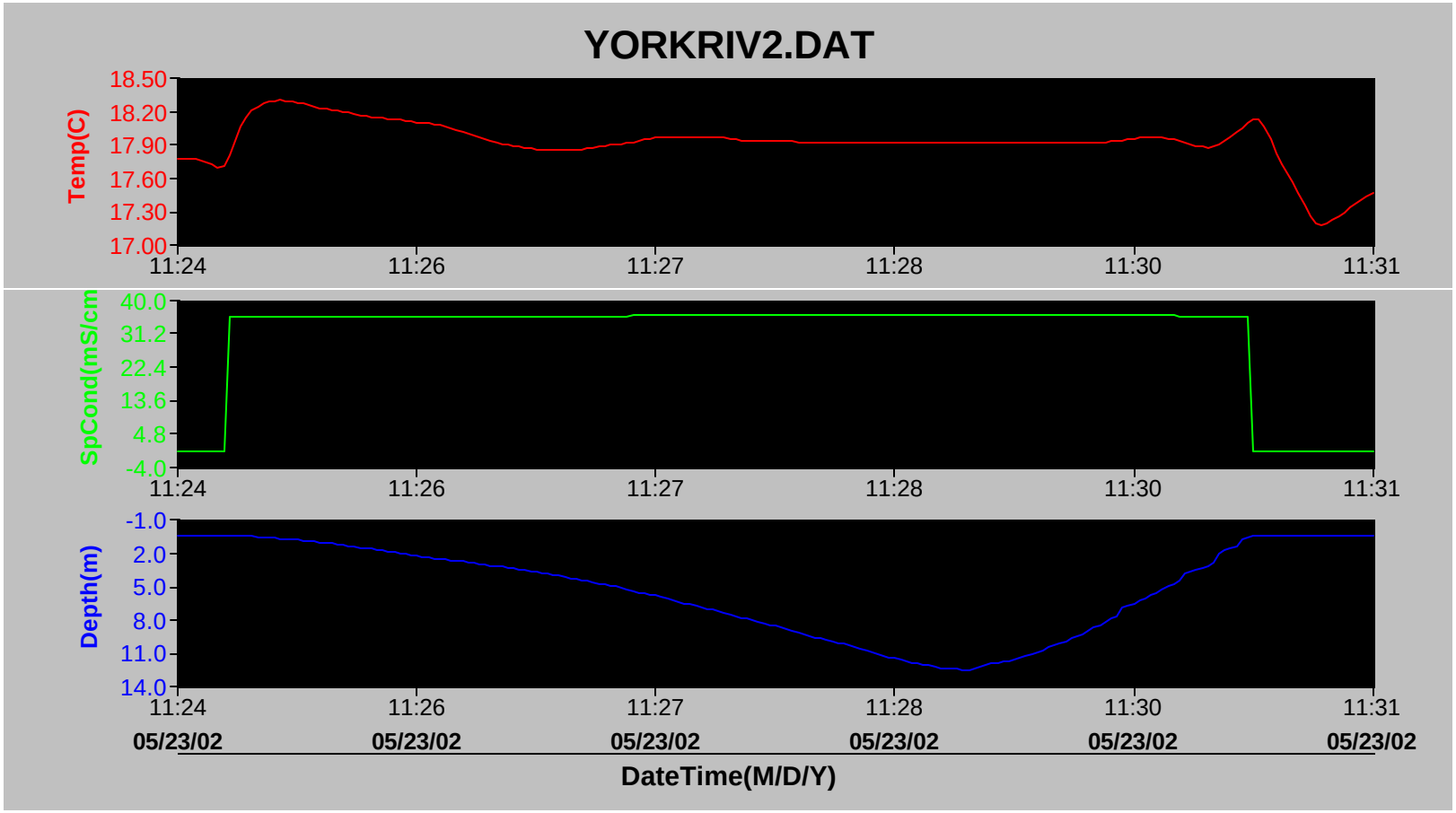
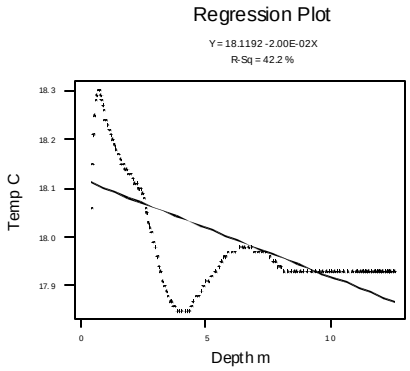
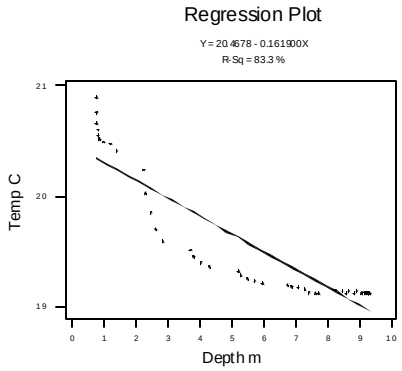


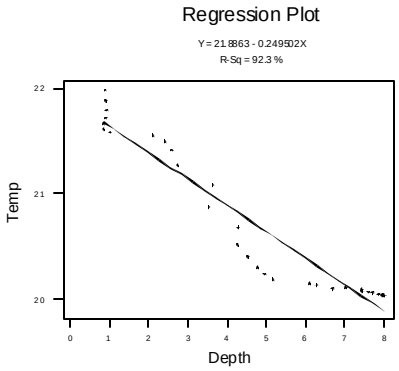
Figure 2. **Temperature, Conductivity and Depth profile of release site for turtle # 198, May 23, 2002, York River mouth, Chesapeake Bay.**



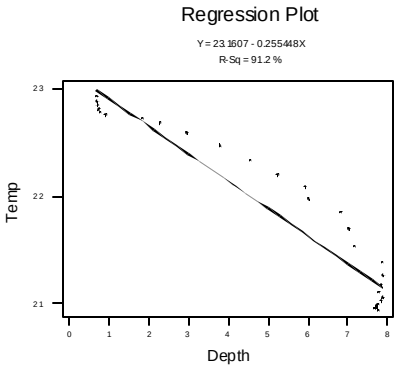
Turtle # 198, May 23, 2002, York River Mouth



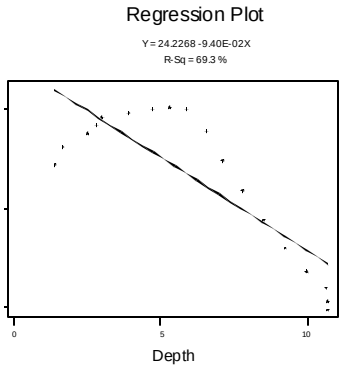
Turtle # 199, May 28, 2002, Bay mouth



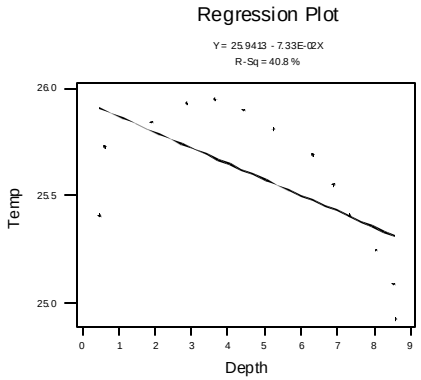
Turtle # 192, June 4, 2002, Bay mouth



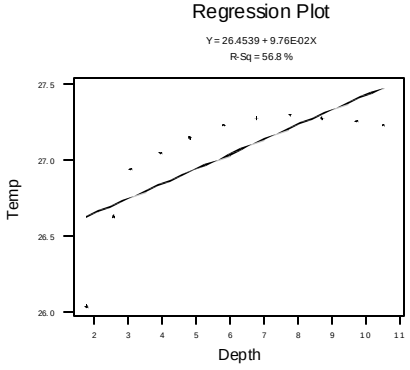
Turtle # 142, June 11, 2002, Bay Mouth



Turtle # 165, June 17, 2002, Bay Mouth

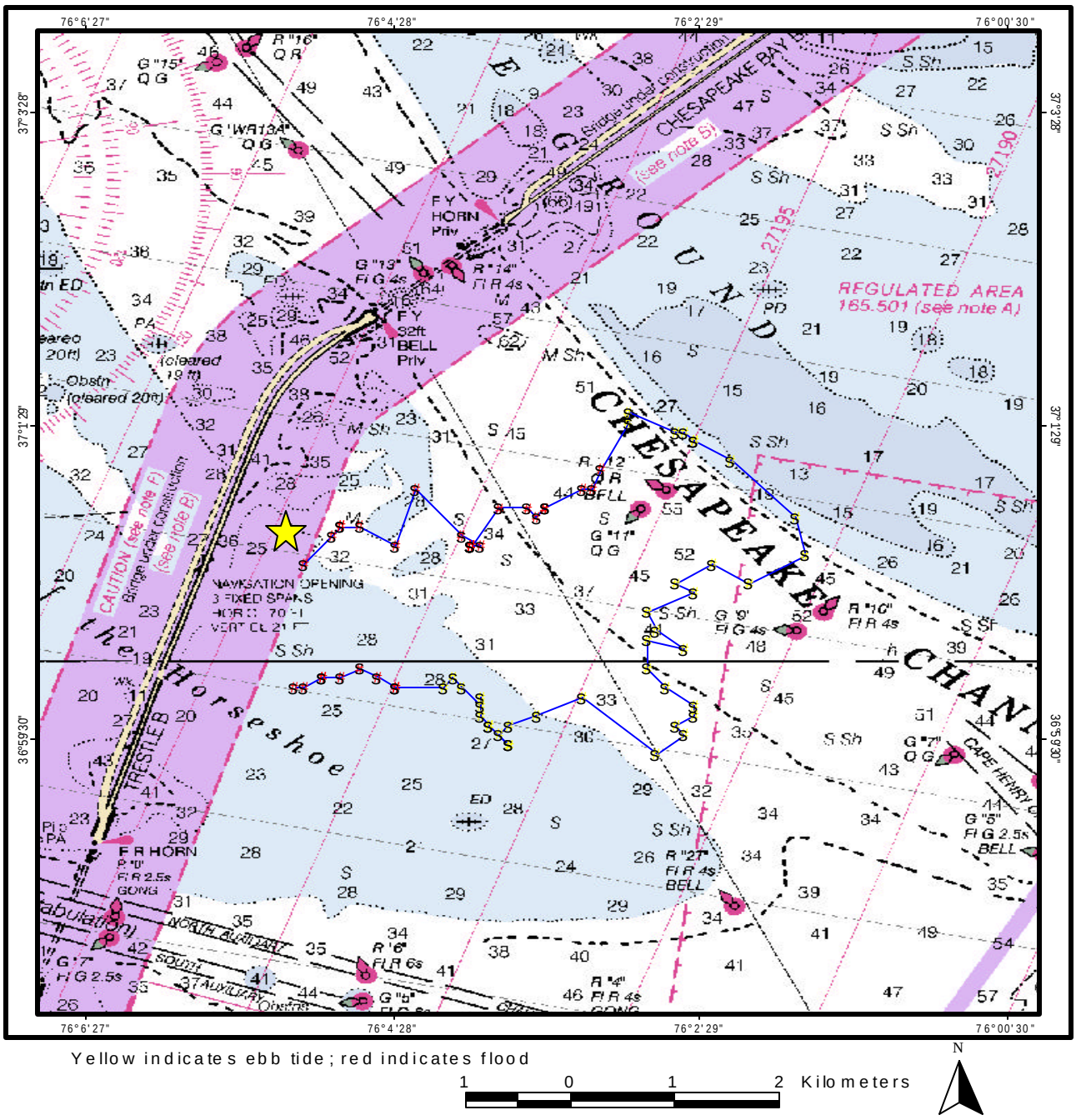


Turtle # 167, June 24, 2002, Bay mouth



Turtle # 211, July 18, 2002; York River mouth

Figure 3. Regressions of Temperature (C) vs. Depth (m) at time of release for all turtles tracked.



Star = start of track

Figure 4. Turtle #199 tracked at the mouth of the Chesapeake Bay, May 28, 2002. NOAA Chart 12221_1.

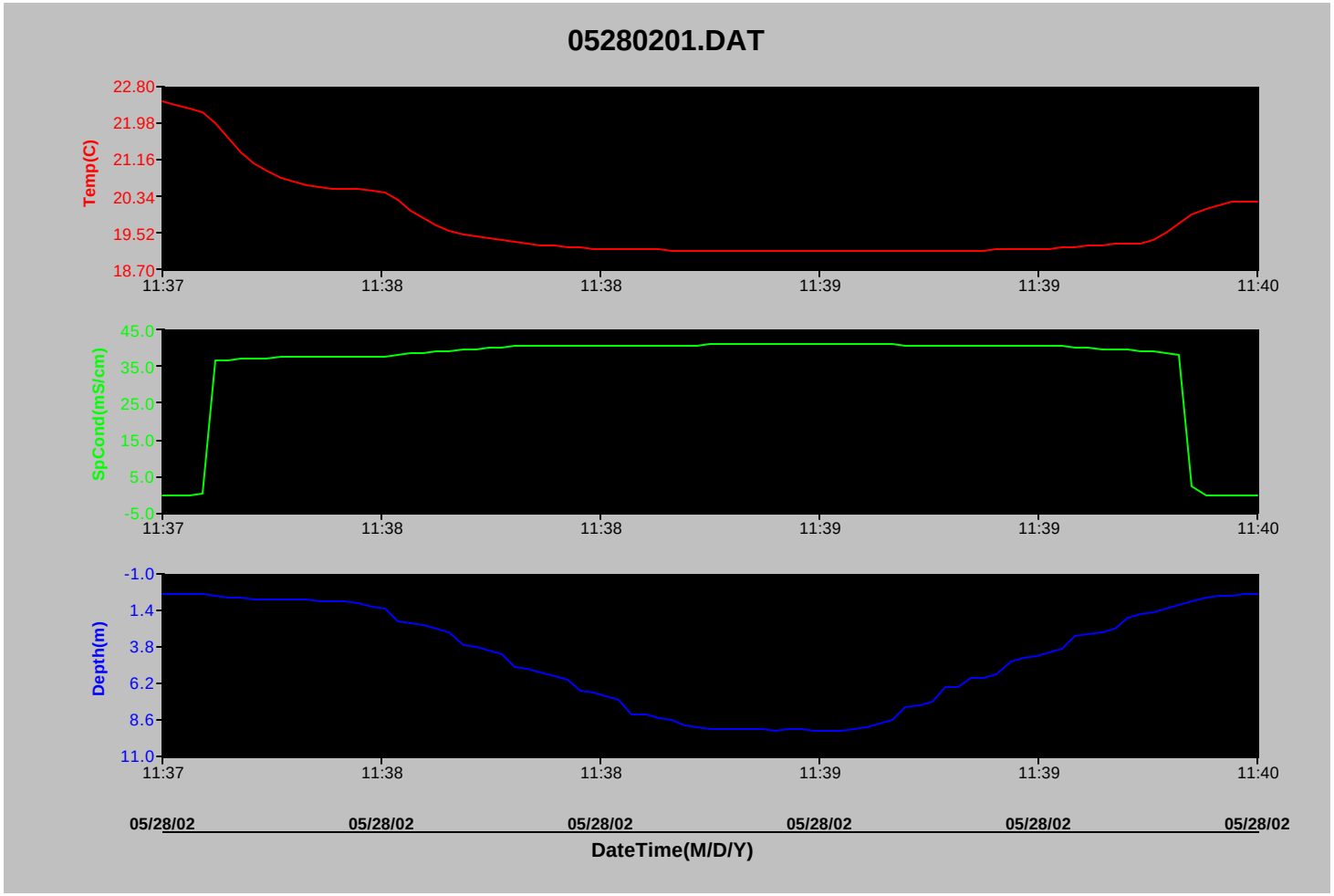


Figure 5. **Temperature, Conductivity and Depth profile of release site for turtle # 199, May 28, 2002, Chesapeake Bay mouth.**

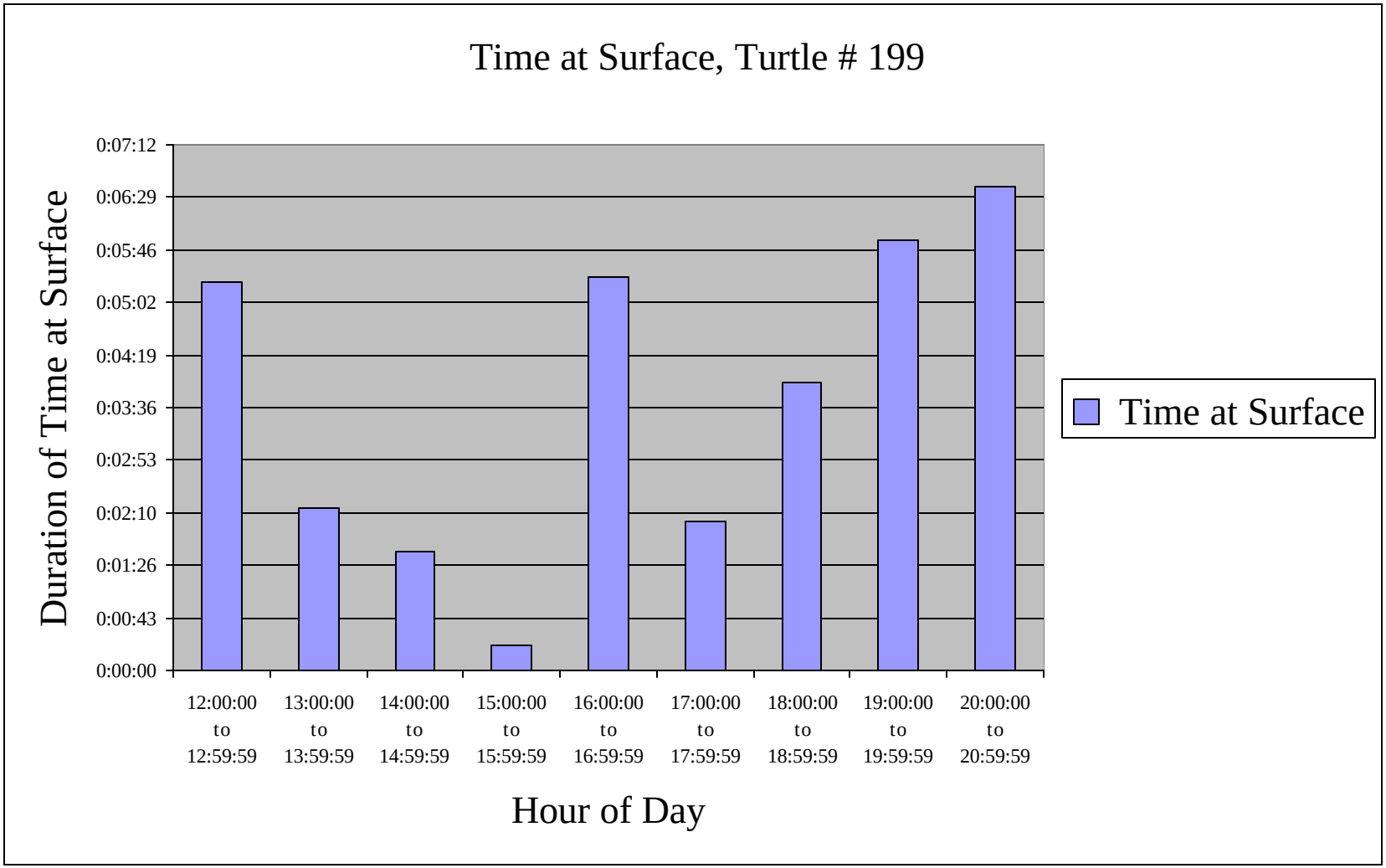


Figure 6. Turtle #199 Surfacing times, May 28, 2002.

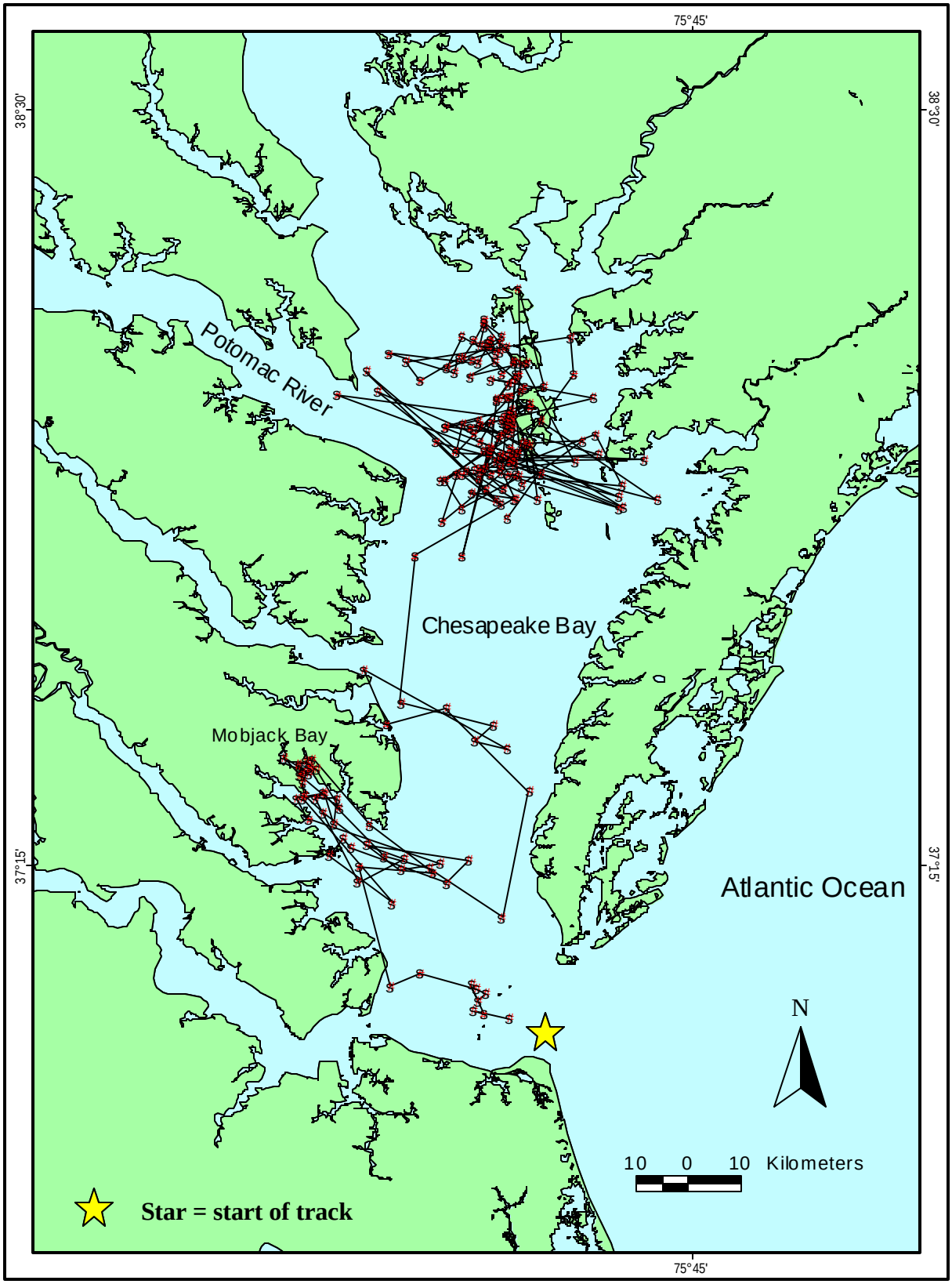


Figure 7. Satellite movements of Kemp's Ridley, June 4 to August 23, 2002

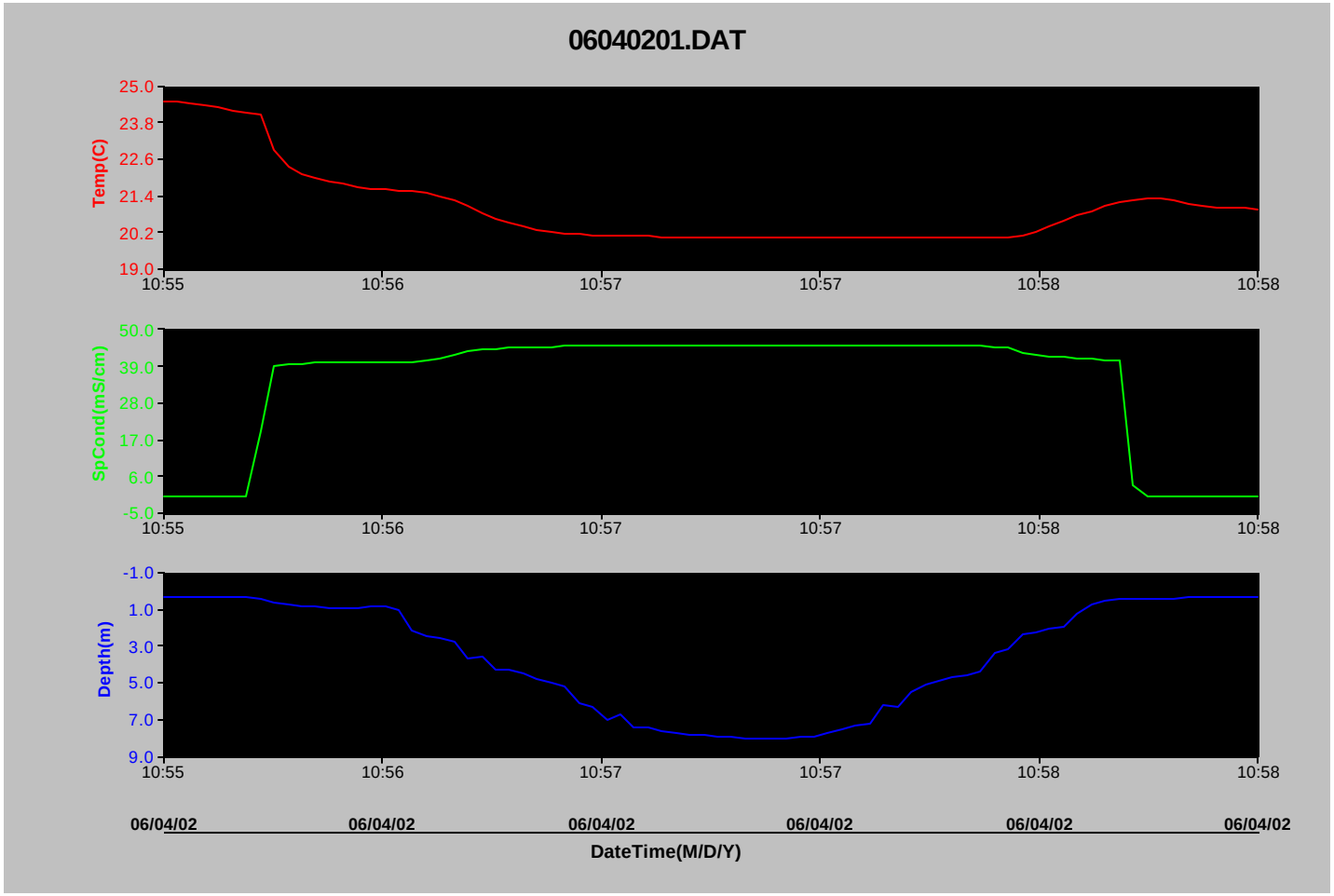


Figure 8. **Temperature, Conductivity and Depth profile of release site for turtle # 192 (Kemp's ridley) , June 4, 2002, Chesapeake Bay mouth.**

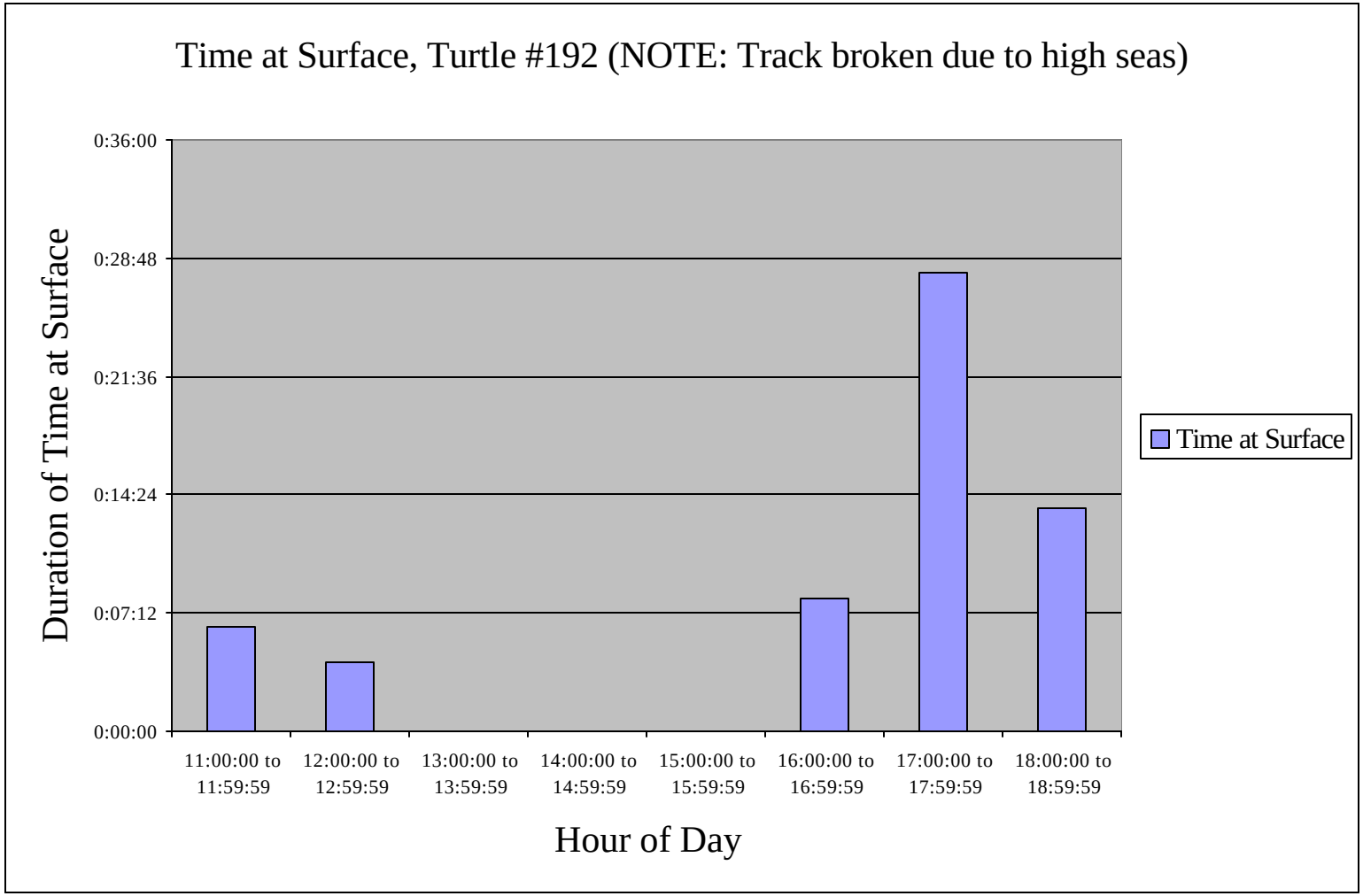


Figure 9. **Turtle #192 Surfacing times, June 4, 2002. Track broken due to high seas**

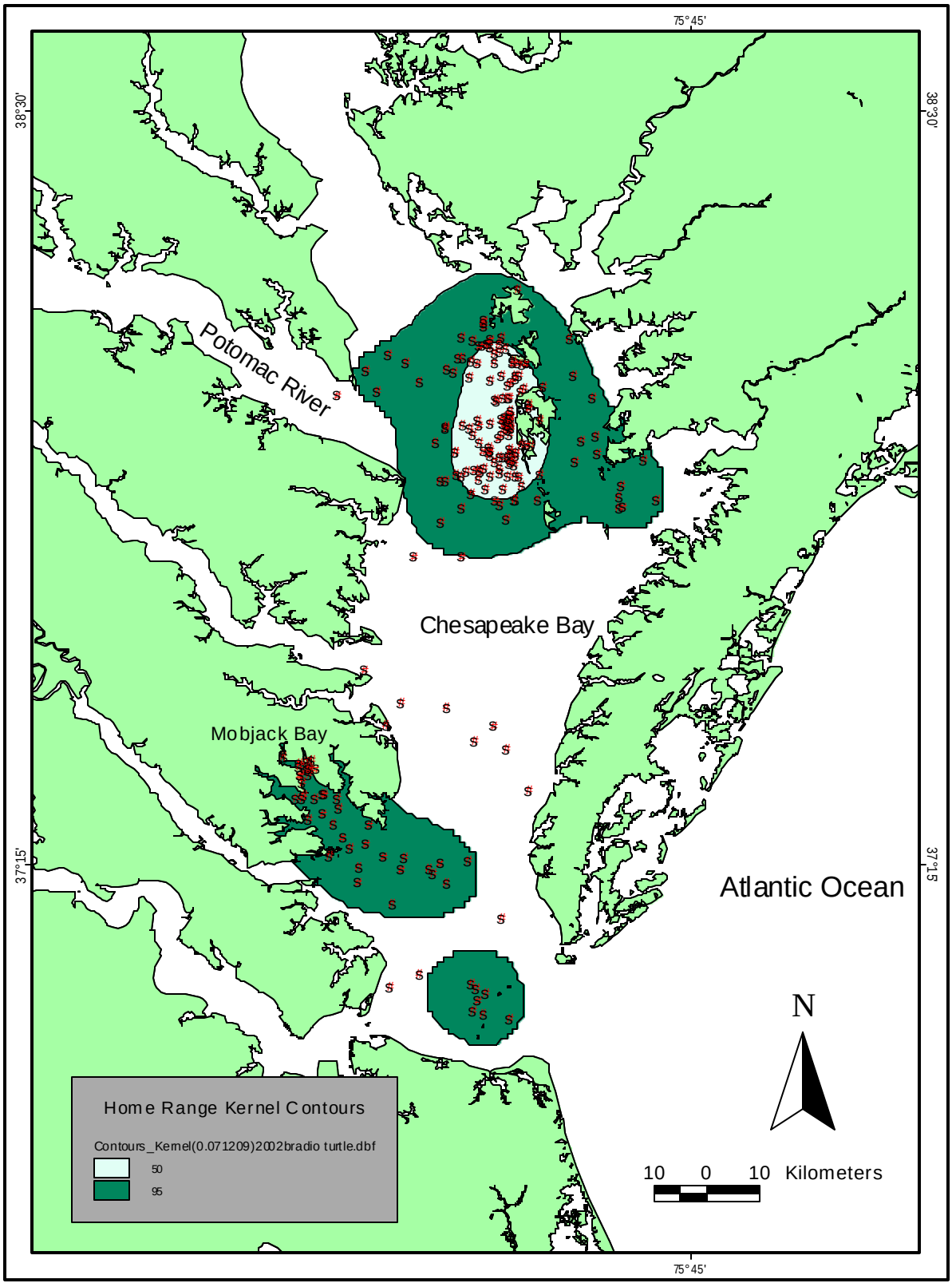


Figure 10. **50% and 95% home range Kernels for Kemp's ridley #192 tracked between June 4 through August 23, 2002**

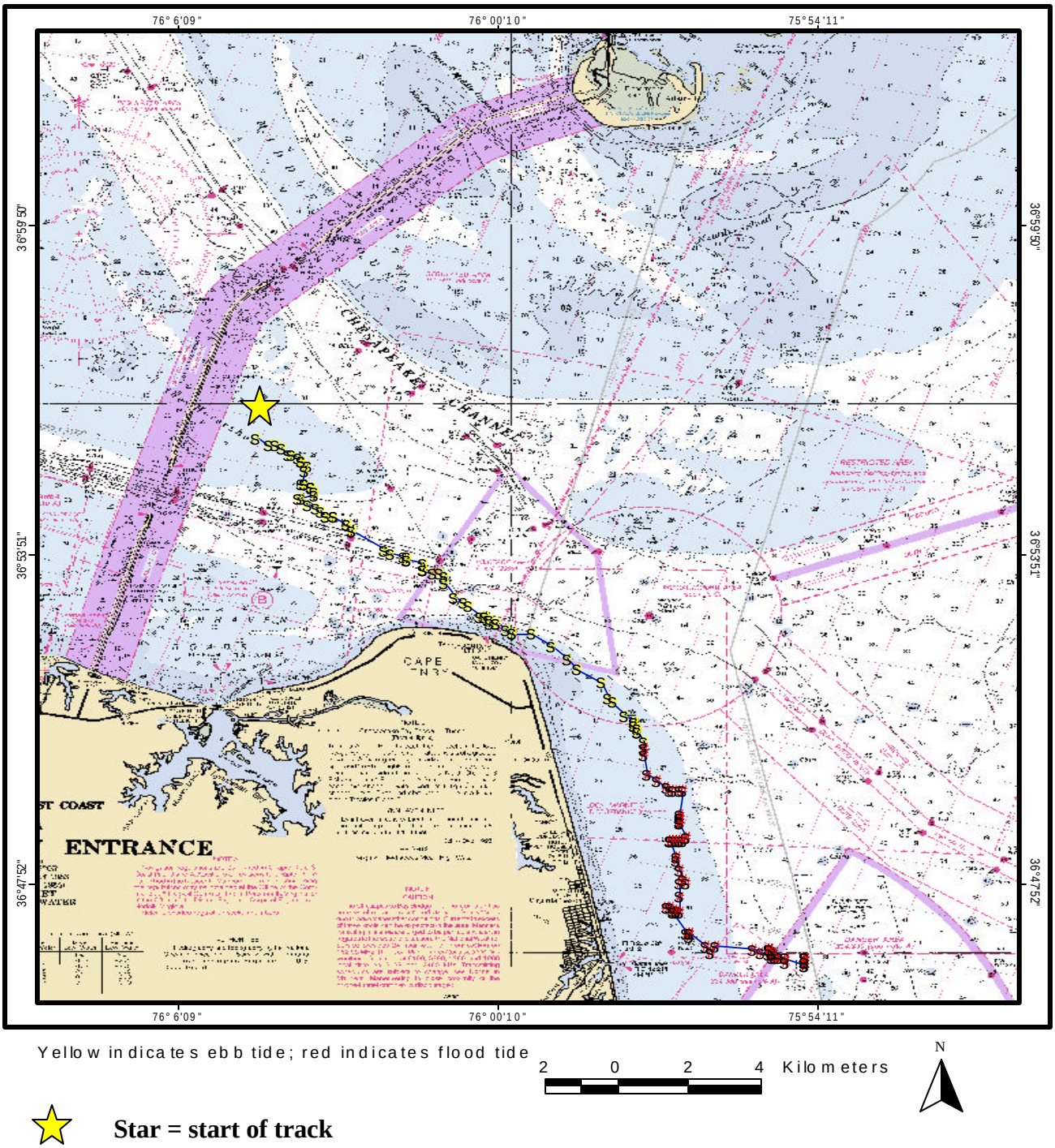


Figure 11. Turtle #142 tracked at the mouth of the Chesapeake Bay, June 11, 2002. NOAA Chart 12221_1.

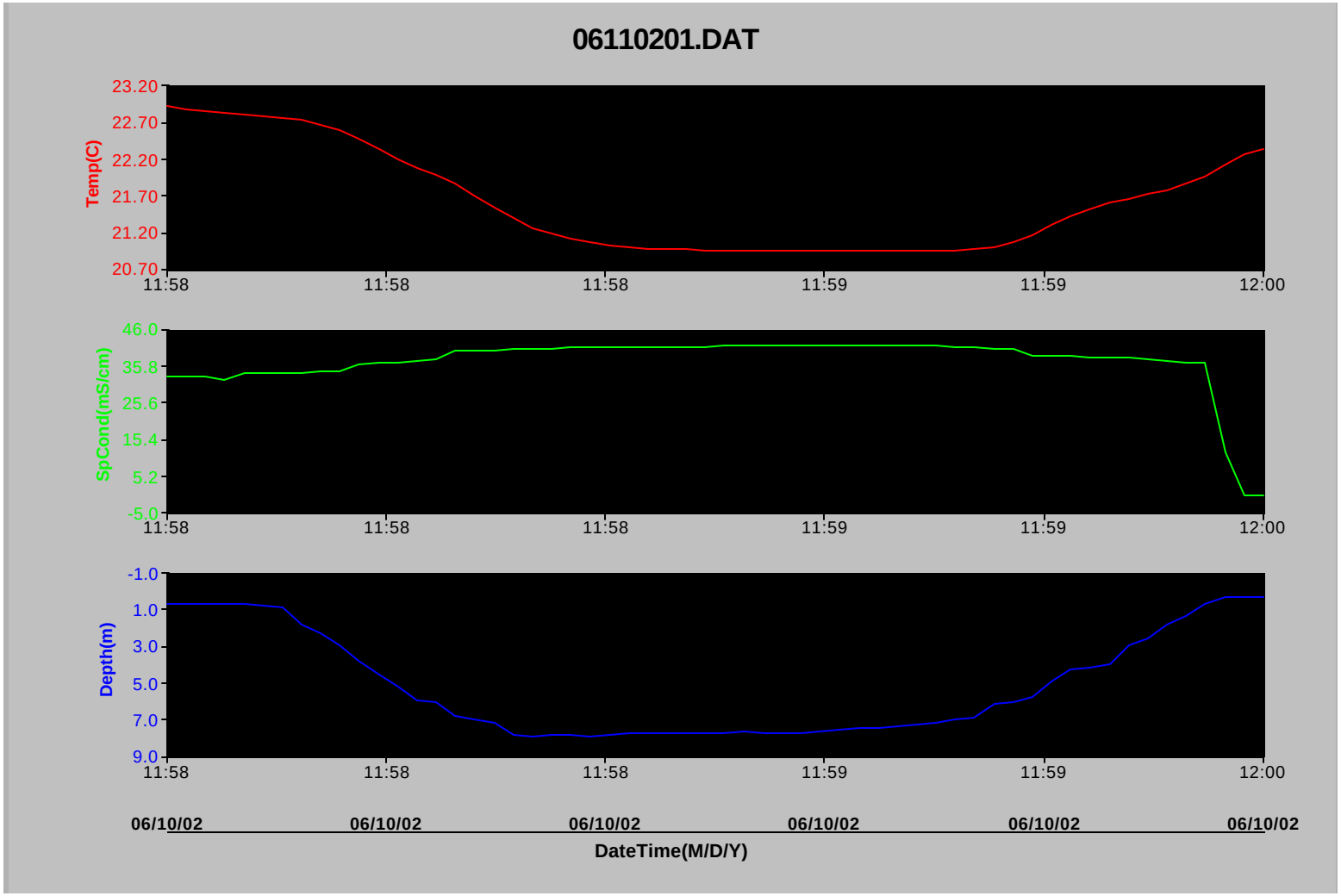


Figure 12. Temperature, Conductivity and Depth profile of release site for turtle # 142, June 11, 2002, Chesapeake Bay mouth.

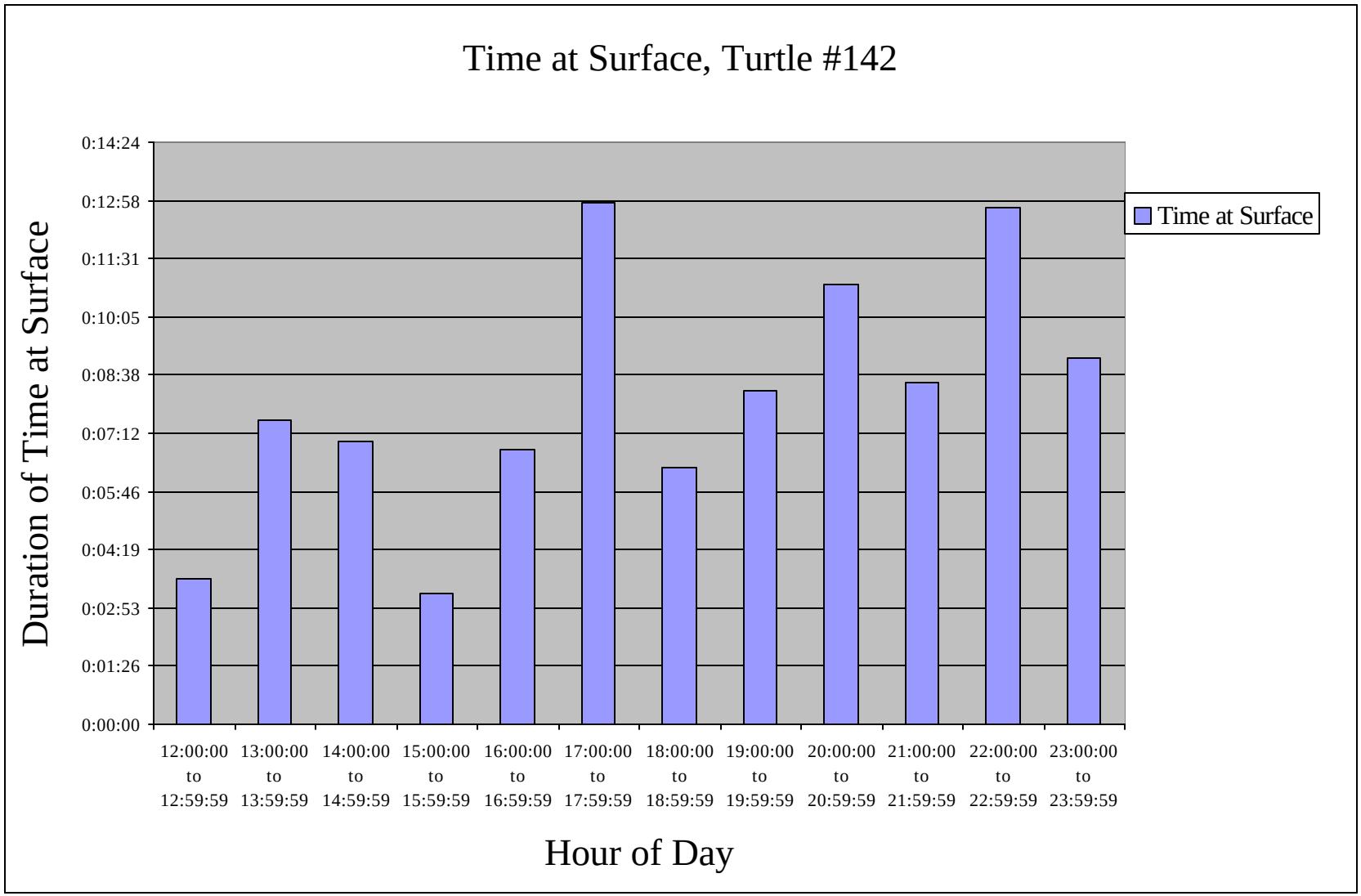


Figure 13. Turtle #142 Surfacing times, June 11, 2002.

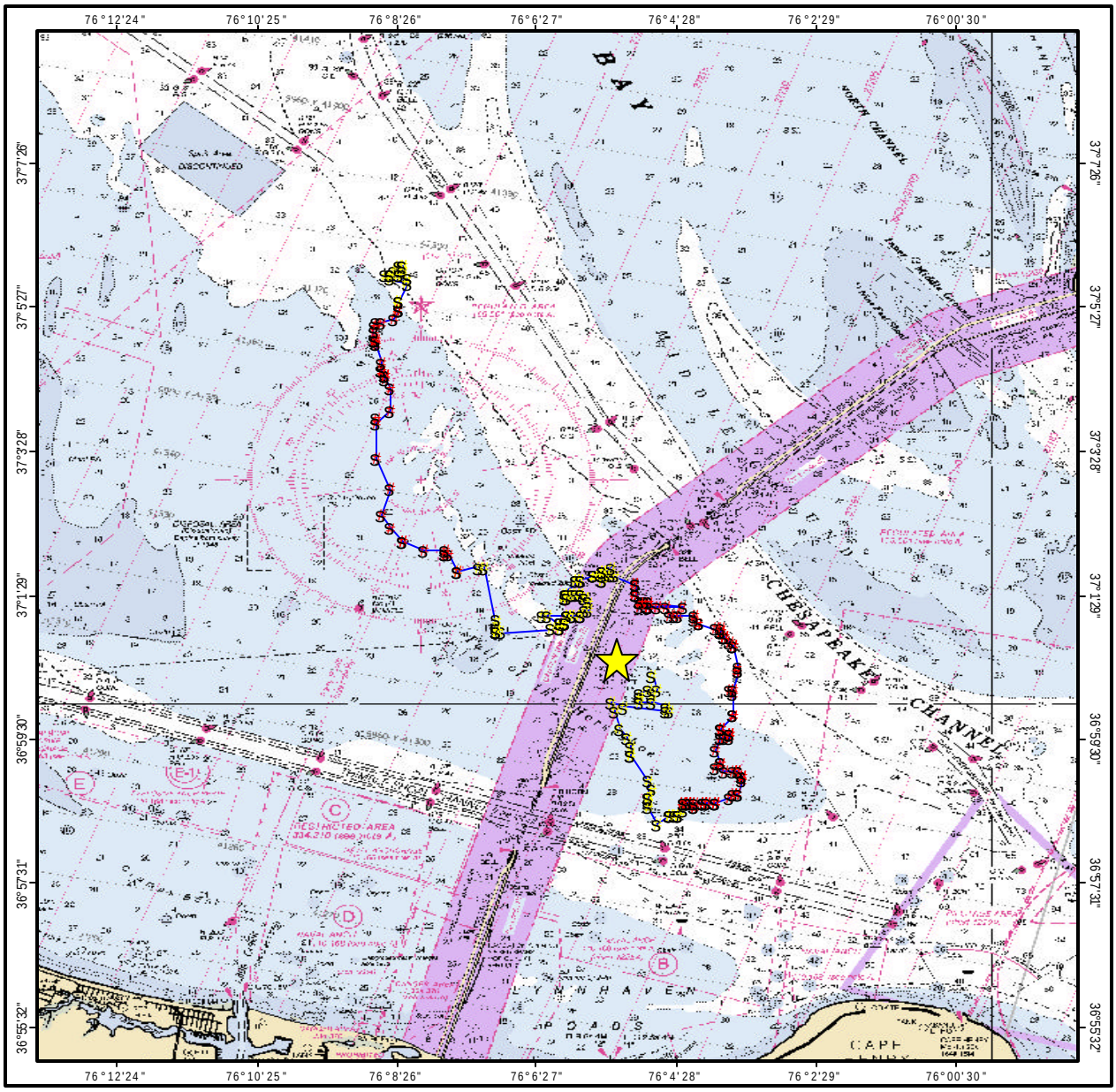


Figure 14. Turtle #165 tracked at the mouth of the Chesapeake Bay, June 17-18, 2002. NOAA Chart 12221_1.

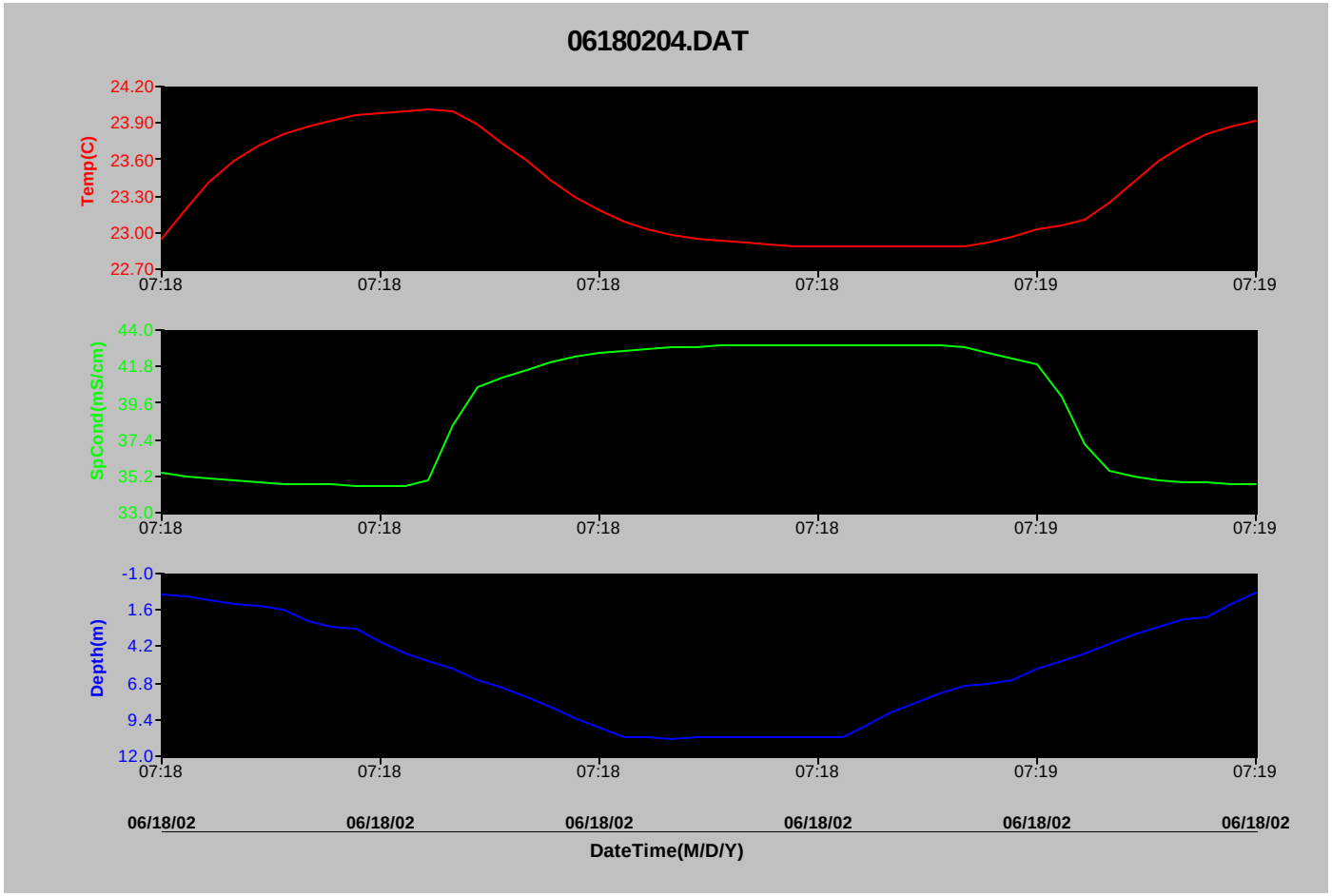


Figure 15. Temperature, Conductivity and Depth profile near release site for turtle # 165, June 18, 2002, Chesapeake Bay mouth.

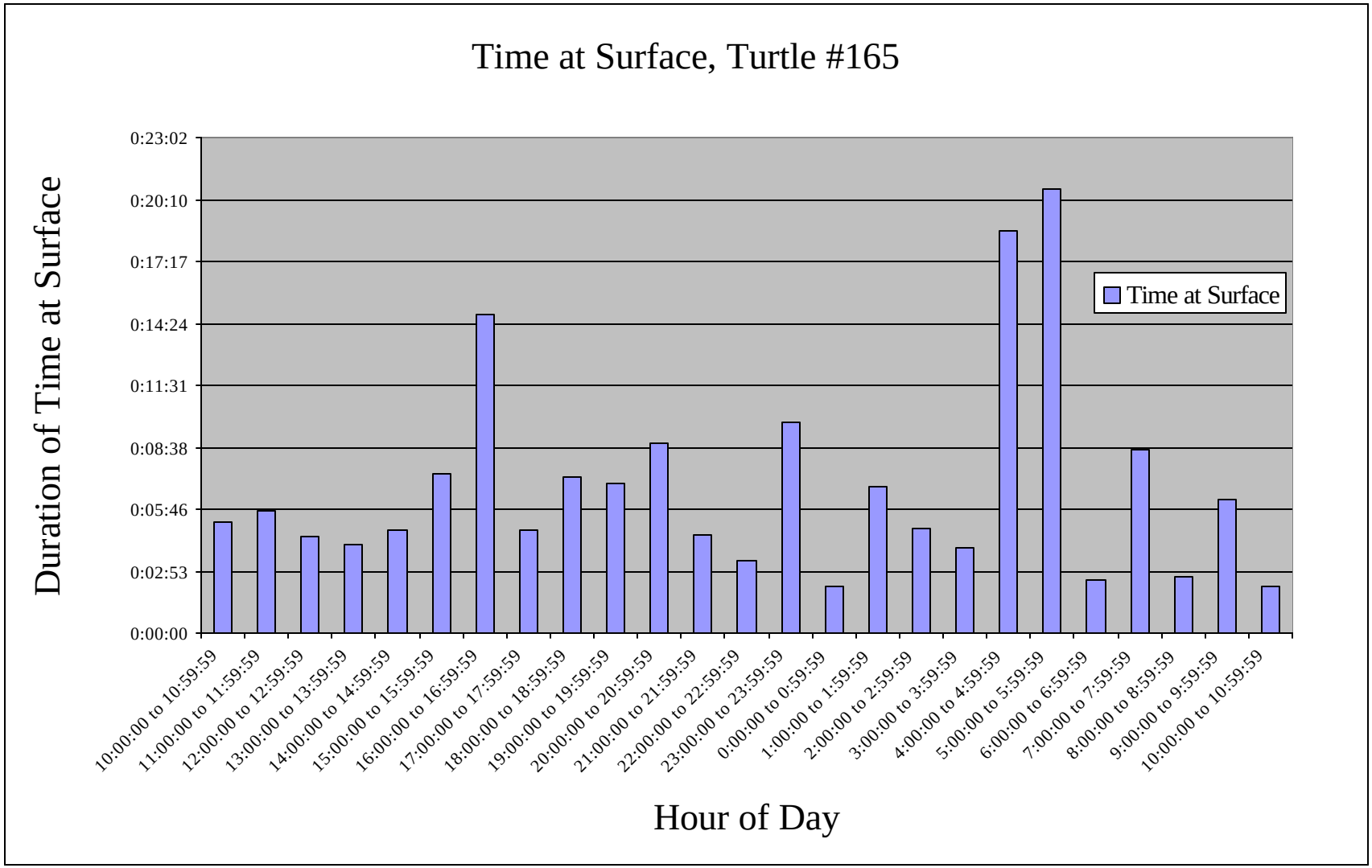


Figure 16. Turtle #165 Surfacing times, June 17-18, 2002.

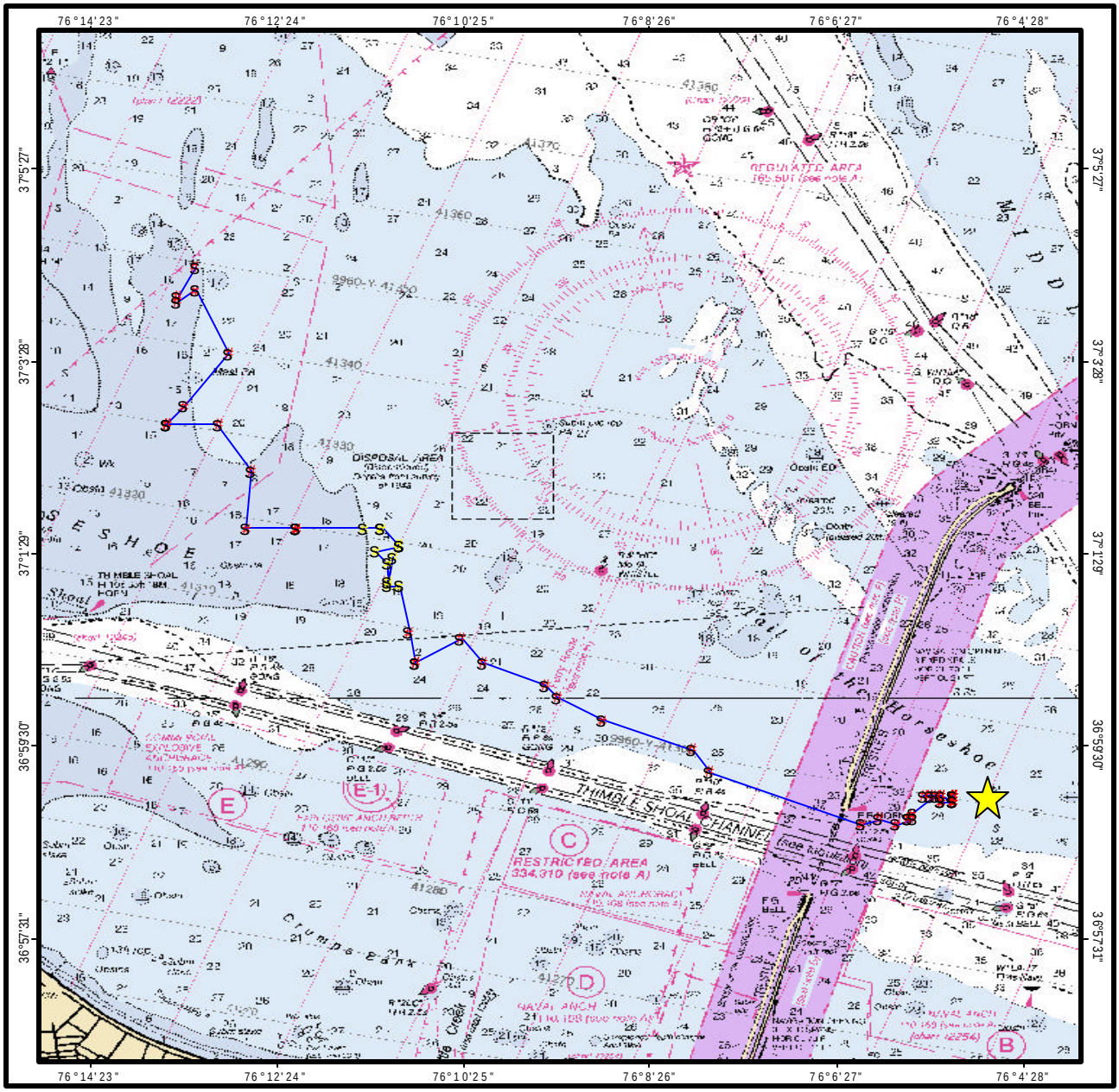


Figure 17. Turtle #167 tracked from the mouth of the York River, June 24-25, 2002. NOAA Chart 12221_1.

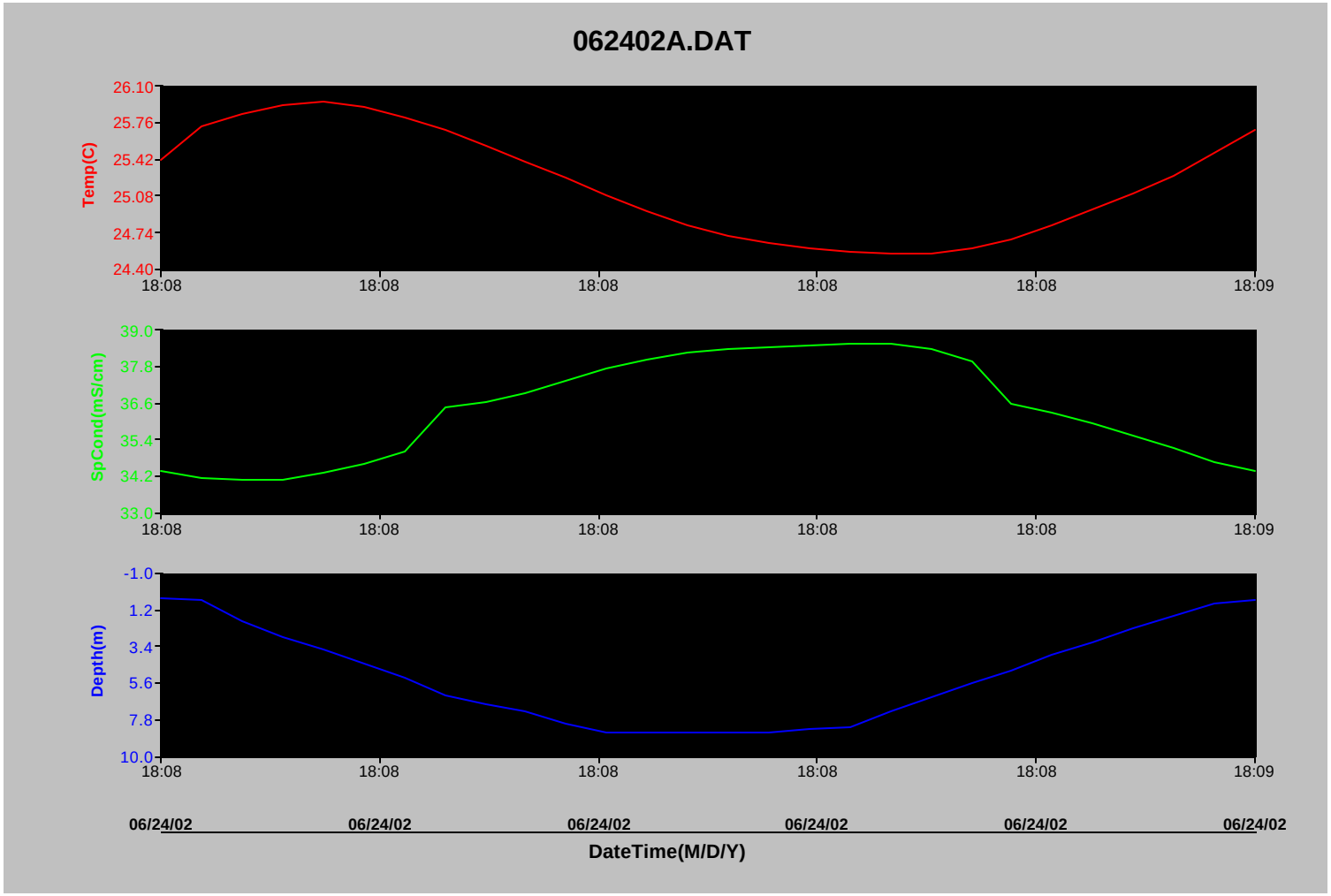


Figure 18. Temperature, Conductivity and Depth profile of release site for turtle # 167, June 24, 2002, Chesapeake Bay mouth.

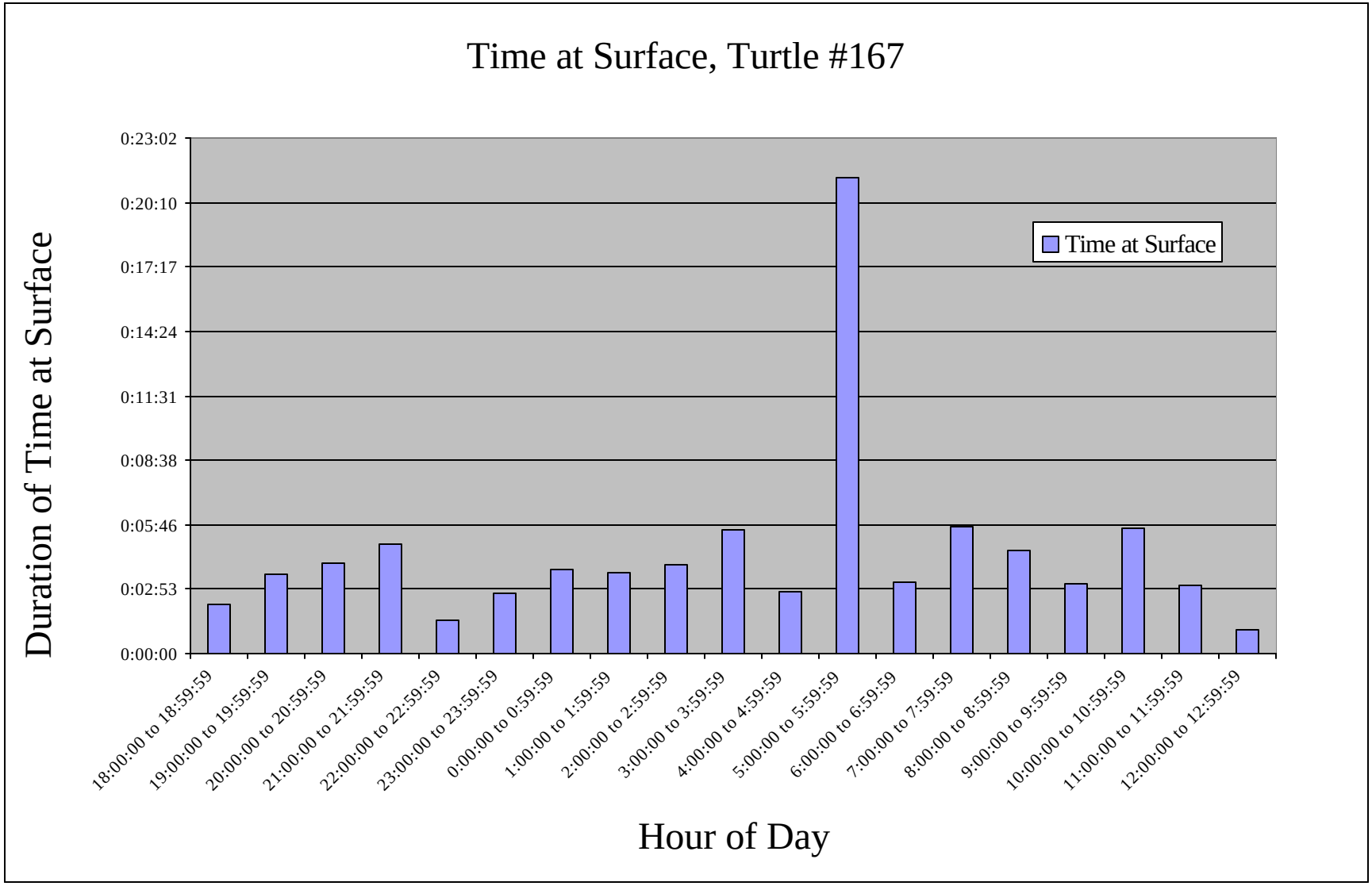
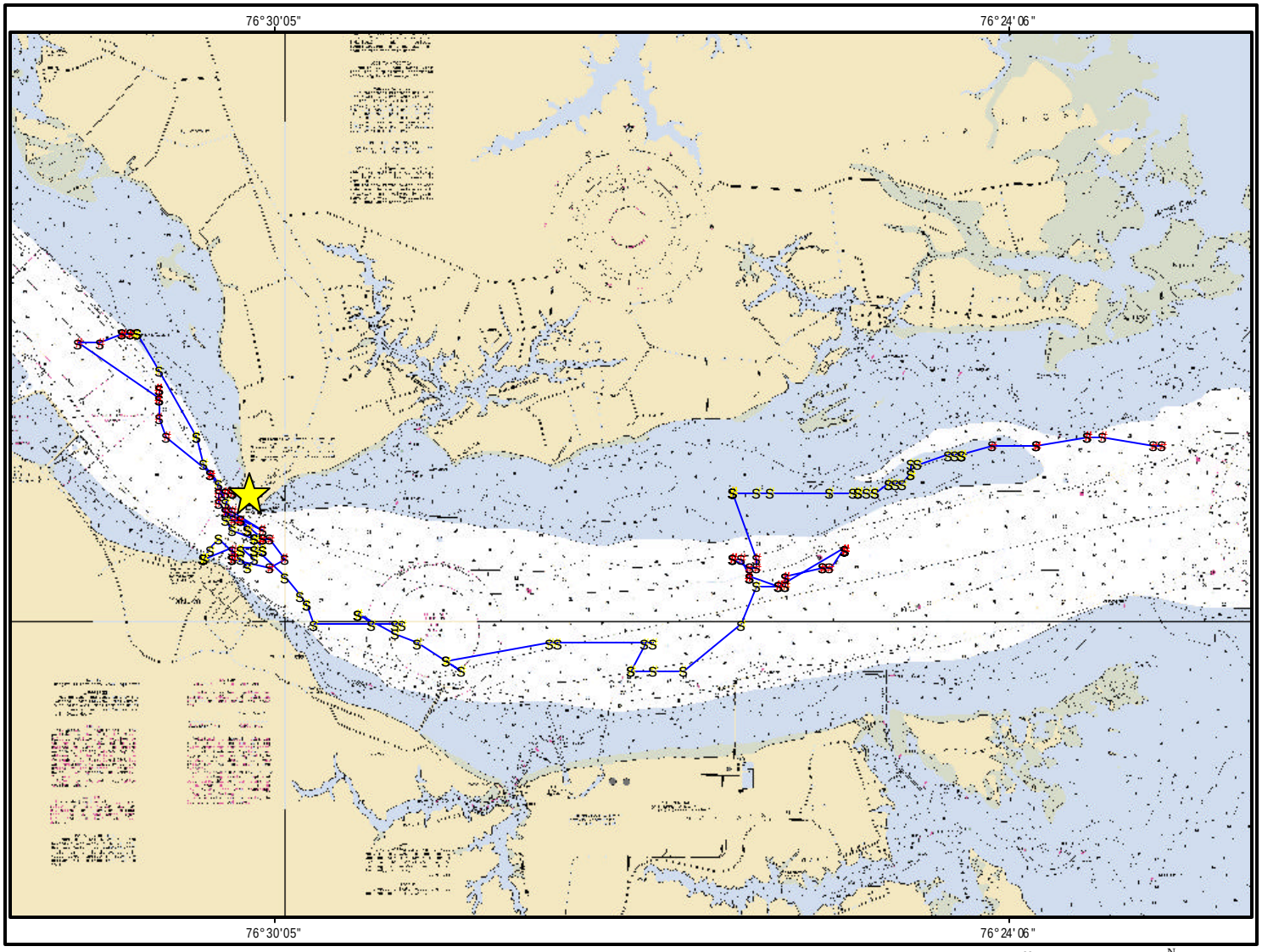


Figure 19. Turtle #167 Surfacing times, June 24-25, 2002.



Yellow indicates ebb tide; red indicates flood

Star = start of track

Figure 20. Turtle #211 tracked from VIMS to the mouth of the York River, July 16-17, 2002. NOAA Chart 12241_1.

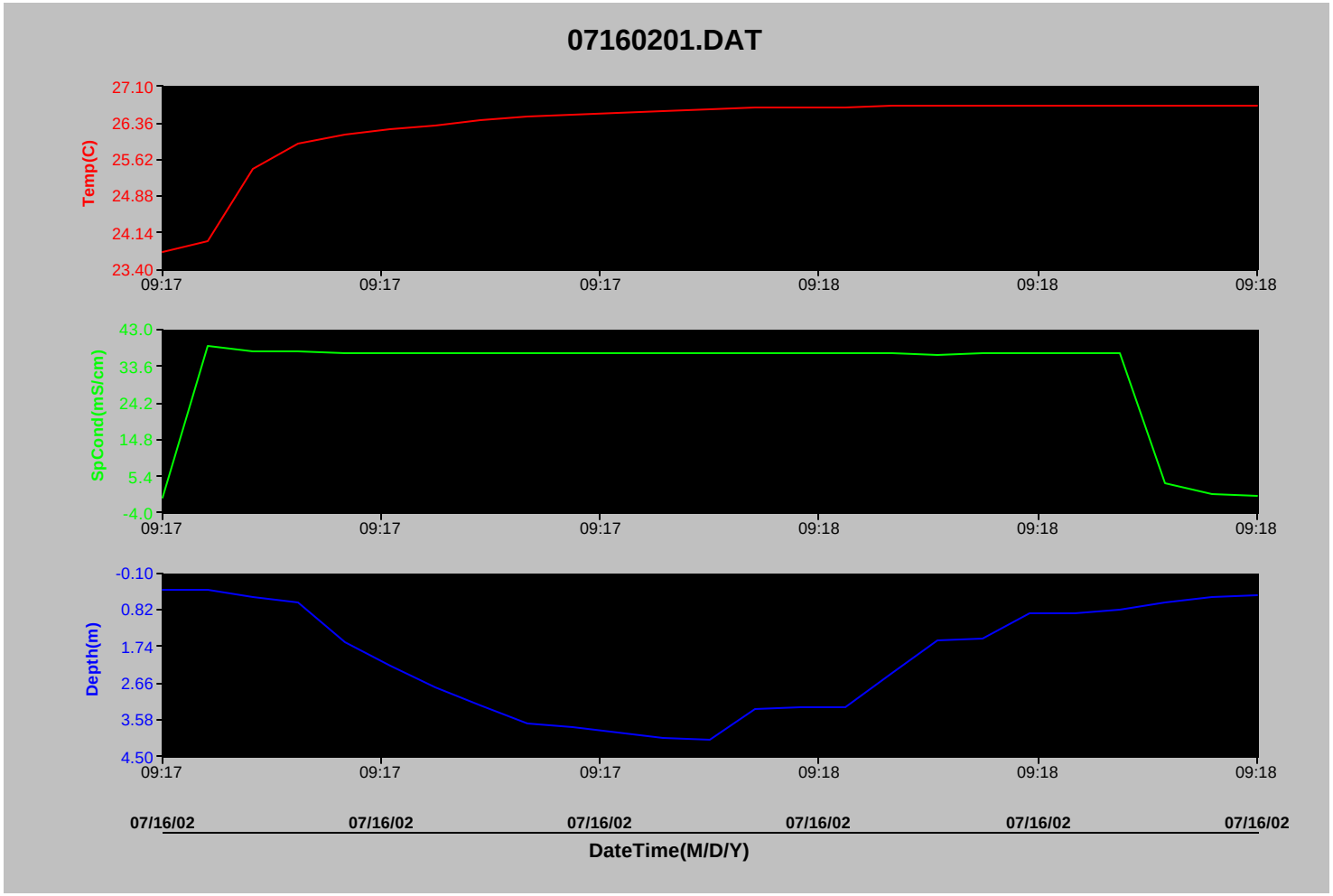


Figure 21. Temperature, Conductivity and Depth profile of release site for turtle # 211, July 16, 2002, York River, Coleman Bridge.

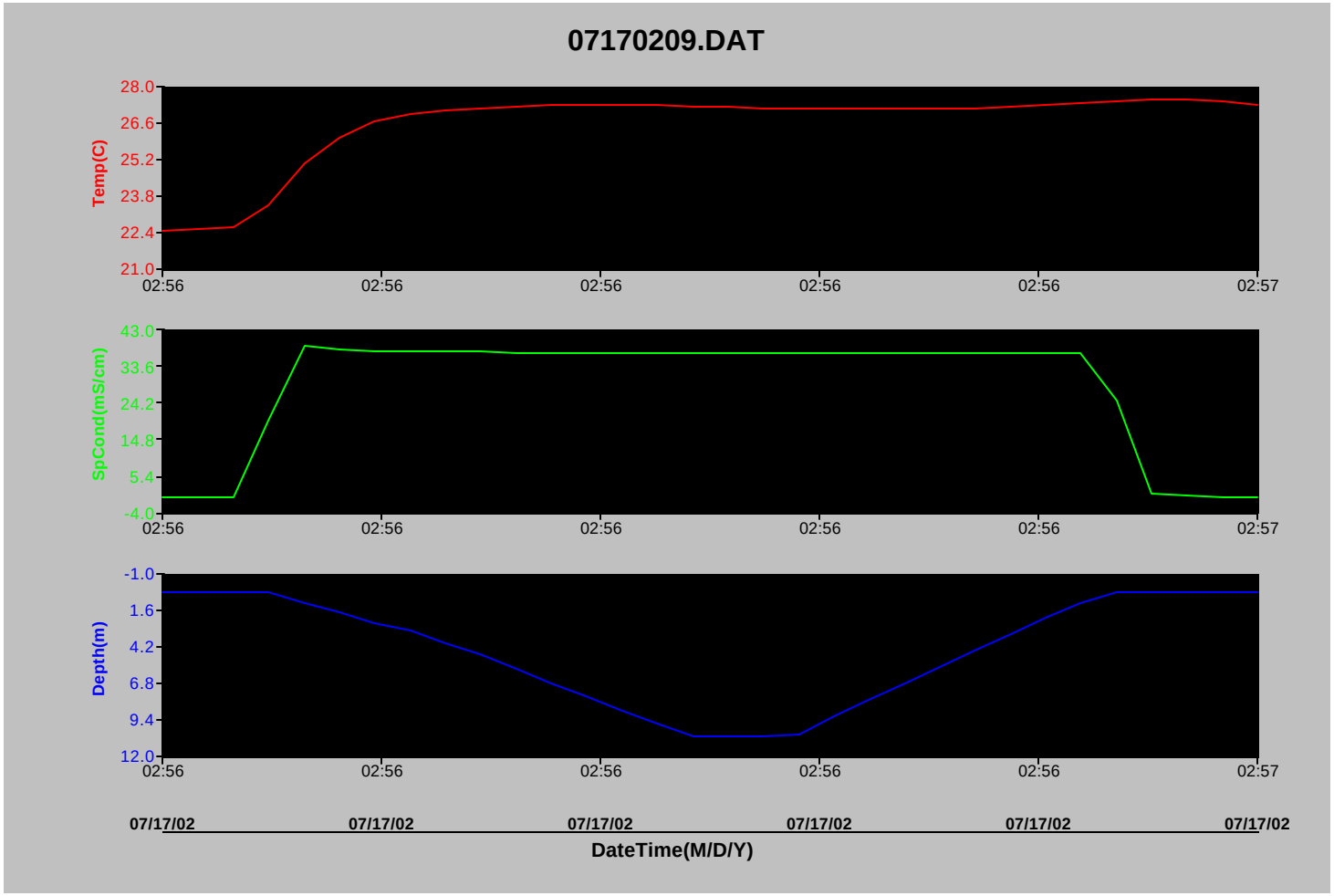


Figure 22. Temperature, Conductivity and Depth profile of last bearing location for turtle # 211, July 17, 2002, York River mouth.

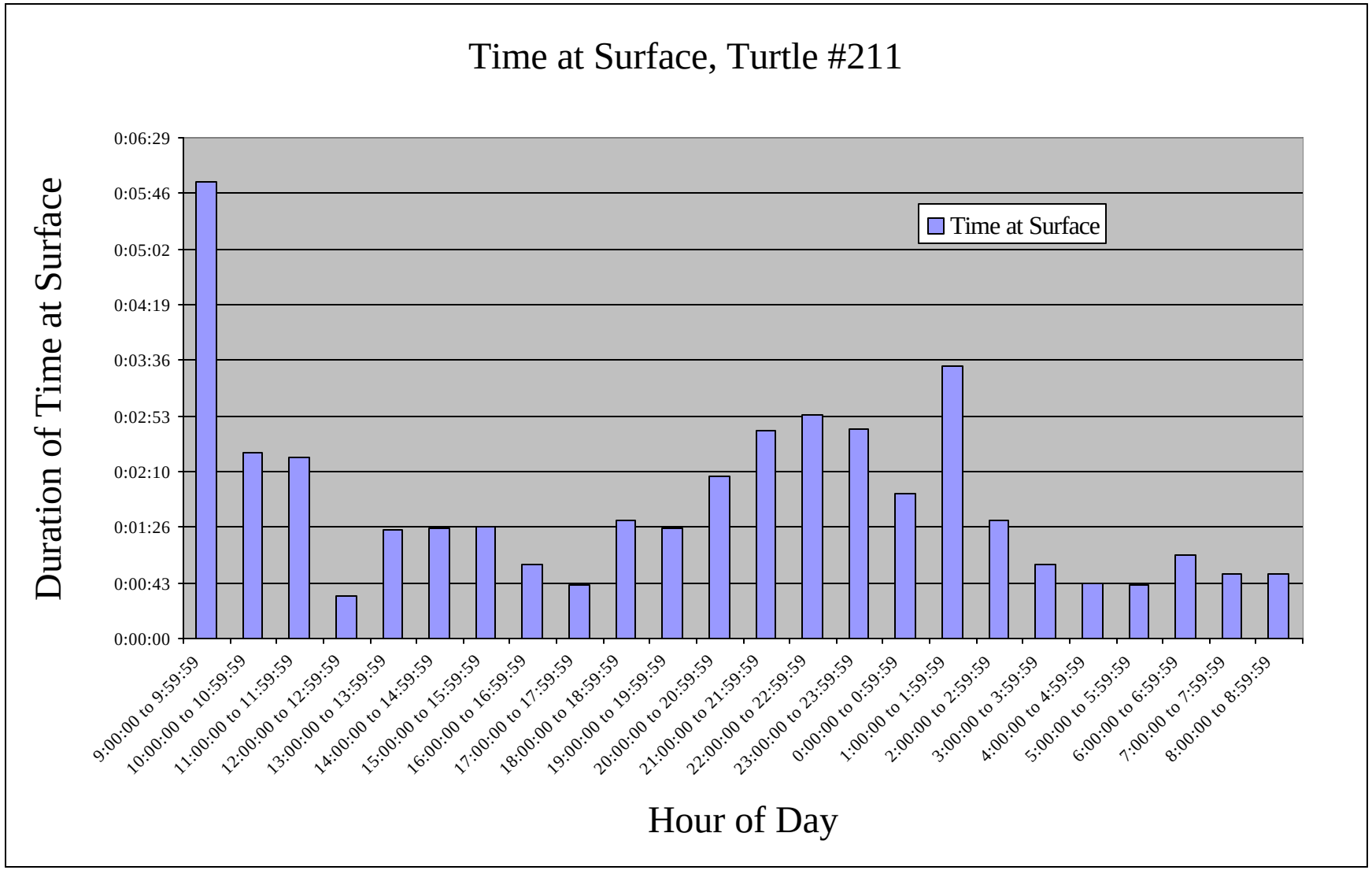


Figure 23. Turtle #211 Surfacing times, July 17-18, 2002.

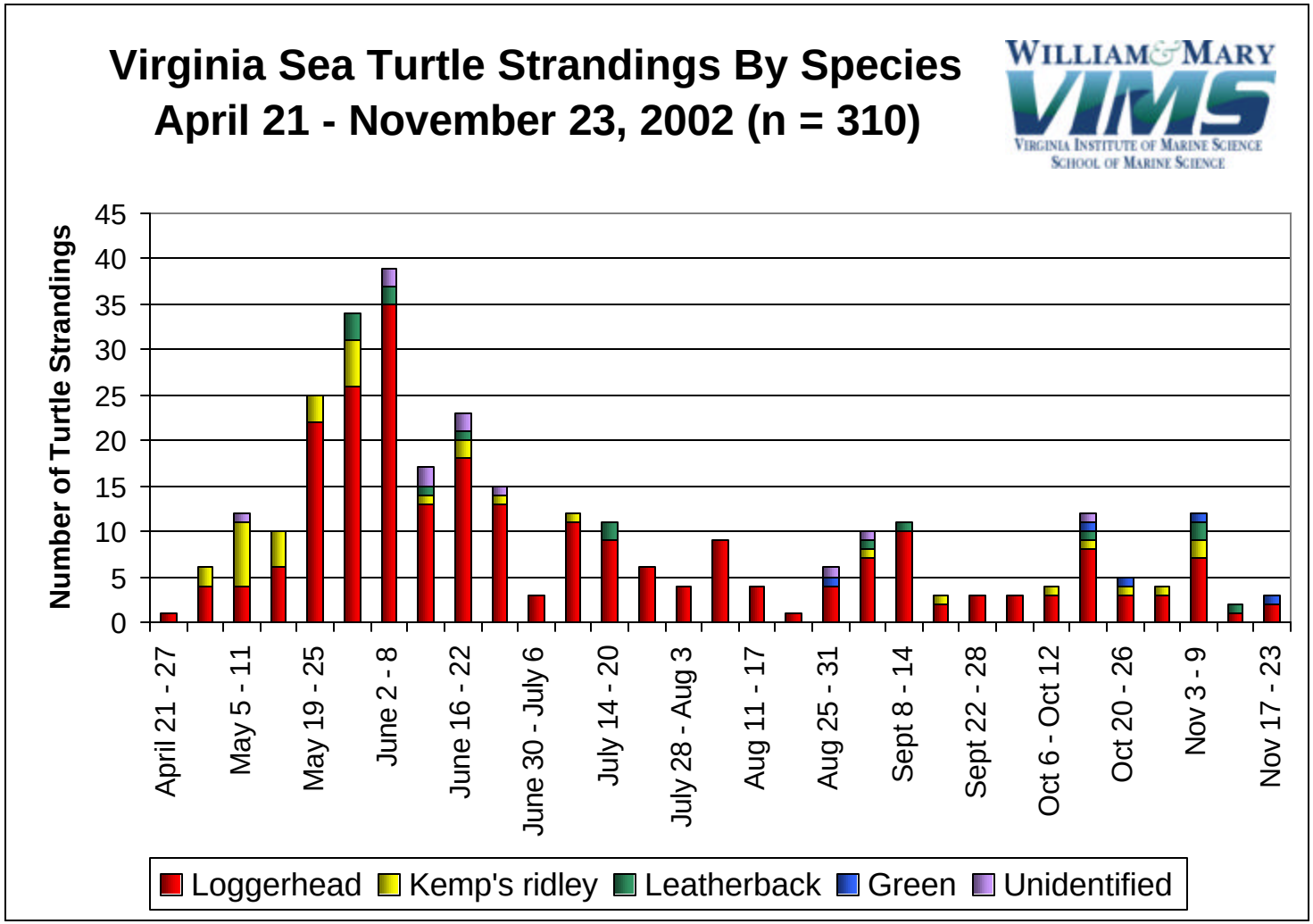


Figure 24. **2002 sea turtle strandings by week and species, April 21-November 23. From Mansfield et al., 2002b.**

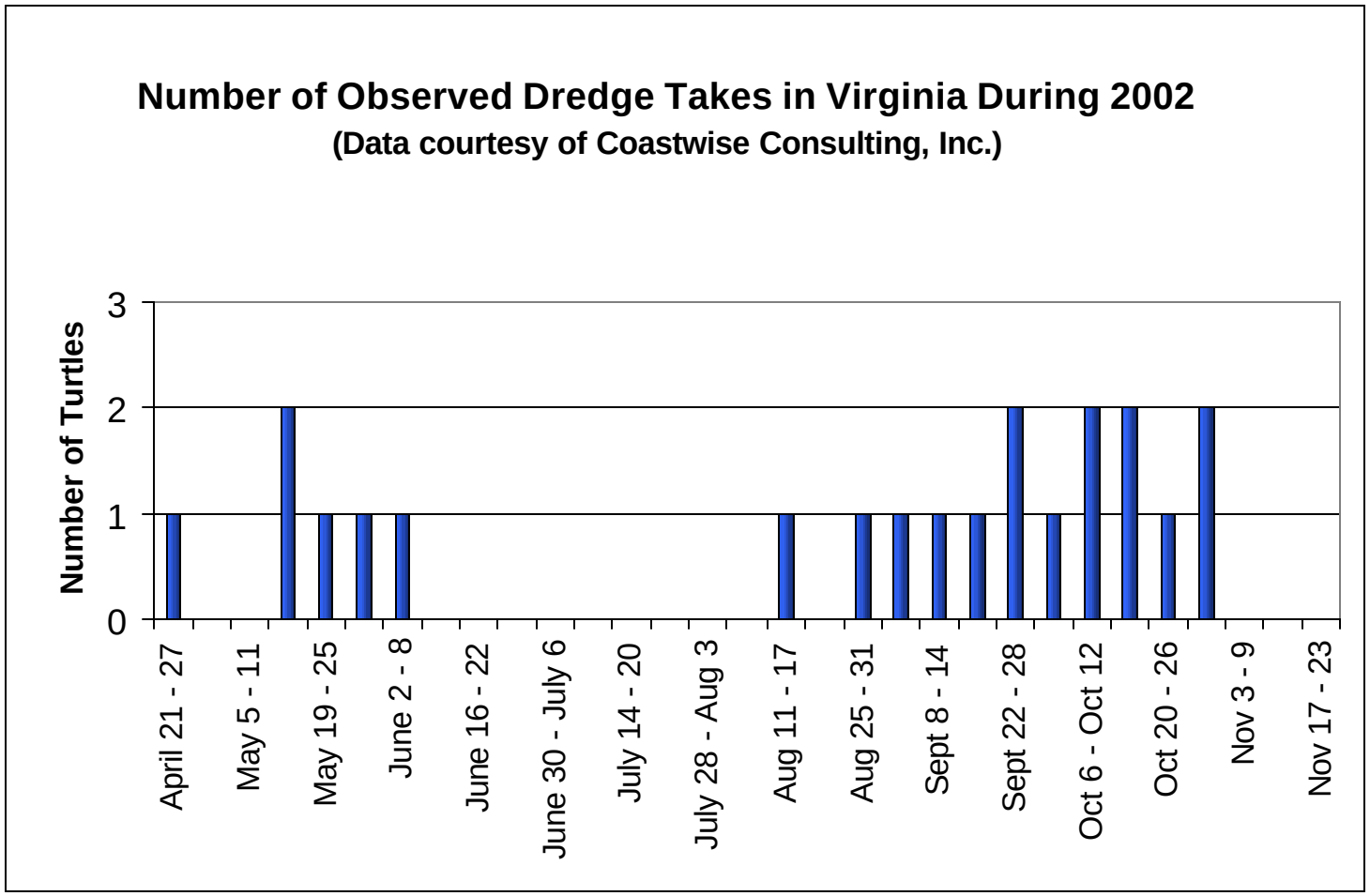


Figure 25. **Number of observed dredge takes by week in Virginia, 2002 as reported to the Virginia Sea Turtle Stranding Network. Data courtesy of Coastwise consulting, Inc.**