Movements of Loggerhead Turtles Caught in the U.S. NED Swordfish Longline Fishery

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The objective of this study is to use real-time satellite telemetry to provide data on the ecology of pelagic stage loggerhead turtles on the Grand Banks, where they interact with U.S. pelagic longline fisheries. This research is not meant to provide data on post-hooking mortality. It is intended that the information stemming from this research will provide information contributing to an effective NMFS management strategy to reduce, prevent, or mitigate the rate of bycatch of sea turtles in longline fisheries. This project is a component of a larger collaborative study, and as such, is intended to provide complementary data to those being collected by archival pop-up satellite transmitters (PSAT) on the same group of turtles.

Prior to the 2002 NED longline fishing season, a series of workshops were held to train, NMFS observers. The workshops were held in Miami and coordinated with the Southeast Fisheries Science Center. Along with some basics of sea turtle biology, observers were trained in sea turtle handling and sampling protocols, hook and line removal, data collection, and satellite transmitter attachment methods for both conventional and PSAT transmitters.

Materials and Methods

The attachment method selected for the real-time transmitters was a one-point attachment, through a 1/4" hole drilled in the overhanging edge of the posterior-most scute of the carapace (Fig.1). This quick process is well suited for the rapid attachment of a buoyant transmitter, which trails along behind, in the slipstream of the turtle. Furthermore, using a short flexible lanyard for attachment enables the transmitter to stand upright and transmit signals to a passing satellite as the turtle rises to the surface to breathe (Fig. 2).

Transmitters were housed within a package designed for simple and efficient attachment to turtles on the deck of a ship at sea. The transmitter housings were slightly buoyant, hydrodynamic, and crush-proof at depths in which turtles are normally active. The resultant package is torpedo-shaped, slightly buoyant, and designed so the antenna stands upright from the dorsal surface as the transmitter trails along passively behind the turtle (Fig. 3.)

The transmitter model chosen for real-time monitoring was a satellite-linked time-depth recorder, type SDR-T16 (Wildlife Computers, Redmond, WA 98052), which serves as the controller for an ST-16 Argos transmitter (Telonics, Mesa AZ). This style recorder combines the ability to monitor depth, position, surfacing activity, and diving profiles with the ability to transmit all of these data to passing satellites on a near-real-time basis.

The original study design included 10 transmitters for the first season, but one failed during initial tests upon start-up prior to being sent out to the observers. This tenth transmitter was sent back to the engineers for testing, and refurbishing, and will be used in the second year of the study.

At the time of start-up the transmitters also were programmed through communications with their microprocessor. Along with location data, all nine transmitters were designed to collect and transmit data on depth, dive duration, and time-at-depth profiles, each of which is stored as histograms in pre-defined intervals. The depth and time-at-depth intervals selected for all nine transmitters were: 0-2, 2-5, 5-10, 10-15, 15-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-100, 100-150, and 150-245 m. The dive duration intervals were: 0-2, 2-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, and >90 min. In addition, all transmitters were programmed to transmit over the same duty cycle, which added up to a total of 8 h per day of

active duty.

As part of a strategy to get a lot of data during the fishing season in addition to some data on longer-term activity of the turtles, the schedules of active duty for the transmitters were variably programmed. Six of the transmitters were scheduled to transmit daily, two were on an alternate-day schedule, and one was preset to transmit only every third day.

In July 2002, just prior to the beginning of the fishing season, transmitters were distributed to fishing vessel captains and NMFS observers, to be included in their turtle sampling kits aboard the vessels. Initially, two real-time transmitters were distributed to each of four observers, and a fifth observer received a single transmitter Since the real-time transmitters were complementary to the PSAT transmitters, the plan of attachment was for the observer to alternate transmitters, attaching a PSAT transmitter to one turtle and a real-time transmitter to the next suitable turtle captured.

During the course of the season, real-time transmitters were attached to five juvenile loggerheads that were incidentally captured in the experimental longline fishery. The attachment process reportedly went smoothly, and all five turtles were observed to be active and apparently healthy upon return to the water. Among this subset of transmitters used in the first season, four were programmed for the maximum transmission schedule and one was set to transmit on alternate days.

Results Summary

Capture and release data – Five juvenile loggerheads were selected for attachment of satellite transmitters for this part of the study in the first season (Table 1). All of these turtles met the criteria that were determined prior to the study. All appeared on board after a PSAT transmitter was attached to a previous turtle; all of the turtles were deemed lightly hooked, or minimally impacted by the capture process; and all were large enough to easily support a transmitter. Four of the five turtles were hooked in the anterior parts of the mouth, ranging from very superficial penetration into the hardened beak area, to deeper penetration into the fleshy tongue and lower jaw. The fifth turtle was merely entangled, with the hook encircling the thinner portion of its upper humerus. All hooks were removed readily, with minimal or no residual damage to the turtle. No problems were encountered during the short attachment process, and all were observed to be swimming vigorously away upon return to the water.

Location data - The first two real-time satellite transmitters (labeled “Jimmy1" and “Jimmy2") were attached to loggerheads caught by the same vessel on 15 and 16 August 2002, respectively (Table 2). The release location of Jimmy1 was approximately Lat. 46° 08' N and Lon. 41° 01' W, a position nearly 54 Nmi east of the southeastern tip of the Flemish Cap (Fig. 4). Over the course of the next 29 days, Jimmy1 moved generally southwards, meandering over a course that carried it much farther than its net distance of approximately 442 Nmi from its release location (Figs. 4-5).

The second transmitter, Jimmy2, was released near Lat. 47° 26' N and Lon. 42° 11' W, about 11 Nmi east of the Flemish Cap and nearly 127 Nmi north of Jimmy1. This turtle’s early movements took it in clockwise loops around the region of the northern Flemish Cap, before it also headed generally southeastwards for the remainder of its 31 day track (Figs. 4-5). It was at this point, a net distance of 210 Nmi from the release location, that the transmitter reported its last diving data (Fig. 5). It has not yet been determined whether this transmitter detached from the turtle, or merely stopped sending auxiliary data. Nevertheless, over the next two weeks, the transmitter continued to move more than 200 Nmi farther along a southern track that was similar to the previous turtle’s route. At one point, although these paths were separated by more than 4 weeks, the routes for the transmitters passed within 17 Nmi of the same location.

A third transmitter, Jeff1, was attached to a loggerhead more than 500 Nmi farther east on 23

September. The release location near Lat. 42° 59' N and Lon. 52° 21' W, was nearly 240 Nmi south of Avalon Peninsula, Newfoundland, on the western fringe of the Grand Banks (Fig. 5). Soon after its release, this turtle began an arching curve southwestward, and thereafter continued on a meandering path along the edge of the continental shelf (Fig. 6). Over the entire 40 day monitoring period, Jeff1 exhibited a net movement of 203 Nmi southwest of the original release point.

The fourth and fifth transmitters were released in October from the same vessel, and both on the eastern fringes of the Grand Banks (Fig. 6). Patrick3 was released on 12 October, 31 Nmi east of the southeastern tip of the Flemish Cap, near Lat. 46° 30' N and Lon. 41° 35' W. Similar to the previous turtle tracked in the same area, this turtle began swimming in loops, one counterclockwise, the other clockwise, moving a great deal more than its calculated net movement of 88 Nmi during the course of its 20 day track. It is possible that such circular paths represent search patterns, especially for an animal trying to orient to some environmental cue.

The following week Patrick2 was released closer to the Tail of the Bank region of the Grand Banks, near Lat. 44° 32' N and Lon. 47°18' W (Fig 6). This turtle headed mainly southeastwards to the Newfoundland Basin, toward the same general area as two of the previous turtles of its cohort. At the finish of its 20 day track, the Patrick2 moved a net distance of 200 Nmi from its original site of capture and release.

Bathymetry - A potentially important environmental feature for these pelagic loggerhead turtles is bathymetry. However, in examining the recorded movements, there was no obvious influence of ocean depth on the locations of the turtles (Fig 6). Overall, the depths over which the turtles moved ranged from 2310 m to 5115 m. Jimmy1 and Jimmy2 moved quickly over a sea floor rise, but principally remained in deeper waters of the Newfoundland Basin. For the most part, there seemed to be a great amount of spatial autocorrelation, with regard to the turtle locations and the depth of the water beneath them. That is, the turtles were captured and released in relatively deep water, there was only deep water in their immediate vicinity, and they would have to move away and up onto the continental shelf to encounter shallow water. Moreover it is likely that depths exceeding 3000 m are beyond the physiological limits of diving for these juvenile turtlesThus, it is likely that the association with deep water was not a direct relationship, and the turtles' movements were not influenced by bathymetry alone.

Water column - The most important information after geo-referenced positions of the turtles is their activity with respect to position in the water column. Knowledge of the depth profiles of turtles is required to properly relate turtle movements with oceanographic correlates such as bathymetric characteristics and water temperature.

The summaries of the percentage of time spent by the five turtles at various depths throughout the water column show very clearly that these young pelagic loggerheads are not shuttling to and from the bottom (Figs. 7-9). Rather, the five turtles cumulatively spent from 50% to 67% of their time in the upper 2 m of the water column. Moreover, they spent very little time at depths below 70 m, and only occasionally ventured deeper than 100 m. The confinement of activity to the upper 10% of the water column makes it highly unlikely that water depth is directly influencing turtle biology in the waters surrounding the Grand Banks. Any associations with water depth are likely indirect, such as the relationship between the continental rise and the North Atlantic Current.

There was no apparent seasonal pattern in depth usage patterns (note that these are only late summer/fall profiles however). Instead, the deeper dives recorded in September and October reflect inherent differences among individual turtles (Figs. 8-9).For example, Jimmy2, Patrick2, and Patrick3 never recorded dives deeper than 70 m, while Jimmy1 made excursions down beyond depths of 130 m in both August and September; and Jeff1 was the deepest diver with dives to as deep as 248 m. The location of the turtles did not obviously affect

the diving depths, but a more detailed analysis at the scale of the individual turtle may be warranted.

Sea surface temperature - Water temperatures appeared to have a direct influence on the movements of the turtles. All told, the five turtles traveled through water temperatures ranging from 14° C to 25° C. When turtles encountered water temperatures at the lower end of this range, they appeared to be stimulated to move. Often these movements took on a meandering or circular path, which gave the distinct appearance that young loggerheads were orienting to thermal cues (Fig.10). The obvious circular paths exhibited by Jimmy2 and Patrick3 both were movements made initially from 17° C water, and immediately into cooler water. As they encountered the cooler water, they continued circling until warmer water was reached. For these, and the other meandering turtles, once the water temperatures started to increase, their paths tended to straighten out. Upon last contact, Jimmy2 was in water temperature warmer than 20° C, Patrick2 was in waters warmer than 22° C, and Jimmy1 and Jeff1 made it to waters exceeding 24° C in temperature. It is likely that water temperature (and relative water temperature) is important to many aspects of the ecology of pelagic juveniles. This could be an optimal indicator for predicting where and when turtles are in the Grand Bangs region.

Looking Forward

As we prepare for the 2003 NED longline experiment we plan to continue aspects of this project that were successful. The training and communication with the observers worked very well, and there was good feedback about the attachment process. Additional phone messages from the observers at sea indicated that the one-hole attachment process was fast, easy, and presented few or no problems, even for a single person in heavy seas. Also the immediacy with which we began to record and process data on the just-released turtles highlights the effectiveness of the real-time transmitters. In two cases, satellite data were streaming in before the first phone message from the observers reporting the capture and release of a turtle. And several participants in the project commented on the usefulness of the maps of the movements of the turtles that were transmitted at frequent intervals during the fishing season. In addition, the collection of data on turtle movements, with respect to position in the water column and relative to sea surface temperatures, seem to have great potential for understanding the ecology and basic behavior of the juvenile loggerheads that are interacting with the longline fishery.

Through the continuation of these successful project elements, we will increase the likelihood of success also in the second study year. Once again, prior to the upcoming season, we will join the observer training sessions for discussions, demonstrations, and hands-on instruction in transmitter attachment techniques. On board the vessels, the plan of alternating between the attachment of PSAT transmitters and real-time transmitters seemed to be optimal for providing complementary data on turtle ecology at sea. This protocol will be repeated. In addition, transmitters will again be programmed to collect as much data on turtle location and diving profiles as possible to supplement our increasing knowledge of the ecology of these pelagic juveniles. We will also continue to program the transmitters to begin recording and transmitting soon after the turtle's release, and keep sending frequent map updates to the collaborating researchers.

In addition to carrying over some of the project design, we are planning on making improvements during the second season, primarily with regard to transmitter programming and attachment. During the first year, the initial desire was to get many data quickly, and to ensure that turtles were being monitored on a real-time basis with respect to the ongoing experimental fishing operations. Therefore no daily transmission limits were imposed on any of the transmitters. Furthermore, six of nine transmitters were pre-programmed for extremely high-energy daily transmission cycles. As a result of the low number of turtles captured, and the luck of the draw, four of the five transmitters used were from this group with maximum duty cycles.

During the second season, monitoring of the same variables will continue, but the priorities will shift toward achieving longer-term tracks. There will still be real-time transmissions during the fishing season, but the transmitters will be programmed to conserve energy on many fronts. Based on the first year's data, it is highly likely that the turtles will surface often during the daytime and the nighttime period. In addition, the current transmitter design greatly enhanced the probability of receiving high-quality transmissions. Therefore, the duty cycles will be reduced to 4 h per transmission day, with 2 h at night and 2 h during the daytime hours. There will be a further limit placed on the number of allowable transmissions in any given day to reduce chance of redundancy. Finally, a higher proportion of the transmitters will be placed on schedules of alternating days, transmitting either once every 2 days or once every 3 days.

To go along with the more energy conserving programming and duty cycles, slight improvements also will be made to the attachment technique. The longer transmitter life will be accompanied by the necessity for longer–term tethers, which will be accomplished mostly through the use of new, heavier lanyard material. This will allow for easier crimping, and for standardization of the process. With the previous lanyards, the observers had to take some care not to crimp too hard and weaken the tether. The new design should alleviate this potential problem and contribute to long-term tracks in the second year.

In the upcoming season, we also will alter some of the measured parameters to better align the two types of satellite transmitter data (real-time and PSAT). This will entail only minor adjustments to the assignment of depth intervals, but will help mesh the data sets in a way to better extract more biological data from the turtles in this study.

In the early going, we are optimistic that good information on the biology of pelagic sea turtles is likely to lead to the development of predictive models upon which management decisions can be based. The picture of loggerhead ecology that may be emerging is one of a pelagic turtle in a juvenile life stage that is adept at working the oceanic zone surrounding the Grand Banks. This region is highly complex, especially in terms of thermal fronts, and probably offers good foraging to these turtles, as it does to the swordfish and tuna that congregate in the area. The subsequent convergence of turtles, fish, and the commercial fishing industry in a relatively confined region during several weeks of the year could continue to be a big problem. The difficulty of management could be greatly alleviated with a basic understanding of the ecology of the turtles. Moreover, some of the gear modifications tested in the first year seem to have great promise for lessening the problems inherent in catching turtles on baited hooks. Through the combination of these gear modification studies and telemetric monitoring, we may find a way to tease apart, and ultimately reduce, the interactions between sea turtles and pelagic longline fisheries on the Grand Banks.

Table 1. Capture details, conditions, locations, and standard straight-line carapace measurements of the five juvenile loggerhead turtles outfitted with real-time satellite transmitters in the 2002 NED Pelagic Longline Fishery season.

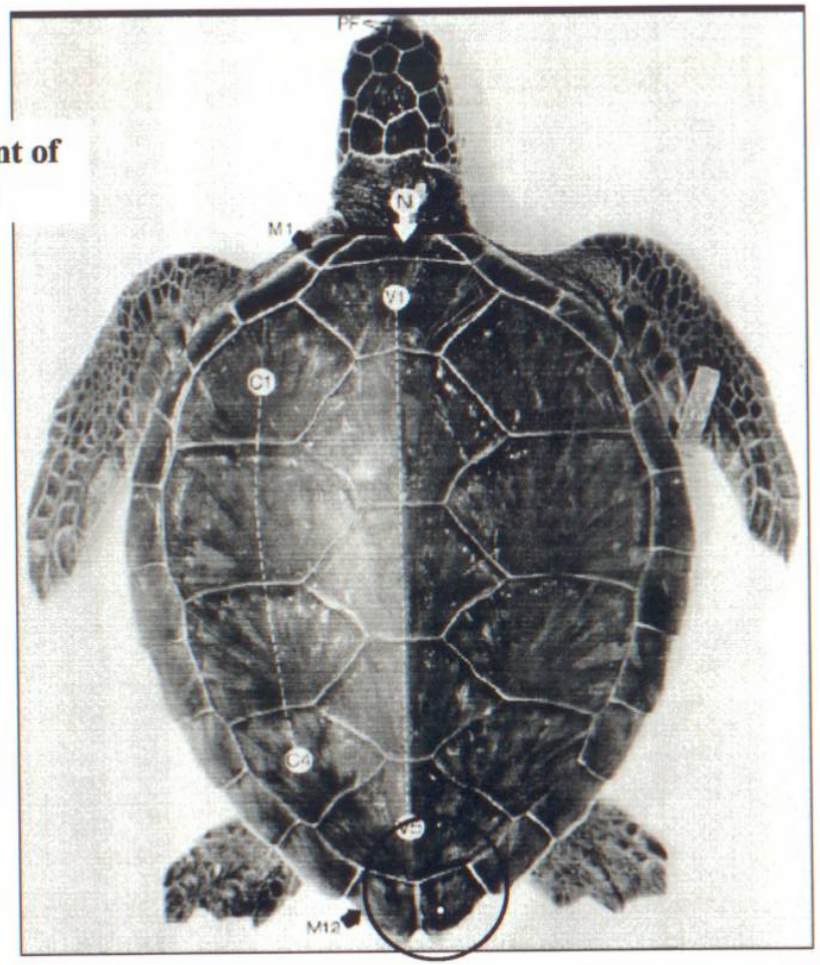
Turtle ID (Lft Rear)	Transmitter ID	SCL (cm) Standard	Hook Location	Comments on Severity of Capture
XXG226	JIMMY1	62.0	Beak	Very lightly hooked. Hook fell out in retrieval net. No Bleeding. Turtle swam away strongly.
XXG228	JIMMY2	59.5	Beak	Very lightly hooked. Hook removed easily by hand. No Bleeding. Turtle swam away strongly.
XXY742	JEFF1	58.0	Tongue	Hook through tongue, but backed out easily. Small hole in tongue. Turtle swam away strongly.
XXG582	PATRICK3	50.1	Flipper	Hook was not penetrating skin. Thin part of humerus was inside the circle of the hook. Turtle swam away strongly.
XXG586	PATRICK2	47.6	Mouth	Lightly hooked in lower jaw, anteriorly, under the tongue. Seemed lethargic, but swam away strongly.

Table 2. Net tracking durations and distances traveled for five loggerhead turtles tracked by satellite transmitter from the Grand Banks region during the U.S. NED Pelagic Longline Swordfish season of 2002.

ID	Release			Last contact			Duration (days)	Distance (km)*
	Date	Lat. (N)	Lon. (W)	Date	Lat. (N)	Lon. (W)		
JIMMY1	8/15/02	46° 08.5'	41° 01.4'	9/13 /02	39° 12.3'	43° 46.4'	29	442
JIMMY2	8/16/02	47° 26.0'	42° 11.0'	9/16/02	45° 45.2'	38° 28.6'	31	210
JEFF1	9/23/02	42° 59.5'	52° 21.8'	11/5/02	41° 29.8'	56° 22.9'	43	203
PATRICK3	10/12/02	46° 01.8'	41° 33.3'	10/31/02	47° 01.3'	39° 37.0'	20	88
PATRICK2	10/17/02	44° 35.7'	46° 54.5'	11/28/02	43° 01.5'	43° 43.1'	11	175

* These are net distances based on beginning and end points only. All are underestimates of actual distances traveled.

Fig. 1. **Instructions for Attachment of Real-Time Satellite Transmitters**



For Loggerheads > 45 cm SCL

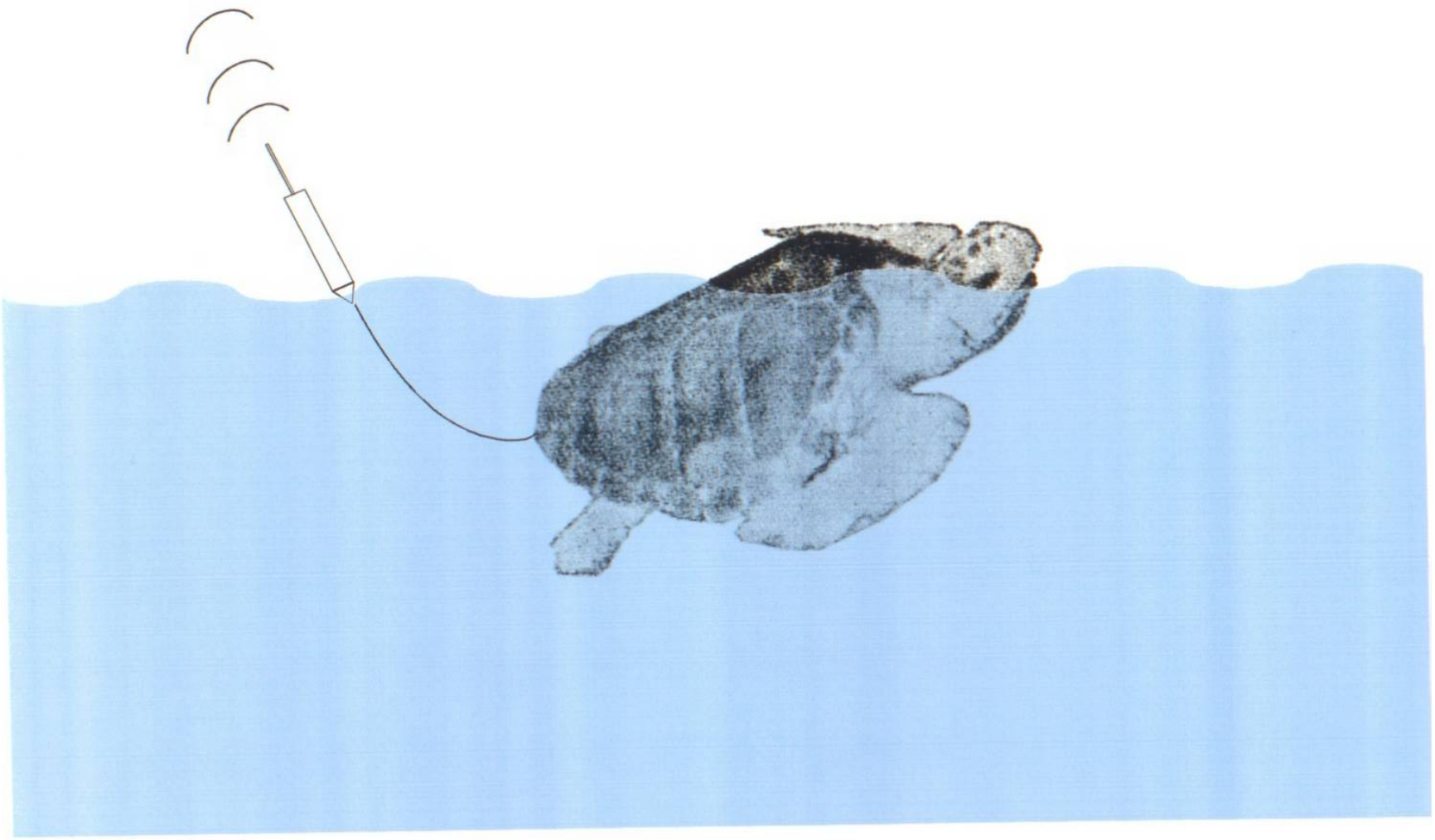
Lightly Hooked Only

1. Choose posterior-most scute on either right, or left side of midline.
2. Clean upper and lower surface of barnacles (so they don't scrape the lanyard).
3. Drill hole 1/2 inch in from outer edge and 1/2 inch away from midline seam.
4. Make loop just large enough to move freely around the scute.
5. Crimp using the 10-12 gauge setting (the bottom crescent)
6. **Leave room to crimp twice -- Don't bear down too hard, just nice and snug.**

Stay a little away from the edge of the sleeve -- reverse crimpers on second crimp.

Check your work and let the turtle go gently into the water.

Fig. 2. Transmitters send encoded messages when the turtle rises to the surface to breathe



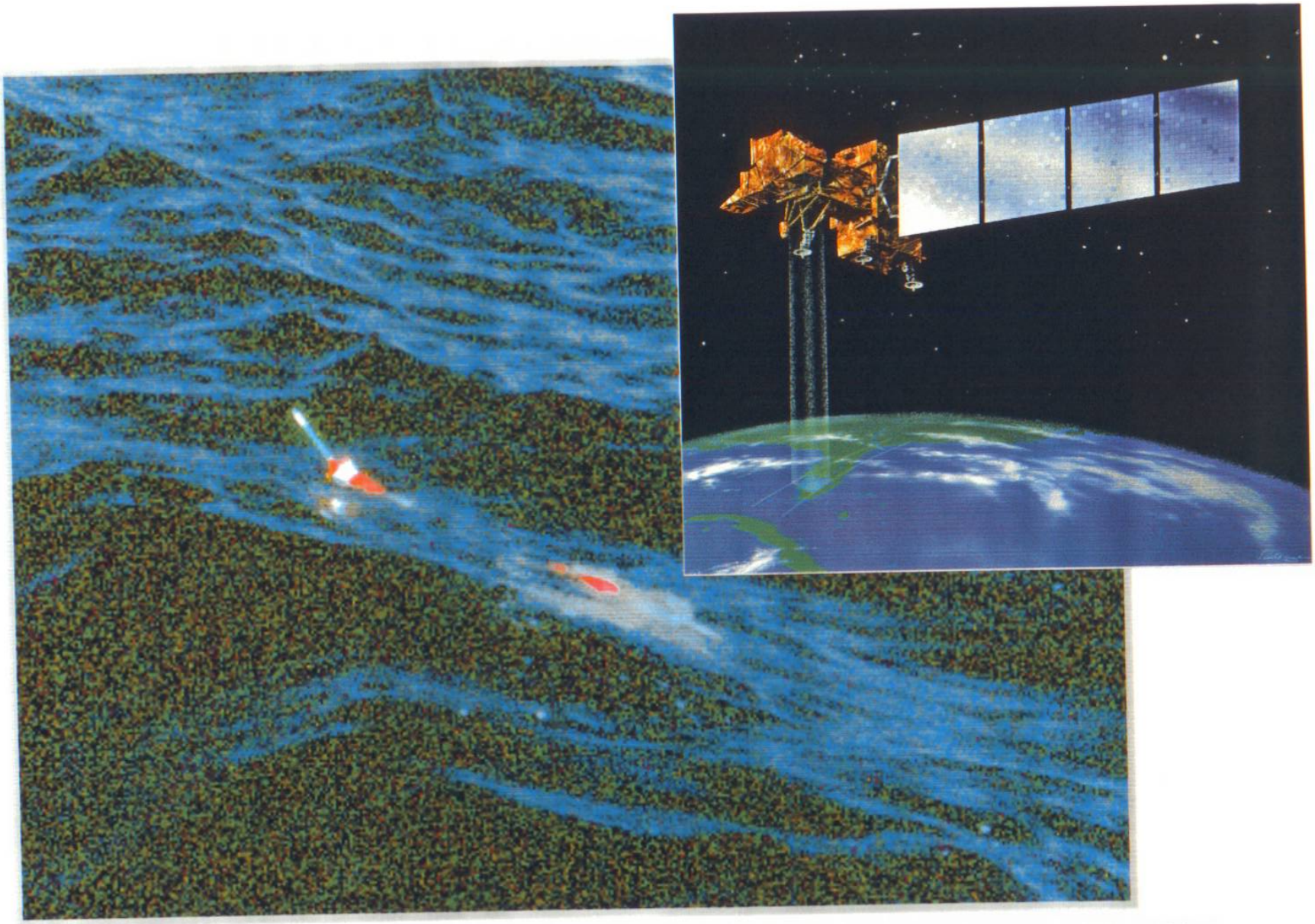
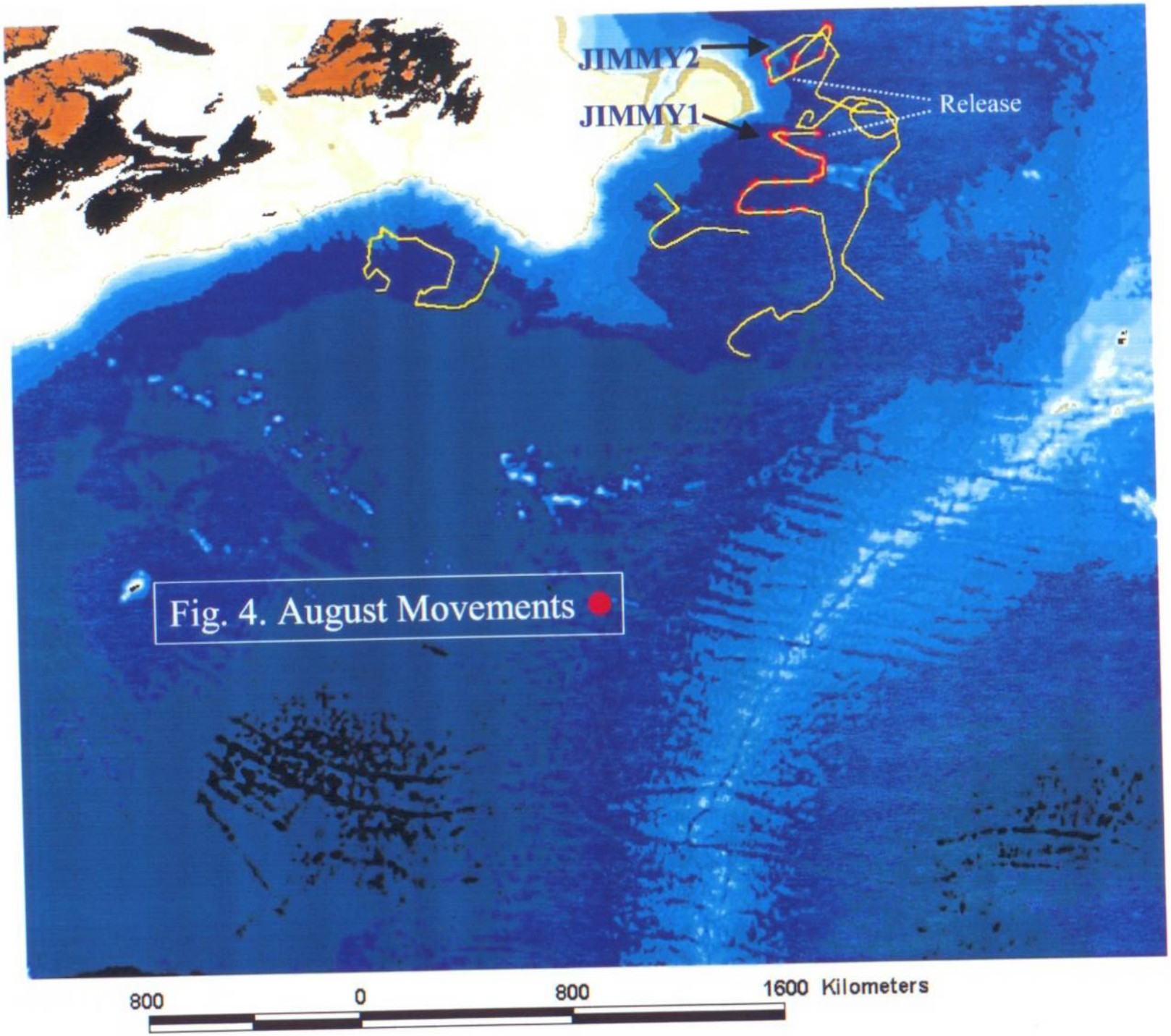
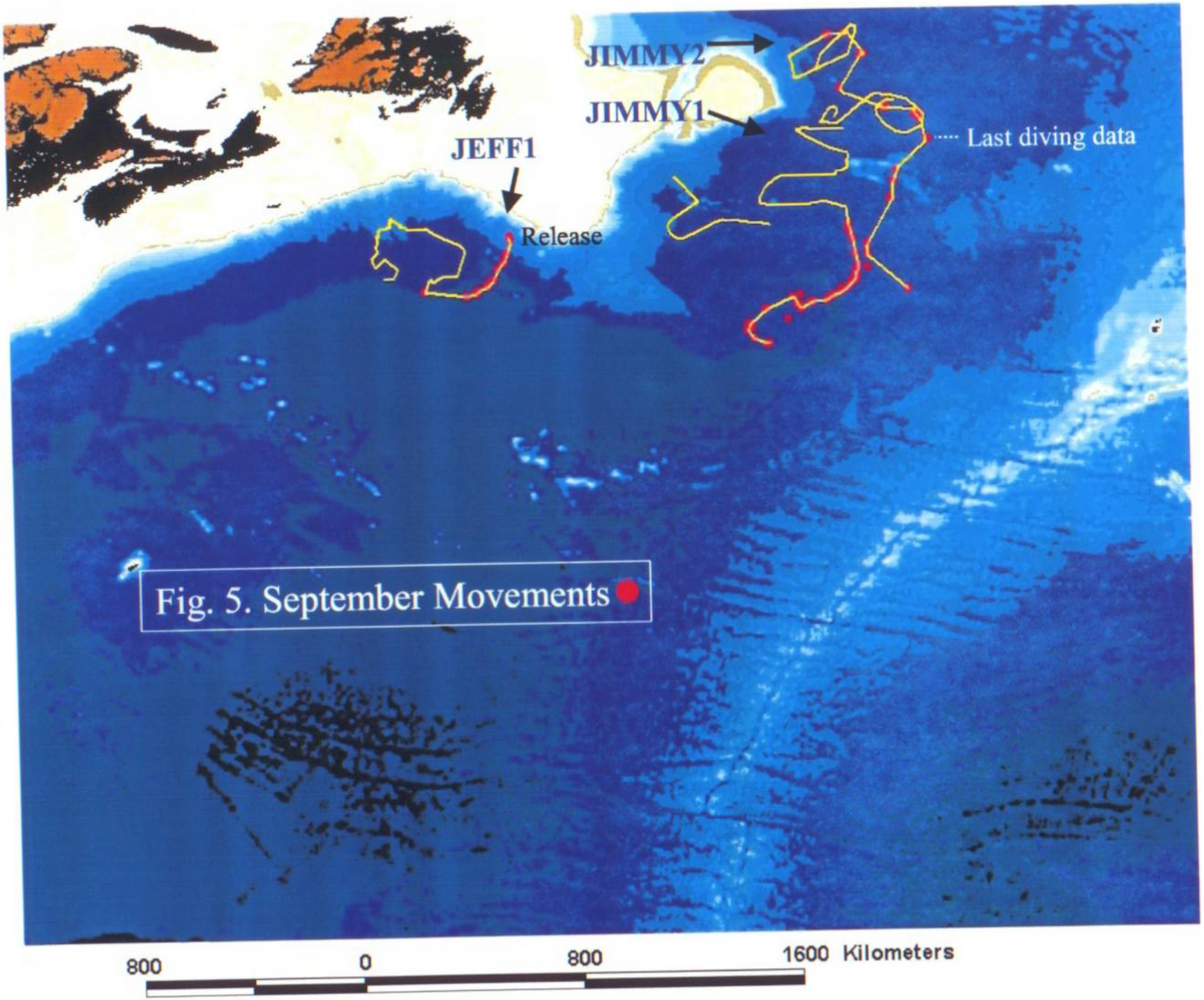


Fig. 3. A sea turtle in open waters illustrates the performance of a trailing, buoyant transmitter. In this position, the transmitter detects the surface and transmits data. The polar orbiting satellites ensure that coverage is global.


JIMMY2
JIMMY1
Release
Fig. 4. August Movements
800
0
800
1600 Kilometers


JIMMY2
JIMMY1
JEFF1
Release
Last diving data
Fig. 5. September Movements
800
0
800
1600 Kilometers

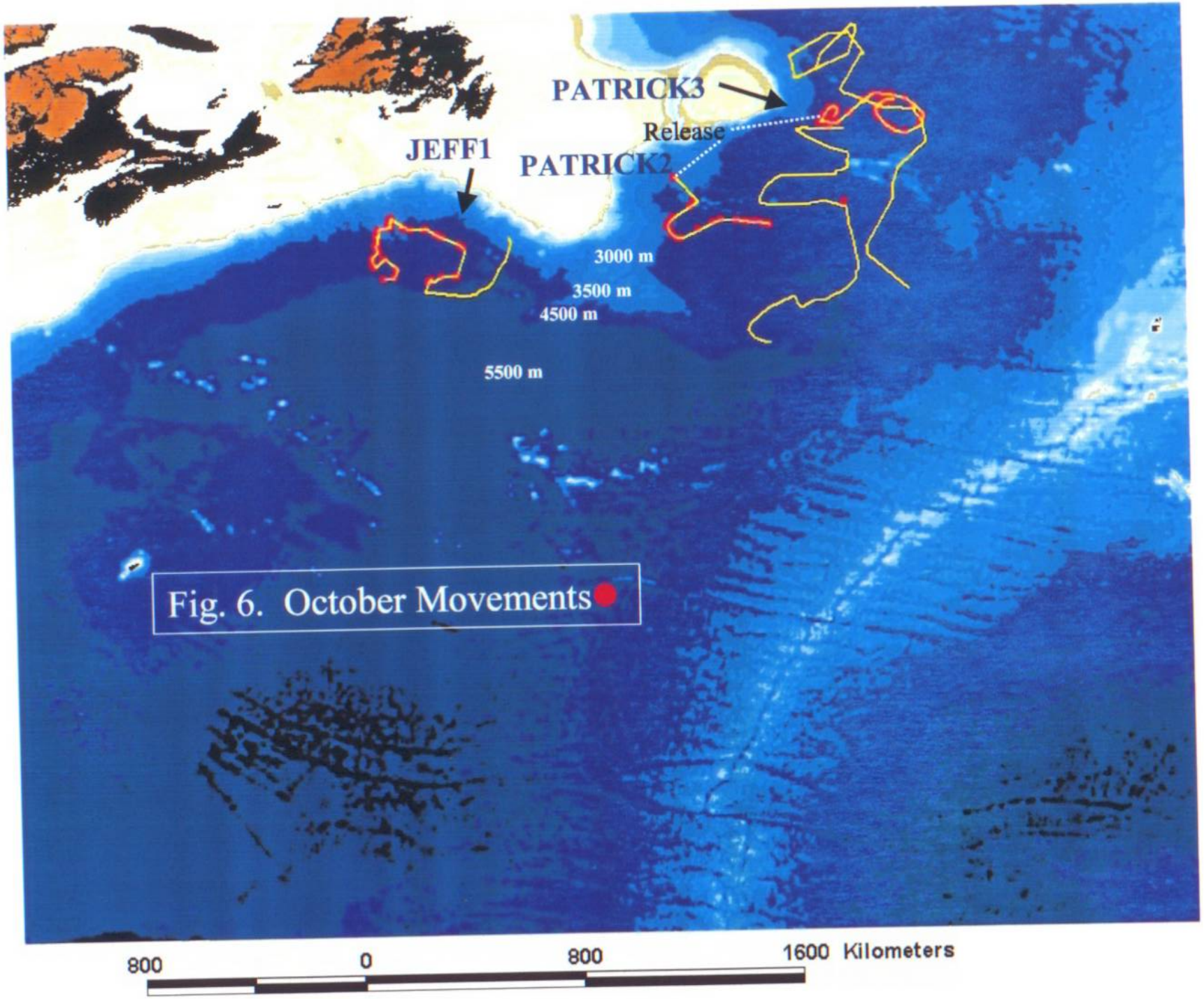


Fig. 6. October Movements

Fig. 7. Percent time spent at depth intervals throughout the water column

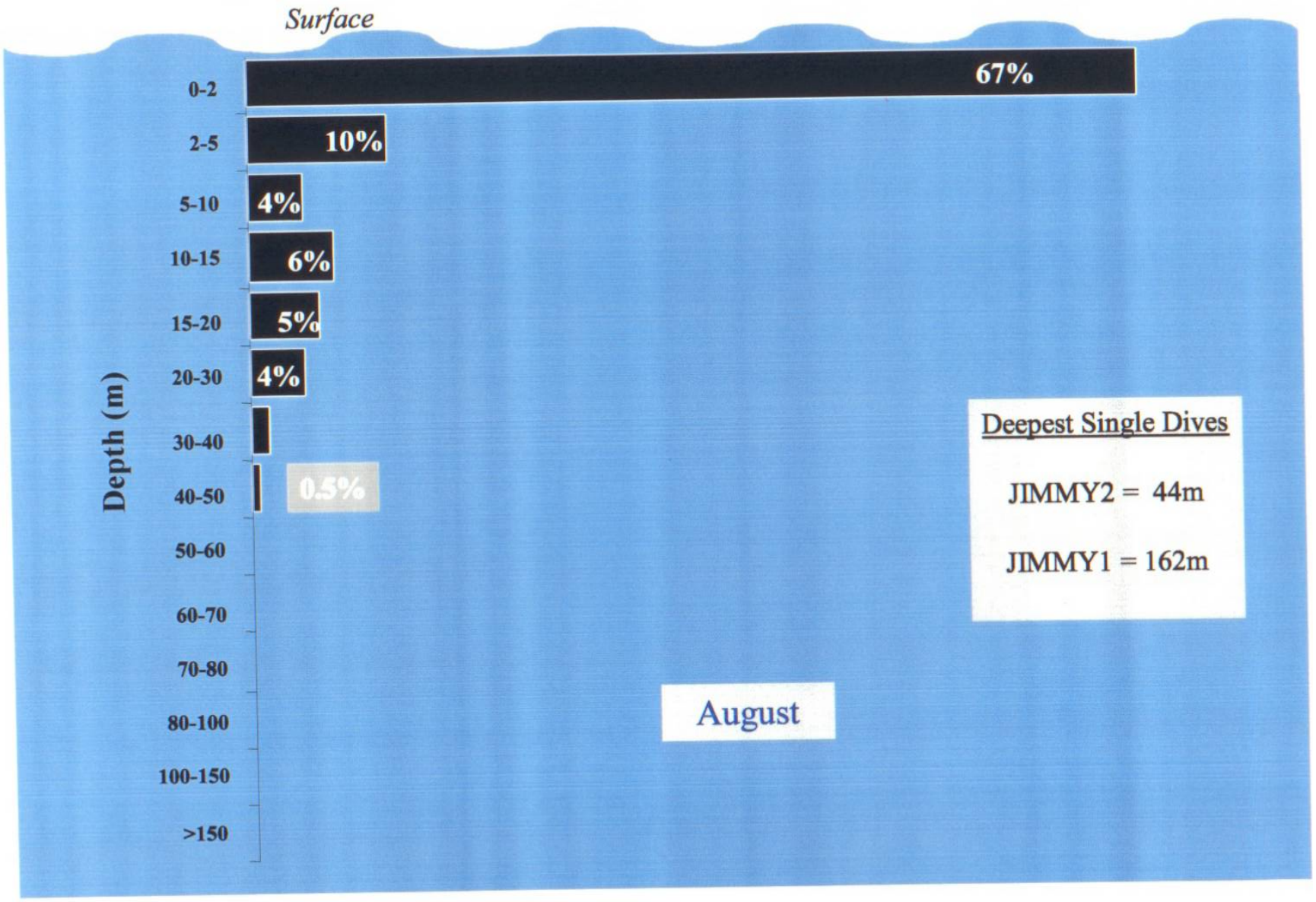
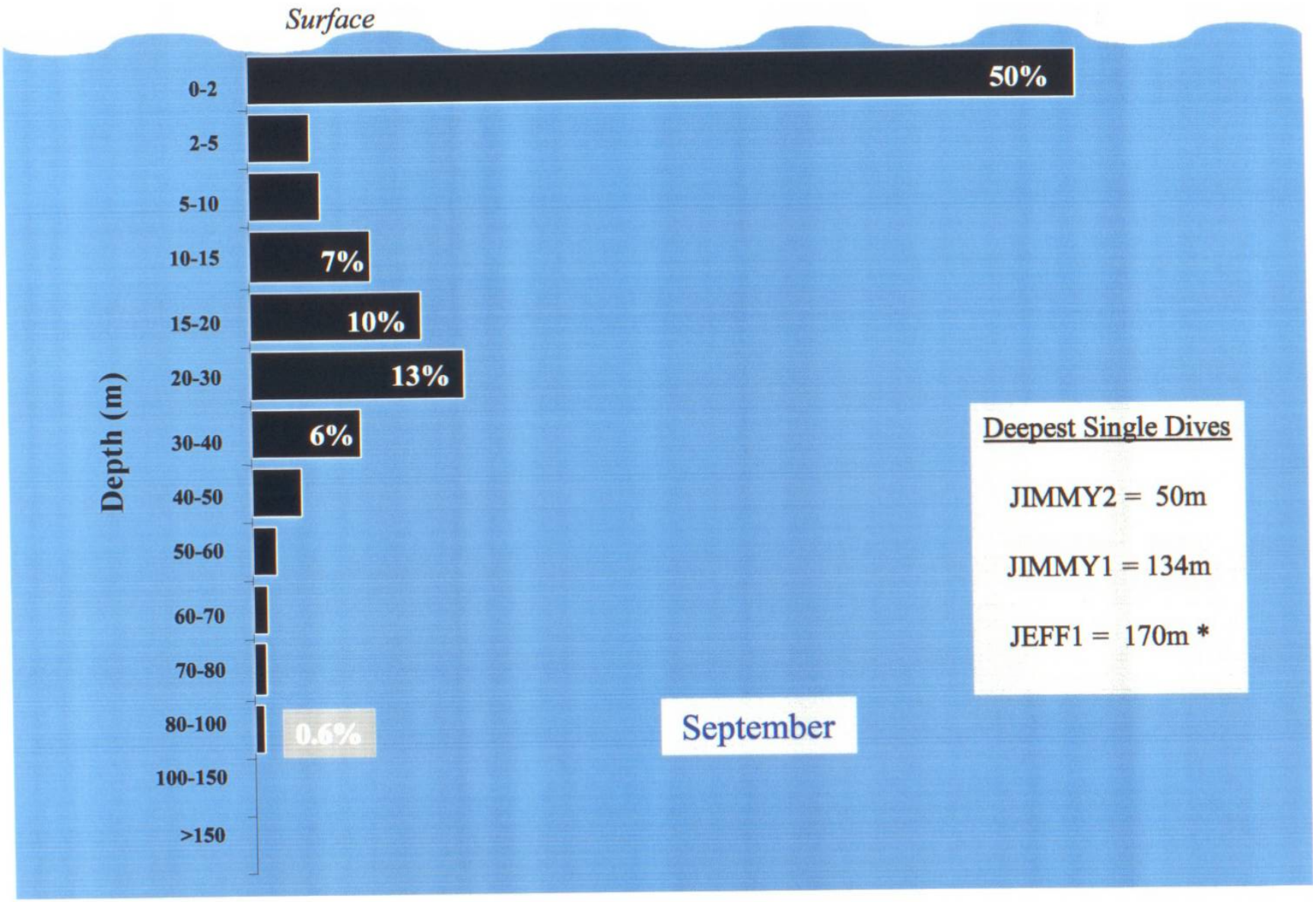
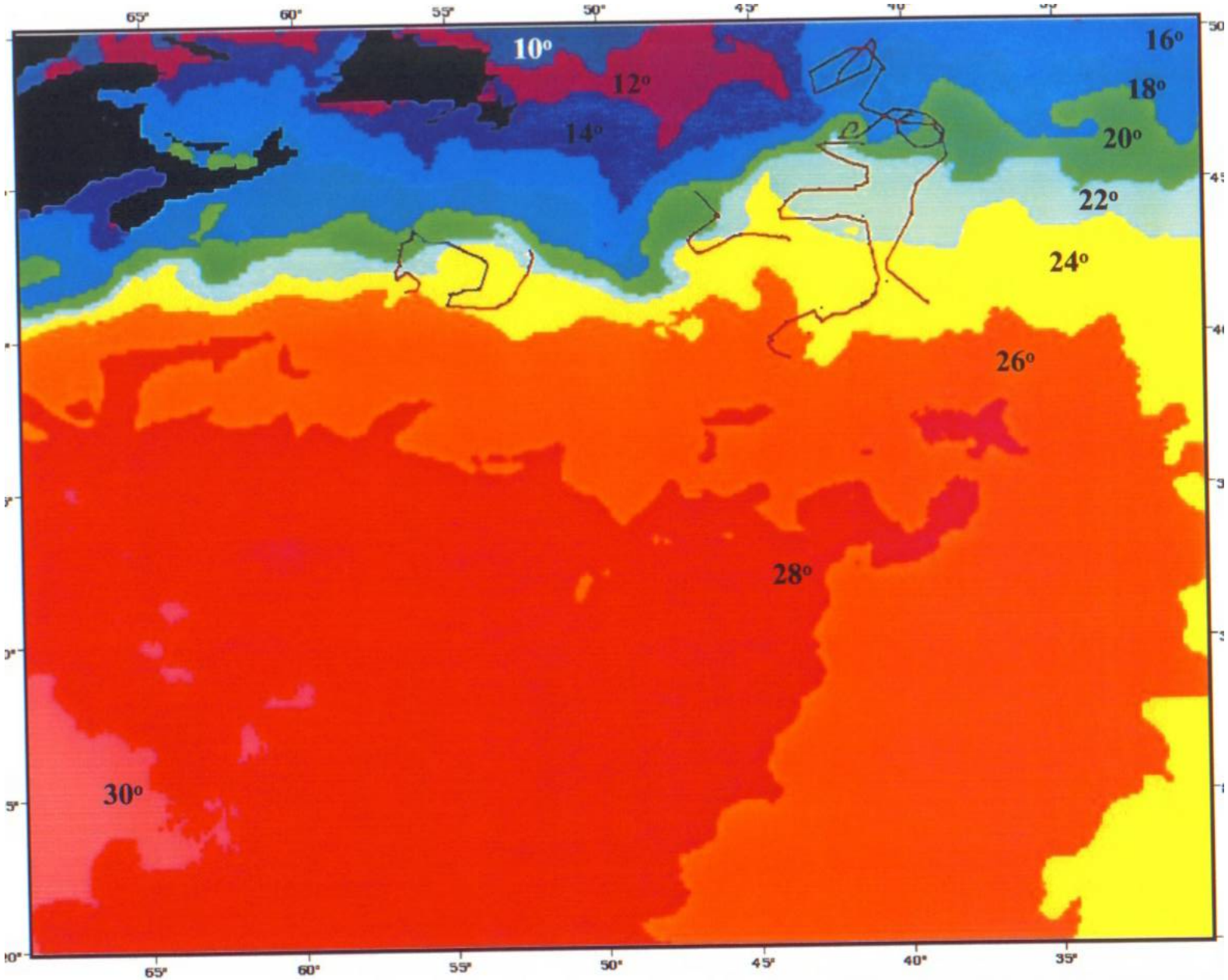


Fig. 8. Percent time spent at depth intervals throughout the water column





. 10. Complete satellite tracks of the five loggerhead turtles with respect to mid-season w
peratures. Water temperatures are MODAS SST data for the day of 1 September 2002.
ODAS data Courtesy of NRL, Stennis Space Center)