PFRP Pelagic Fisheries Research Program

Volume 7, Number 2 April–June 2002

Quantifying Sea Turtle Mortality with PSATs

Yonat Swimmer, Richard Brill and Michael Musyl

The incidental capture of marine turtles in longline fishing gear is generally accepted to be a significant factor contributing to the decline of sea turtle populations in both the Pacific and Atlantic Oceans (Heppell et al., 1999; NMFS, 2001a). Pelagic-stage juvenile hard-shelled turtles (e.g., Loggerheads, Caretta caretta*) are generally hooked in the mouth, presumably because they have bitten baited hooks (Figures 1 and 2), whereas Leatherback turtles (*Dermochelys coriacea*) are most often hooked in the flippers or entangled in fishing lines.*

While most turtles that interact with longline gear are eventually released alive, they are often released with hooks remaining in their mouths, throats, gastrointestinal tracts or flippers (Aguilar et al., 1995; Oravetz, 1999). The ultimate effects of these hooks and the stress of capture are unknown. Rates of post-release mortality have not yet been adequately quantified, and available estimates are highly controversial. Given the growth in U.S.-permitted longline fishing vessels in both the Pacific and Atlantic over the past two decades (Hoey, 1996; Ito and Coan, 1999), the question of post-release mortality rates holds growing importance.

The assessment of sea turtle mortality attributed to hooking or entanglement is difficult. Current estimates are based on a combination of known recorded mortality (i.e., turtles dead upon retrieval of longline gear), cessation of transmissions from satellite tags (Parker et al., in press), and captive studies in which turtles hooked on longlines were placed in tanks and observed over time (Aguilar et al., 1995). Needless to say, mortality estimates are extremely variable (ranging from 8 to 95% for Loggerheads and Leatherbacks), thus making it impossible to define a reasonable overall mortality rate following interactions with longline fishing gear (Aguilar et al., 1995; McCracken, 2000; NMFS, 2001b).

Our goal is to quantify the rates of mortality and morbidity in turtles released from longline gear by using state-of-the-art pop-up satellite archival tags (PSATs). PSATs record data on swimming depth, water temperature and daily estimated geolocation (Musyl et al., 2001; Hill and Braun, 2001). Originally designed to track the movement of large pelagic fish (Lutcavage et al., 1999; Arnold and Dewar, 2001), PSATs can be programmed to release and download data up to two years after deployment, providing a record of long-term movement patterns and associated physical environments.

Figure 1. A subadult Olive Ridley Sea Turtle (*Lepidochelys olivacea*) hooked in longline fishing gear (photo by Yonat Swimmer).

More important, however, PSATs will release and begin transmission of stored data if a turtle dies and sinks, or if its tag is shed. Therefore, unlike conventional satellite tags, PSATs provide data that clearly differentiate mortalities from shed tags. Depth data collected by the tags can also be used to determine the extent of morbidity following release. Once at the surface, the tag will download its archived data to a satellite (including the pop-off location directly determined by ARGOS). Some of the tags can conserve battery power by transmitting only when the satellite is in view (SIV). For a tag that has collected data for a year, it normally takes two to three weeks for the archived data to be downloaded.

PSAT Utility and Longevity

In the absence of any mechanical/electronic failure or unusual biological event (e.g., a tag is eaten by a shark), we are confident about the usefulness of PSATs for differentiating a shed tag from a mortality. Our confidence is based partly on earlier successes with tagging blue sharks (*Prionace glauca*). In a collaborative effort between the University of Hawai'i and the NMFS, 14

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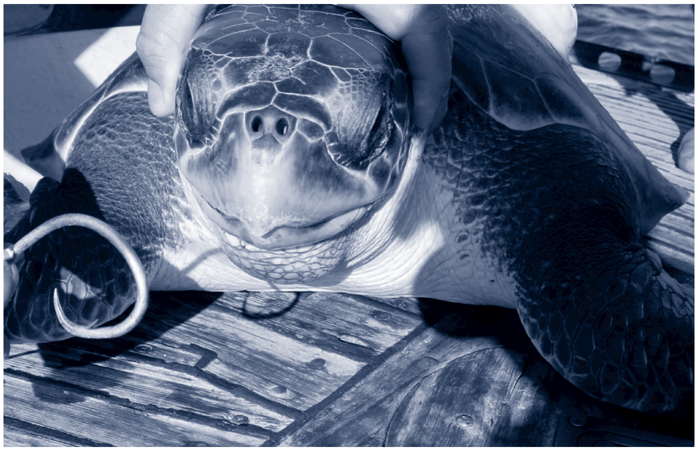

Figure 2. Longline hook removed from lower jaw of an Olive Ridley Sea Turtle in Costa Rica (photo by Yonat Swimmer).

sharks were tagged with PSATs in the Central Pacific following capture by longline gear (see also PRFP Newsletter, July-September 2001, pp. 13-14). The tags were programmed to release at a depth of 1,200 m, which is beyond the depth blue sharks would normally reach (Scarotta and Nelson, 1977; Carey and Scharold, 1990). The depth-data record from one male shark is shown in Figure 3. The animal clearly exhibited normal movement patterns for the first five days following release. After this it succumbed, presumably to injuries sustained during the interaction with longline fishing gear. This is clearly evidenced by the plummeting descent of the PSAT followed by a rapid ascent after automatic release at the programmed depth of 1,200 m. We believe similar tag programming and function will be useful to indicate mortality in marine turtles.

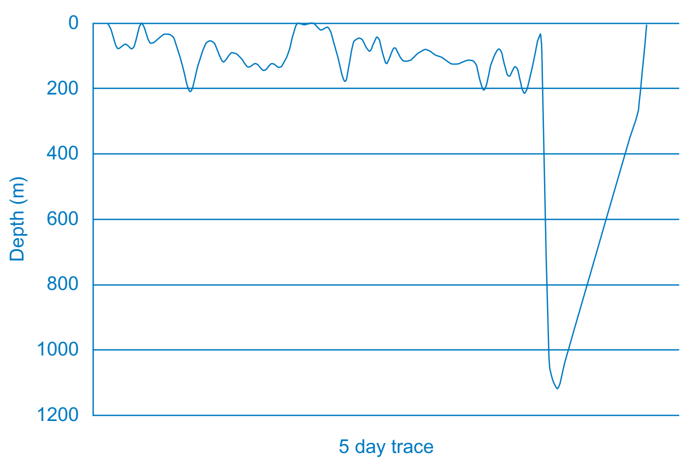

Figure 3. Depth data for a male blue shark (*Prionace glauca*) tagged with a PSAT around the Hawaiian Islands in April 2001. Data are not recorded in consecutive time intervals due to the PSAT's duty cycle, which is approximately one day on and one day off.

Given their longevity, PSATs also enable researchers to determine the long-term movement patterns of turtles, and the nature of their physical environments (i.e., to correlate data on the turtles' dive-depth profiles and migratory routes with information on currents, sea surface temperatures, and primary productivity, collected simultaneously by satellites). Collection of long-term data will, in turn, allow design of time-area fishery closures that are effective in reducing rates of interaction between turtles and longline gear, but that are likewise acceptable to fishermen.

We are currently employing PSATs designed by both Microwave Telemetry, Inc. (Columbia, Md., USA; www.microwavetelemetry.com) and Wildlife Computers (Redmond, Wa., USA; www.wildlifecomputers.com). Algorithms used to estimate geographic positions from PSAT data are currently assumed to allow accuracy of ± 0.5º longitude and ± 1.0º latitude (Musyl et al., 2001). But double-tagging studies (i.e., placing both conventional platform terminal transmitters [PTTs] and PSATs on the same animal) are currently underway on Leatherback turtles. The resulting data should allow us to better determine, and eventually further refine, the accuracy of light-based algorithms for providing daily geopositions for moving pelagic animals.

Attaching PSATs to Hard-Shelled Turtles

As PSATs had never before been used on marine turtles, our first task was to devise a method of attachment that would be strong, long lasting, and non-harmful. This method had to be easy and reliably employed, even by inexperienced fisheries observers working in the difficult conditions associated with small (generally less then 30 m) U.S. commercial longline vessels operating on the high seas. To meet all these requirements, we designed a baseplate that could be glued to the turtle's carapace, and attached via tether to the PSAT (Figure 4). As the baseplate must be resistant to crushing and loss of buoyancy at depth, we decided on a syntactic foam designed to maintain its buoyancy down to 2,500 m. The material, manufactured by Syntech Materials, Inc. (Springfield, Va., USA; www.syntechmaterials.com) is relatively inexpensive and easily fabricated into any shape using common tools.

We did find, however, that the length of the tether was critical. It had to be long enough that the PSAT would float with its antenna upward to allow successful transmission to a satellite in the event that the tag was shed with the baseplate attached (Figure 5). Using a 270-pound-test fluorocarbon line, we found the minimum tether length to be 28 cm. To attach the PSAT and baseplate to the tether, we used stainless steel crimps (from Nicopress Inc.; The National Telephone Company, Cleveland, Oh., USA; www.nicopress.thomasregister.com) that are matched to the diameter of the fluorocarbon line.

Most important, we found a simple marine epoxy to be highly suitable for attachment of the baseplate to the carapace of hard-shelled turtles (Marine Fix® Fast, by Eclectic Products Inc., Houston, Tx., USA; www.webhorizon.com/am/Eclectic_Products Frame1Source1.htm). It is inexpensive and available at marine

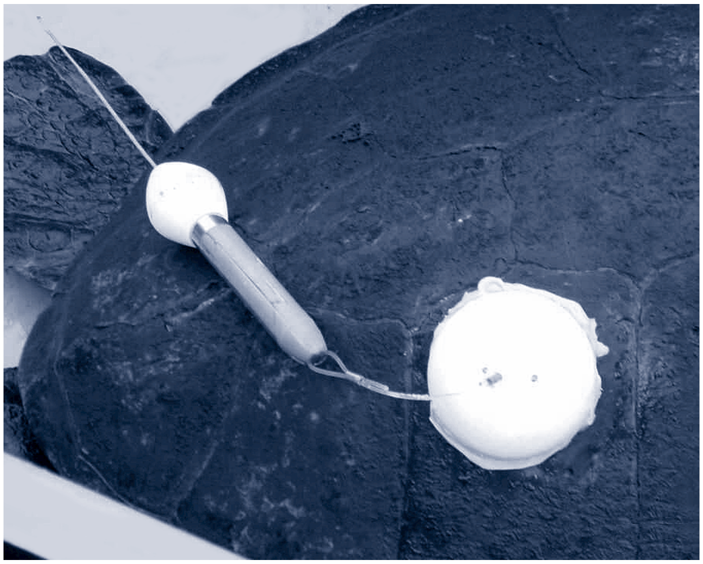

Figure 4. A syntactic foam baseplate mounted on a turtle's carapace. A fluorocarbon tether, connected with stainless steel crimps, attaches the baseplate to the PSAT (photo by Yonat Swimmer).

supply and home improvement stores. The two parts of the epoxy are mixed and spread on the flat side of the baseplate, which is then gently pressed onto a relatively flat portion of the carapace. Depending on ambient temperature, the epoxy generally hardens enough within one hour for the turtle to be released. Moreover, the epoxy will cure and adhere even if wet. However, in order to prevent the tag from sinking if it is shed, the amount of epoxy used should be monitored; for example, with a 3-in diameter baseplate, no more than ~165 g of epoxy should be used. Furthermore, as the two-part epoxy needs only to be mixed in equal proportions, it is simpler to use than fiberglass resin. Our procedures and relevant observer training manual have been reviewed and approved by the NMFS Office of Protected Species.

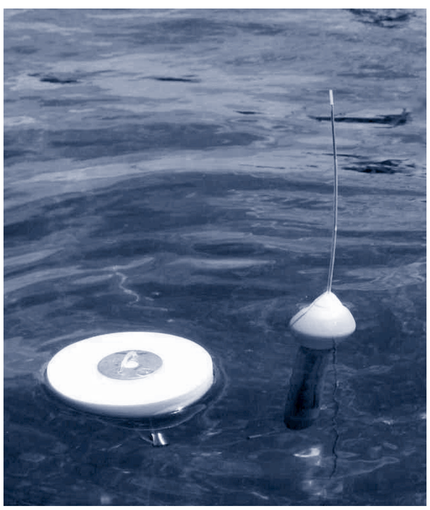

Figure 5. If the PSAT and baseplate are shed from the turtle, successful transmission to a satellite requires that the tether be long enough for the tag to float with its antenna upwards (photo by Yonat Swimmer).

We have confirmed the suitability of this epoxy using four subadult Green Sea Turtles maintained in captivity at the NOAA/NMFS Honolulu Laboratory Kewalo Research Facility (Figure 6). We found the dummy PSATs would remain attached for up to nine months, but that the baseplates could be removed by a firm tug on the tether. In other words, we found that the epoxy and foam baseplate combination results in adequate adhesion to the carapace, yet still provides a margin of safety in that the PSAT will detach if it becomes entangled in marine debris. Just as important, we found no evidence of damage or obvious pathology in the area of the carapace covered by the baseplate, even after nine months.

Practical Considerations and PSAT Limitations

PSATs are designed to be deployed at sea by scientific observers, many of whom have little or no experience with sea turtles. Therefore, the attachment method described above is designed to provide maximal safety both to the turtle and the person attaching the tag. Admittedly, there is some chance that epoxy-adhered PSATs may detach more readily than those tethered to baseplates that are "bolted" through the carapace, but we prefer that turtles have the ability to shed tags; the alternative is to risk that they become entrapped under a ledge or entangled in marine debris via PSATs that are affixed too tightly.

At present, the geolocation capabilities of PSATs are not as precise as conventional PTTs. Therefore, for research in which fine-scale location is required, PTTs are the more appropriate tool. For our purposes, however, one of the most important features of the PSAT is the ability to distinguish a tag shed at mortality, which usually is not possible with conventional satellite tags— and for this, we sacrifice some fine-scale geolocation resolution. Therefore, depending on the questions asked, a conventional tag

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Figure 6. A baseplate securely mounted on the carapace of a captive Green Sea Turtle (*Chelonia mydas*) using a simple marine epoxy; the hydrodynamic tag is designed to be pulled with minimal drag (photo by Yonat Swimmer).

might be preferred to a PSAT. For example, for use on marine turtles that live primarily in the neritic, where fine-scale resolution of movement patterns is desired, and where entrapment under ledges may be more likely than in the pelagic environment, a small conventional PTT glued to the carapace would likely be a better choice.

Successful Taggings at Sea

On July 28, 2001, an Olive Ridley (*Lepidochelys olivacea*) was brought aboard a Hawai'i-based commercial longline vessel after being hooked in the mouth. The hook was not retrievable. The observer on board successfully applied a PSAT and released the turtle at 19º 22' N, 160º 7' W. The turtle was at liberty for 82 days before the tag was shed. During that time it traveled from its point of release to 16º 1' N, 127º 30'W, indicating the turtle generally swam in a southwesterly direction (263º) and covered a straight-line distance of 1,874 nmi (Figure 7). Data generated for this graph have been analyzed using a state space Kalman filter statistical model, which was used to estimate geolocation errors, movement parameters and most probable tracks from the recovered data (Sibert et al., in press). Histograms of dive-depth profiles (Figure 8) indicate that during the day, the turtle spent nearly 60% of its time within the top 50 m, and only rarely exceeded depths of 250 m. During the night, the turtle remained in somewhat deeper water, spending nearly 45% of its time at depths of 10 to 100 m. The maximum recorded dive depth was 544 m, with a corresponding temperature of 4º C. More important, the data indicate that the turtle was still functioning normally after 4 months, in spite of the longline hook not being removed.

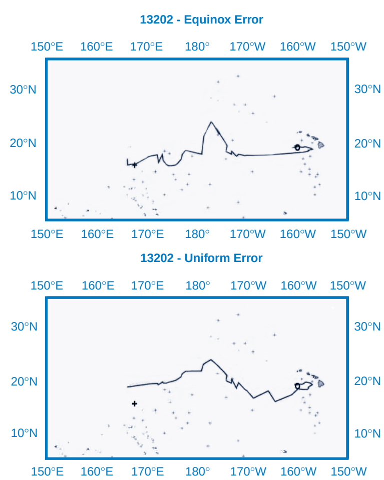

Figure 7. Daily geolocation estimates for an Olive Ridley Sea Turtle caught on commercial longline gear, determined using a state space Kalman filter statistical model. The turtle was at liberty for 82 days from late July until mid-November 2001.

To date, observers on Hawai'i-based commercial longline vessels have taken PSATs on more than 55 longline trips over the last seven months. Because of current court-ordered restrictions on gear-setting practices (designed to reduce turtle interactions), the turtle described above is the only one within our program tagged with a PSAT from the Hawai'i-based longline fleet.

Therefore, in an effort to tag more longline-caught turtles, we recently traveled to Costa Rica, where there is a substantial commercial longline fleet primarily targeting dolphin fish (dorado or mahimahi; *Coryphaena hippurus*) off the Pacific Coast.

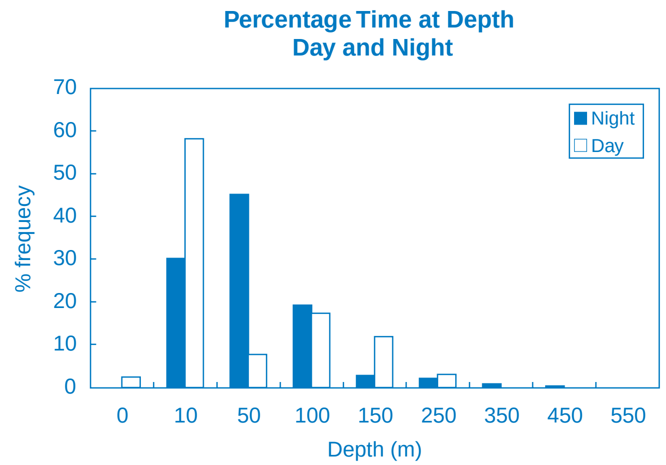

Figure 8. Histograms of time at depth (day and night) for an Olive Ridley Sea Turtle caught and released from a commercial longline vessel operating near the Hawaiian Islands.

This fleet experiences a relatively high bycatch of sea turtles (primarily juvenile Olive Ridleys). In collaboration with Randall Arauz (Central American Director, Sea Turtle Restoration Project), and with the full cooperation of the commercial longline fishermen, we were able to deploy PSATs on four longline-caught animals. The severity of injury due to hooking differed among the four turtles, and will eventually be correlated with data received from the PSATs. We also were able to capture three free-swimming juvenile Olive Ridleys. Turtles caught and tagged while free-swimming are especially valuable, as the data they generate will serve as controls against which to compare the behaviors (and possible mortalities) of hooked animals. The PSATs deployed were programmed to release after 6 or 12 months.

Acknowledgments

We thank George Balazs, David Gremminger, Lianne Mailloux, Robert Morris, and the staff of the NMFS Marine Turtle Research Program for care and handling of the turtles. We sincerely appreciate the efforts of John Sibert, who processed our geolocation data through his Kalman filter. We acknowledge the NMFS-SWFSC Honolulu Laboratory and the University of Hawai'i Joint Institute for Marine and Atmospheric Research-PFRP for providing resources and funds to support this research. Opinions expressed are those of the authors and do not reflect the views of NOAA or NMFS. Mention of product names does not imply endorsement by NOAA or NMFS. Research on live animals was performed in accordance with all applicable laws and regulations of the United States.

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Pelagic Fisheries Research Program Newsletter

Volume 7, Number 2 **April–June 2002**

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Printing Quality Graphics & Printing, Honolulu, Hawaii 96814

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