

especially in studies where only short movements result. Positions received from Argos designed as LC 1, 2, and 3 are defined as quite accurate. However, no definitions of accuracy are given by Argos for LC 0, A, B, and Z positions. For these data the responsibility rests with the researcher to judge reliability and usefulness. Positions supplied may be reasonable and acceptable in one transmission, and totally unacceptable for the same LC designation when received at other times. The positions shown in the interior of the island in the accompanying figures are clearly inaccurate, hence serve to emphasize this important point.

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SATELLITE TELEMETRY OF MIGRANT MALE AND FEMALE GREEN TURTLES BREEDING IN THE HAWAIIAN ISLANDS

George H. Balazs¹ and Denise M. Ellis²

¹ National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822-2396 U.S.A.

² Joint Institute of Marine and Atmospheric Research, c/o 2570 Dole Street, Honolulu, Hawaii 96822-2396 U.S.A.

Satellite telemetry using the Argos system was conducted during 1995 for the first time on adult male green turtles, *Chelonia mydas* (honu), breeding in the Hawaiian Islands at French Frigate Shoals (24°N, 166°W). In addition, a nesting green turtle was satellite-tagged in 1995 to expand upon data obtained during 1992 and 1993 when five other migrant females were successfully tracked by satellite to their resident foraging pastures (Balazs, 1994; Balazs *et al.*, 1994).

The goal of this work is to develop detailed maps of the specific routes taken by males and females between breeding and foraging areas and to determine swimming and diving behaviors during the migrations. When viewed in conjunction with environmental, geomagnetic, and other factors, these data will provide insight into the navigational mechanisms of green turtles in the Hawaiian Islands. The satellite telemetry studies of green turtles by Liew *et al.* (1995) and Papi *et al.* (1995) in Malaysia, and Schroeder *et al.* (in press) in Florida, constitute parallel lines of important research.

METHODS

Telonics ST-3 backpack transmitters were placed on two adult males during early June 1995 and on a nesting female in late September 1995. The deployment schedules were planned to coincide with estimated departure times from French Frigate Shoals for periods of mating and nesting. The transmitters were programmed with a duty cycle of six hours on, six hours off. The units were turned on at a time of day computed to synchronize with optimum satellite overpasses for the region of deployment.

The transmitters were safely and securely attached to the carapace using thin layers of fiberglass cloth and polyester resin. The transmitters measured 17 x 10 x 3.5 cm with the antenna extending 13 cm from the top. At special request to the manufacturer, the full length of the antenna was sheathed in tubing to provide added protection against damage. Silicone Elastomer, a two-part quick curing-rubber product, was also incorporated to properly mount the transmitter

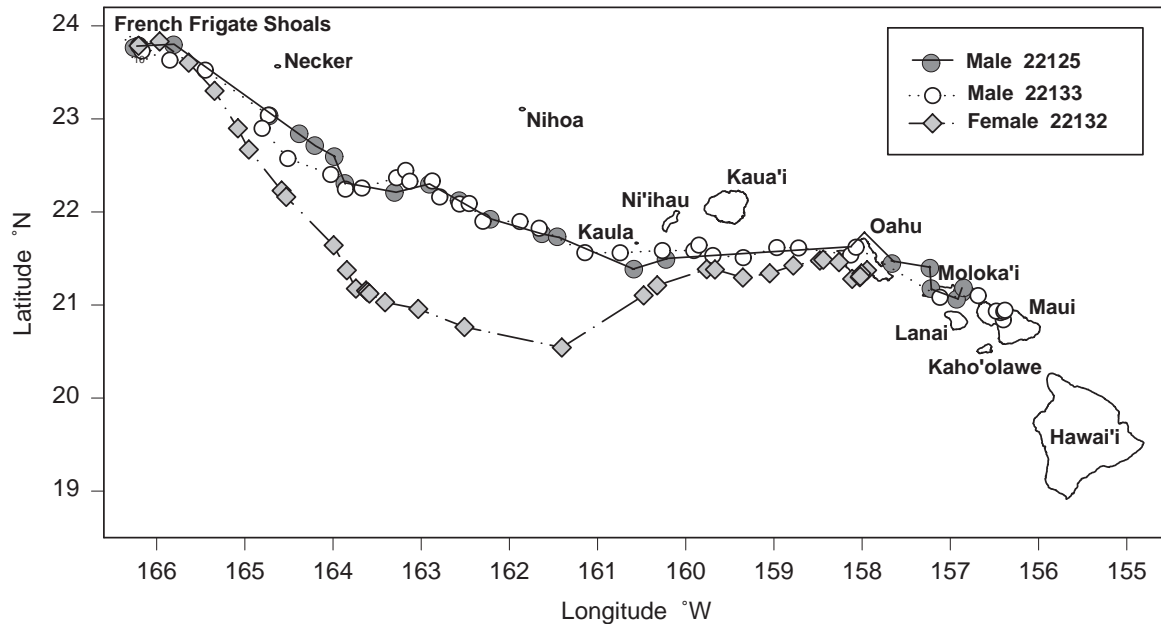


Figure 1. Post-reproductive migratory routes of adult male and female green turtles from French Frigate Shoals to Molokai, Maui, and Oahu in the main Hawaiian Islands.

against the carapace before applying the fiberglass. During the attachment process turtles were harmlessly confined in a prone position using a shaded portable plywood pen. Step-by-step directions for the entire attachment procedure are set forth in Balazs *et al.* (in press).

RESULTS

Detailed satellite tracking was successfully accomplished for the post-reproductive open ocean migrations of the two males and one female, as shown in Figure 1. The results are summarized as follows:

Male 22133

This turtle was equipped with a transmitter on 6/7/95 after being found basking ashore during the daytime at East Island, French Frigate Shoals (see Whittow and Balazs, 1982). The turtle measured 87 cm in straightline carapace length (SCL). A flipper tag (6038) revealed that the turtle had been originally identified 13 years earlier on 6/8/82 while basking at this same site. The turtle was seen there again on 6/4/84. On 6/19/95, 12 days after transmitter deployment, the turtle departed French Frigate Shoals and traveled 1200 km to the southeast on a journey lasting 30 days. On 7/19/95 the turtle arrived at Kahului Bay, an important foraging and underwater resting areas for green turtles on the northern coast of Maui (see Balazs *et al.*, 1987). The voyage mainly occurred over water thousands of meters deep, out of sight of land, and against prevailing winds and currents. The turtle's swimming speed averaged 1.7 km/hour. After reaching Kahului Bay, satellite transmissions continued for only 12 days before terminating on 8/1/95. During the migration the Argos system relayed 33 positions deemed suitable for tracking a

turtle for an extended distance across the high seas.

Male 22125

A transmitter was attached to this 86 cm SCL turtle at East Island after it was captured while basking ashore on the afternoon of 6/8/95. Four days later on 6/12/95 the turtle departed on a 1050 km migration to the southeast that lasted 26 days. On 7/8/95 the turtle arrived in coastal waters of Panahaha on the southern shore of the island of Molokai. This area is known as prime foraging and underwater resting habitat for green turtles. The journey of male 22125 also occurred against prevailing winds and currents over deep water and mainly without benefit of visual contact with the Hawaiian Islands. Also, like male 22133, the turtle followed a route around the north shore of the island of Oahu before continuing eastward. The average swimming speed was 1.7 km/hour, identical to male 22133. During the migration, the Argos system relayed 21 positions judged acceptable for the purposes of this research. After arriving at Molokai the transmissions sporadically continued for nearly six months before terminating in late December 1995.

As illustrated in Figure 1, exceedingly similar oceanic pathways were taken by both males, even though they were never in contact with one another, and their final destinations were different.

Female 22132- A transmitter was deployed on this 98 cm SCL turtle after she came ashore to nest at East Island on the night of 9/22/95. A flipper tag had been applied three months earlier during a previous nesting on East Island. Female 22132 departed on 9/26/95 traveling 1050 km to the southeast taking 23 days at an average swimming speed of 1.9 km/hour. The trip was completed on 10/19/95 with her

arrival along the Ewa coastline near the entrance to Pearl Harbor on Oahu's southern shore. The Argos system relayed 28 positions of relatively high quality during the migration. After reaching the Ewa coastline, transmissions continued on nearly a daily basis for over six months, thereby clearly demonstrating the turtle's extended residency to this area.

The migratory pathway of female 22132 was substantially farther to the south than the routes followed by the two male turtles. However, the route of female 22132 was very similar to three of the four post-nesting females satellite-tracked in past years migrating from French Frigate Shoals to Oahu (Balazs, 1994; Balazs *et al.*, 1994).

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GROWTH RATES AND RESIDENCY OF IMMATURE GREEN TURTLES AT KIHOLO BAY, HAWAII

George H. Balazs¹, Marc Rice², Shawn K.K. Murakawa³, and George Watson²

¹National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822-2396 U.S.A.

²Hawaii Preparatory Academy, P.O. Box 428, Kamuela, Hawaii 96743 U.S.A.

³Joint Institute for Marine and Atmospheric Research, c/o 2570 Dole Street, Honolulu, Hawaii 96822-2396 U.S.A.

Long-term studies of green turtles, *Chelonia mydas* (honu), in nearshore waters of the Hawaiian Islands have been underway to obtain comprehensive information on growth rates, food sources, habitat use, developmental and reproductive migrations, underwater behaviors, health status, and population trends (Balazs, 1980, 1982, 1991, in press; Balazs *et al.*, 1987, 1993, 1994a, 1994b; Russell and Balazs, 1994). The Hawaiian Archipelago includes 132 islands and reefs extending for 2400 km across the North Pacific. However, the eight main islands at the southeastern end of the chain account for nearly all coastal benthic habitats suitable for foraging and resting by post-pelagic green turtles. Adult

males and females residing throughout the chain migrate to breed at isolated French Frigate Shoals (23° 47'N, 166° 12'W) situated at the mid-point of the archipelago (Balazs, 1976, 1980, 1983). Systematic monitoring at this site for 23 consecutive seasons (1973-95) has documented an approximate threefold increase in the number of nesting females (Fig. 1). This encouraging sign of population recovery is attributed to protection extended in 1978 under the U.S. Endangered Species Act. Similar increases have been seen for immature turtles inhabiting nearshore waters of the main islands, such as reported here for Kiholo Bay.