# Radio Telemetry of Hawaiian Green Turtles at Their Breeding Colony

Andrew E. Dizon was with the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812 and George H. Balazs is on an Intergovernmental Personnel Assignment from the Hawaii Institute of Marine Biology, University of Hawaii, to the NMFS Honolulu Laboratory. Dizon is now with the Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

ANDREW E. DIZON and GEORGE H. BALAZS

## Introduction

More than 90 percent of the breeding activity of the Hawaiian green turtle, *Chelonia mydas,* occurs at a small atoll situated about midway along the 2,450 km length of the Hawaiian Archipelago (Fig. 1). Here, principally during May and June, turtles gather to copulate and nest.

Because of the specificity of the marine turtle's choice of breeding sites and times, any significant disturbance by man during this period could have profound effects upon the population. Yet little is known about the marine habitat of the animals during this period. Most of the work (Balazs, 1976, 1980) has involved hauled-out turtles when

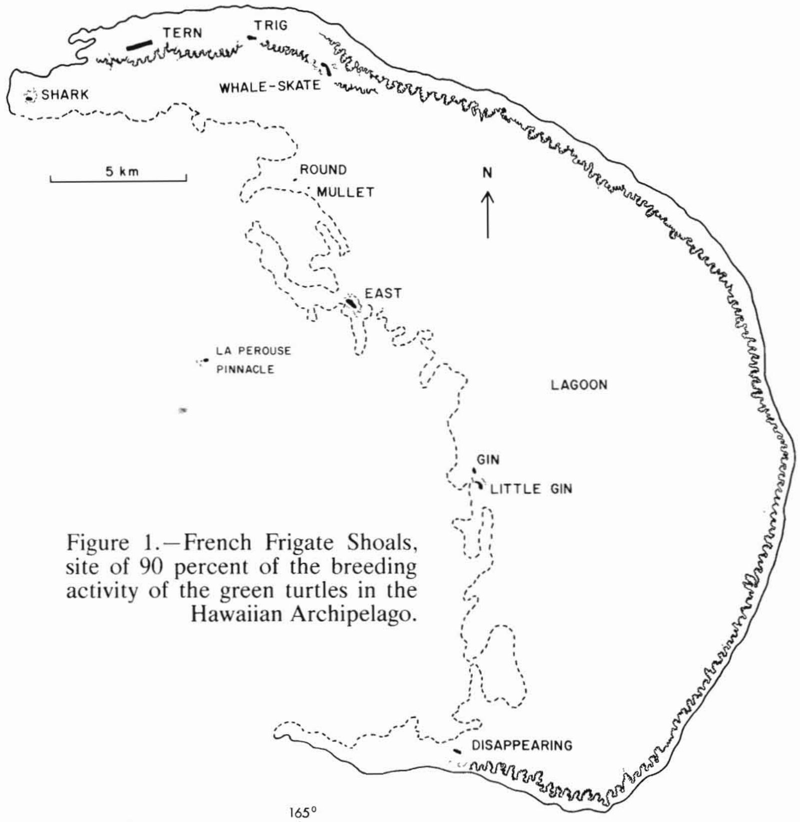
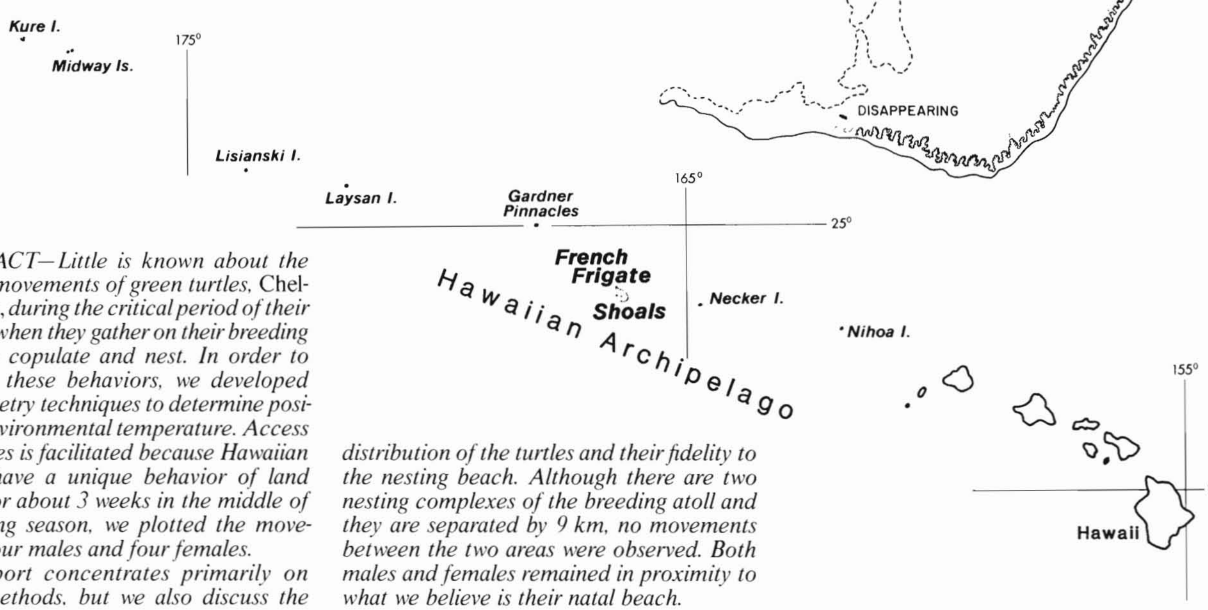



Figure 1.—French Frigate Shoals, site of 90 percent of the breeding activity of the green turtles in the Hawaiian Archipelago.




*ABSTRACT—Little is known about the range and movements of green turtles,* Chelonia mydas, *during the critical period of their life history when they gather on their breeding grounds to copulate and nest. In order to investigate these behaviors, we developed radio telemetry techniques to determine position and environmental temperature. Access to the turtles is facilitated because Hawaiian* Chelonia *have a unique behavior of land basking. For about 3 weeks in the middle of the breeding season, we plotted the movements of four males and four females.*

*This report concentrates primarily on tracking methods, but we also discuss the distribution of the turtles and their fidelity to the nesting beach. Although there are two nesting complexes of the breeding atoll and they are separated by 9 km, no movements between the two areas were observed. Both males and females remained in proximity to what we believe is their natal beach.*

they are readily visible to the investigator. Where the turtles go between the periods when they crawl out on the beach remains a mystery. Yet it is when the turtles are in the nearshore waters that the greatest potential for conflicts with humans exists. Managers of the habitat must be informed about the distribution of the turtles during the breeding period in order to avoid potentially damaging interactions.

The purpose of our study was to develop radio telemetry techniques to locate turtles throughout their breeding habitat and to study their range and behaviors during the breeding period. This report will concentrate primarily on the tracking technique and briefly describe the breeding habitat range. Specific details of their behaviors will be the subject of a subsequent paper.

Green turtle at French Frigate Shoals.

## The Site

The breeding atoll is called French Frigate Shoals (FFS). It is a crescent-shaped platform which rises to within about 40 m of the surface (Amerson, 1971). Extensive reef growth has occurred on the platform and now there are about 12 permanent islands, 4 with well-established vegetation.

Tern Island, the largest, was modified during World War II to serve as a refueling base for aircraft support of the Midway Campaign. It was later used by the U.S. Coast Guard which maintained a loran station there until 1979. The U.S. Fish and Wildlife Service now maintains the island with several resident biologists. French Frigate Shoals as well as most of the other islands of the northwestern segment of the archipelago are units of the Hawaiian Islands National Wildlife Refuge and are designated officially as a Research Natural Area. Tern Island was the base of our operation.

## The Turtles

Work over the past 8 years on the turtles of FFS has revealed much about their natural history. The turtles arrive at the breeding atoll during mid-April to early June. Courtship and copulation take place then. Nesting starts as early as mid-May, peaking in June, and has all but ceased by mid-August. Nesting takes place over most of the larger stable islands with approximately 55 percent nesting at East Island and 35 percent at Whale-Skate/Trig Island complex (Fig. 1). As many as six egg clutches may be laid by a single female during one season but the mean is 1.8. The interval between oviposition in turtles that nest more than once averages 13 days, ranging from 11 to 18 days. Females journey to the breeding atoll once every 2 or more years; males every 1 or more years. The turtles come from and return to feeding pastures located in the rest of the archipelago. These long-range precise migrations to and from the breeding islands have been documented by the marking and subsequent recapture of 52 turtles (Balazs, 1976, 1980).

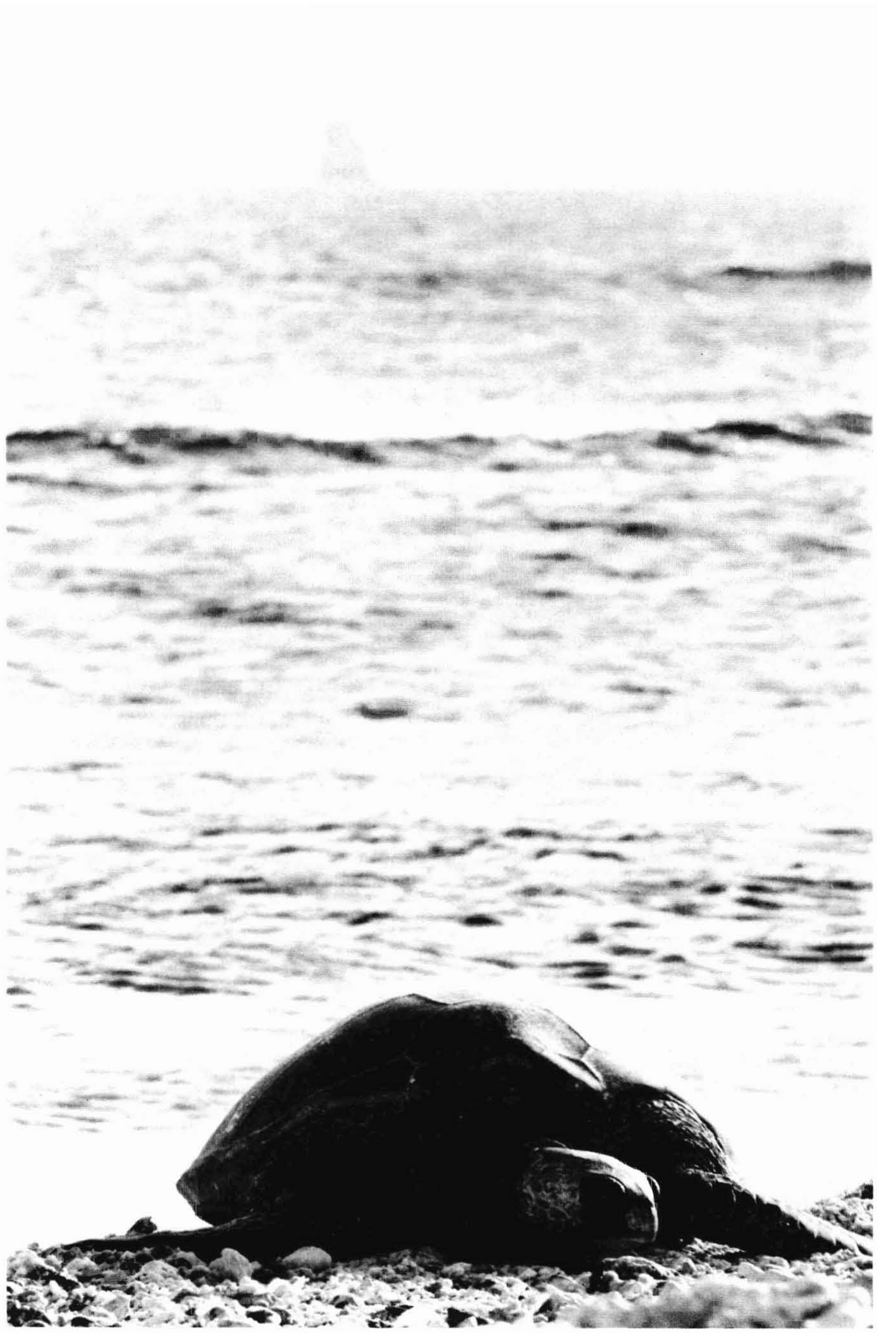
Hawaiian *Chelonia* exhibit a unique behavior which make them quite amenable to biological study. The turtles bask on land for extended periods both day and night, and while basking they are relatively easy to capture and tag. French Frigate Shoals is one of eight breeding colonies designated for high priority by the World Conference on Sea Turtle Conservation (1979) by reason of unique ecology and isolation. Balazs (1980) in a study period extending over 8 years has tagged over 140 adult male and 528 adult female turtles. Yet mark-and-recapture studies are not well suited for delimiting the critical habitat of the turtles during their sojourns within the nearshore waters between nesting or basking period on land. Extensive trapping in the water to recapture the marked animals is impractical. Identification marks painted on the shells allow for visualization of limited movements, but most turtles are quickly lost to the observer when they are not basking or nesting.

We felt that radio telemetry to determine movements was the least intrusive method of determining positions during trips away from the beach. We attached small transmitters to the turtle's carapace and fixed their positions by triangulation from two distant receiving stations. With this technique we were able to determine positions of the turtles during basking or swimming on the surface. As a result we were also able to ascertain the fraction of time the animals spent on the surface or on land and how much time submerged. These data are necessary to correct past and future census information since, at any one time, only a fraction of the turtles are visible to an observer. Our transmitters were sensitive to the environmental temperature so that we could determine whether turtles were basking on land or swimming at the surface. This information as well as other performance parameters of the turtles will be the subject of a subsequent paper. For now, we are interested in the techniques and range.

## Past Telemetry Work Within Breeding Colonies

"One of the conspicuous gaps in the behavioral ecology of the green turtle . . . is the lack of data on the movements of females during the 12-14 day periods between their emergences at the nesting beach" (Carr et al., 1974). Actually, a number of studies have been conducted but more data still need to be generated (Carr, 1967a, 1967b, 1972; Baldwin, 1972; Meylan, 1978, in press; Standora et al., 1979; Feazel, 1980; Mortimer, 1981). The internesting movements of two other species have also been investigated (loggerheads, *Caretta caretta*, Murphy, 1979; Stoneburner, 1979; and Kemp's ridley, *Lepidochelys kempi*, Pritchard, 1980). All of these data are characterized by few subjects, no males, and short tracking periods. Most utilized a towed drogue usually equipped with a pennant and light. Sometimes sophisticated satellite transmitters were employed (Stoneburner, 1979; Daniel, 1980). Thus technical equipment is not cause for the information gap. Nor is size a problem since in fact telemetry devices (both radio and acoustic) are available for use on juveniles and hatchlings (Ireland, 1979a, 1979b; Garmon, 1981; Timko and DeBlanc, 1981; Stinson and Fritts[1]). Our goal was to deploy radio transmitters on both male and female turtles, track them throughout a significant portion of the reproductive period, and collect as many distributional, behavioral, and physiological data as possible.

[1]M. L. Stinson, 1553 Avocado Drive, Vista, CA 92083; T. Fritts, National Fish and Wildlife Laboratory, Tulane University, Belle Chasse, LA 70037, pers. commun.



Green turtle basking at French Frigate Shoals.

## The Transmitters and Their Deployment on the Turtle

The 2 m (149 mHz) transmitters we employed were purchased as "off-the-shelf" items from Telonics, Inc.[2] Mesa, Ariz., (Fig. 2). These were hermetically encapsulated 7.5 × 4 × 3 cm, round-edged boxes with a mounting flange

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

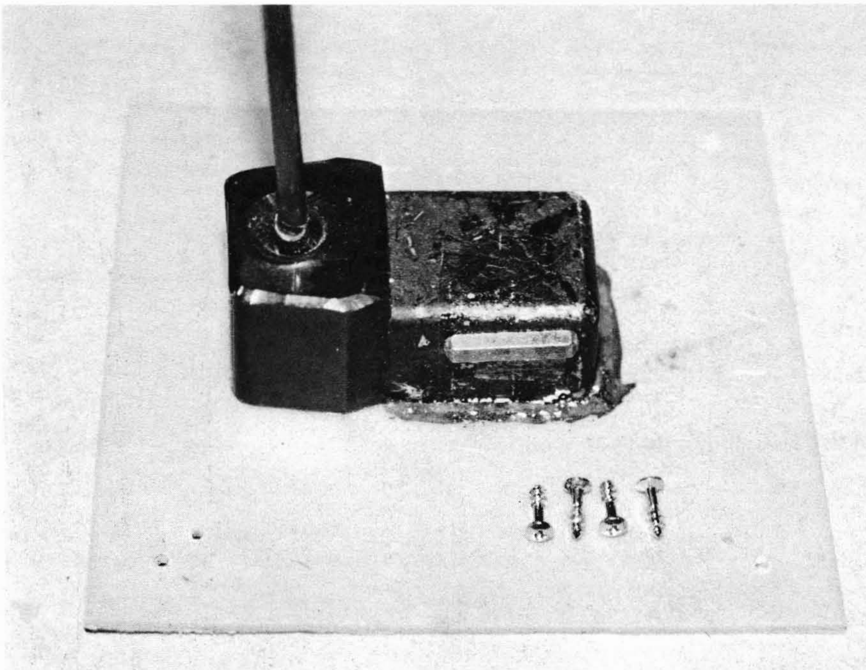


Figure 2.—The transmitter and its mounting plate. Note the thread design on the bone screws and the magnet which is used to turn the transmitter off.

attached to the bottom. A flexible quarter-wavelength stub antenna emerged from the front and extended 46 cm. The transmitters were temperature-sensitive; as the package warmed, the pulse rate increased. We observed an effective range of over 10 km when the transmitter package was awash at the sea surface and the receiving antenna was elevated about 9 m.

Since we were interested in following the animals for a long period, a reliable attachment method for the transmitter was critical to the success of the project. Hawaiian *Chelonia* have a habit of resting within coral caves and under outcroppings. A tethered transmitter would be useless and unless provided with a breakaway link, would pose a danger to the animals.

The study areas of the other workers reported earlier were generally free from such obstructions. Thus we had to attach the transmitter directly to the shell. To conform to the curvature of the shell and yet provide a wide mounting base, the transmitter was secured to a 15 × 15 cm, 0.6 cm thick piece of high molecular weight polyethylene (Fig. 2). This very tough but flexible plastic easily conformed to the carapace.

The plastic was attached to the shell with surgical bone screws fabricated for orthopedic repairs (mallolar style, Zimmer Inc.). The screws were made of a proprietary alloy which made them unreactive within the tissues of the shell and impervious to the seawater. The thread of the screw was designed to provide great holding power with the very shallow penetration which we required. Experiments with captive turtles demonstrated that the attachment technique was sound but the silvery coating of the transmitters was particularly appealing to fellow tank-mates and numerous biting attacks were made on the units. This problem was eliminated by camouflaging the transmitters with roofing tar and sand.

The actual attachment was choreographed and refined until it took less than 45 seconds. At dusk, the basking turtle was stealthily approached by one of us and turned over on its back. A short time later, after nightfall, the chosen turtle was propped up at about a 45° angle (head up) while still on its back. Sand was removed to allow room to work under it. A battery-driven drill, equipped with a counterbore bit and a positive stop to limit the depth of the hole was used to make four pilot holes in the carapace. The plastic plate, already equipped with the transmitter, was then screwed into place. The magnet holding the transmitter turned off was removed and a radio check back to the receiving stations was made to ascertain that everything was working. Cold-process roofing tar was applied to the transmitter, plate, and screws and then covered with sand and the turtle righted. The bionic *Chelonia* immediately scrambled to the ocean and swam off and the tracking began (Fig. 3).

### The Receivers

We employed two separate receiving stations in order to fix positions of the transmitter-carrying turtles. One was located in the old Coast Guard facility on Tern Island; the other, 13 km away at East Island. Tern Island was the primary receiving station which monitored continuously. The East Island station was only active at 6-hour intervals: 0300, 0900, 1500, and 2100. During that time period bearings were obtained on each of the turtles and their positions plotted.

The receiving equipment at Tern Island consisted of two receiver systems: An omnidirectional antenna connected to a receiver with a frequency scanner and a highly directional antenna connected to a receiver with a signal processor for digital measurements of period and signal strength. The East Island station had a highly directional antenna and a receiver equipped with a processor. The directional antenna at Tern Island (mounted about 9 m off the ground) was positioned with a motorized antenna rotor while the one at East Island (5 m off the ground) was rotated by hand. Bearings were determined from the antenna rotor control box at Tern Island and a compass mounted on the mast at East Island. Under all but the weakest signal conditions, our accuracy of bearing was about ±5°.

In addition to bearing fixes every 6 hours, the station at Tern Island sampled every 10 minutes throughout the whole study period and continuously during three 24-hour periods. The frequency scanner was programmed to scan through the transmitter frequencies. When a signal was detected, the pulse rate was read to determine temperature of the transmitter. These data will be presented in a subsequent paper but it should be mentioned that the amount of time spent on the ocean surface when the signal could be detected was usually less than 1 minute. Thus not much time was available for us to measure pulse rate and fix position.

Every 6 hours the receiving equipment at East Island was turned on. When a turtle signal was detected at Tern Island by the scanner-equipped receiver, the information was relayed to East Island and both stations attempted to fix the bearing of the signal with the directional antennas. Sometimes it was impossible to obtain fixes on all of the turtles. We would hear the signal from a given turtle, but it would not stay on the surface long enough to get an accurate fix.

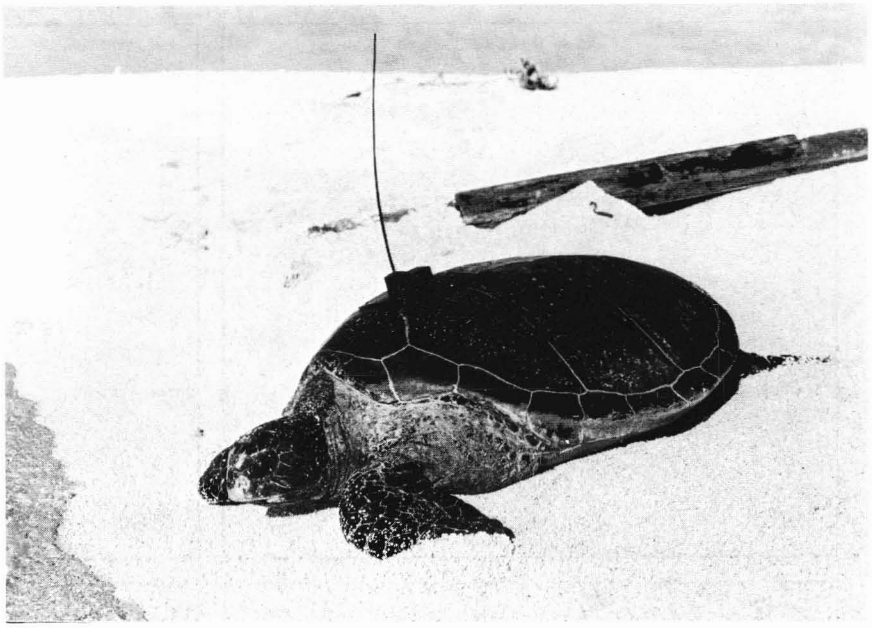


Figure 3.—Transmitter-equipped female 200 returning to the ocean after gear attachment.

**Table 1.—Tagging and tracking data. Tagging data are from Balazs' long-term study of the green turtles of Hawaii (Balazs, 1980). The "off" date refers to the date when the last signal was received from the transmitter, WS = Whale-Skate Island, TRIG = Trig Island, and EAST = East Island.**

| Tagging | First tagging | First recovery | Second recovery | Transmitter deployment On | Off | Days |
|---|---|---|---|---|---|---|
| Male 350 | | | | | | |
| Date | 7/31/75 | 4/12/76 | 9/25/77 | 6/08 | 9/04 | 73 |
| Location | WS | WS | WS | WS | | |
| Male 360 | | | | | | |
| Date | No previous record | | | 6/08 | 6/27 | 19 |
| Location | | | | WS | | |
| Male 510 | | | | | | |
| Date | No previous record | | | 6/09 | 6/14 | 5 |
| Location | | | | WS | | |
| Male 540 | | | | | | |
| Date | 5/03/70 | 5/04/79 | | 6/09 | 8/12 | 49 |
| Location | TRIG | TRIG | | TRIG | | |
| Female 200 | | | | | | |
| Date | | | | 6/09 | 6/30 | 21 |
| Location | 3/22/68 | | | TRIG | | |
| Female 450 | | | | | | |
| Date | 7/10/70 | 7/05/74 | | 6/08 | 11/13 | 143 |
| Location | EAST | EAST | | WS | | |
| Female 490 | | | | | | |
| Date | 6/19/79 | 6/29/79 | | 6/09 | 8/07 | 60 |
| Location | WS | WS | | WS | | |
| Female 530 | | | | | | |
| Date | No previous record | | | 6/09 | 8/10 | 63 |
| Location | | | | TRIG | | |

[1]Southeast Island, Pearl and Hermes Reef (Fig. 1).

## Residence Times

Four males and four females were equipped with transmitters. For convenience, the turtles were identified by the last three digits of the frequency of their transmitters. For instance, the male equipped with a 149.350 mHz transmitter was known as male 350 (Table 1). This animal was originally tagged with a flipper tag on 31 July 1975 while basking on Whale-Skate Island and recovered on 12 April 1976 and 25 September 1977 while again basking on the same island. The turtle was captured again on Whale-Skate Island and the transmitter attached on 8 June 1980.

Male 540 (149.540 mHz) was originally tagged on 3 May 1979 while basking on Trig Island and found again a day later in the same place. Copulation injuries were noted at the time. The transmitter was attached on 9 June 1980 while on Whale-Skate Island.

Males 360 and 510 had no previous tagging history and had transmitters attached on 8 and 9 June, respectively, while they were on Whale-Skate Island.

Female 200 was originally tagged on 22 March 1968 while basking on Southeast Island, Pearl and Hermes Reef (Fig. 1). The transmitter was attached while the animal was basking on Trig Island 9 June 1980.

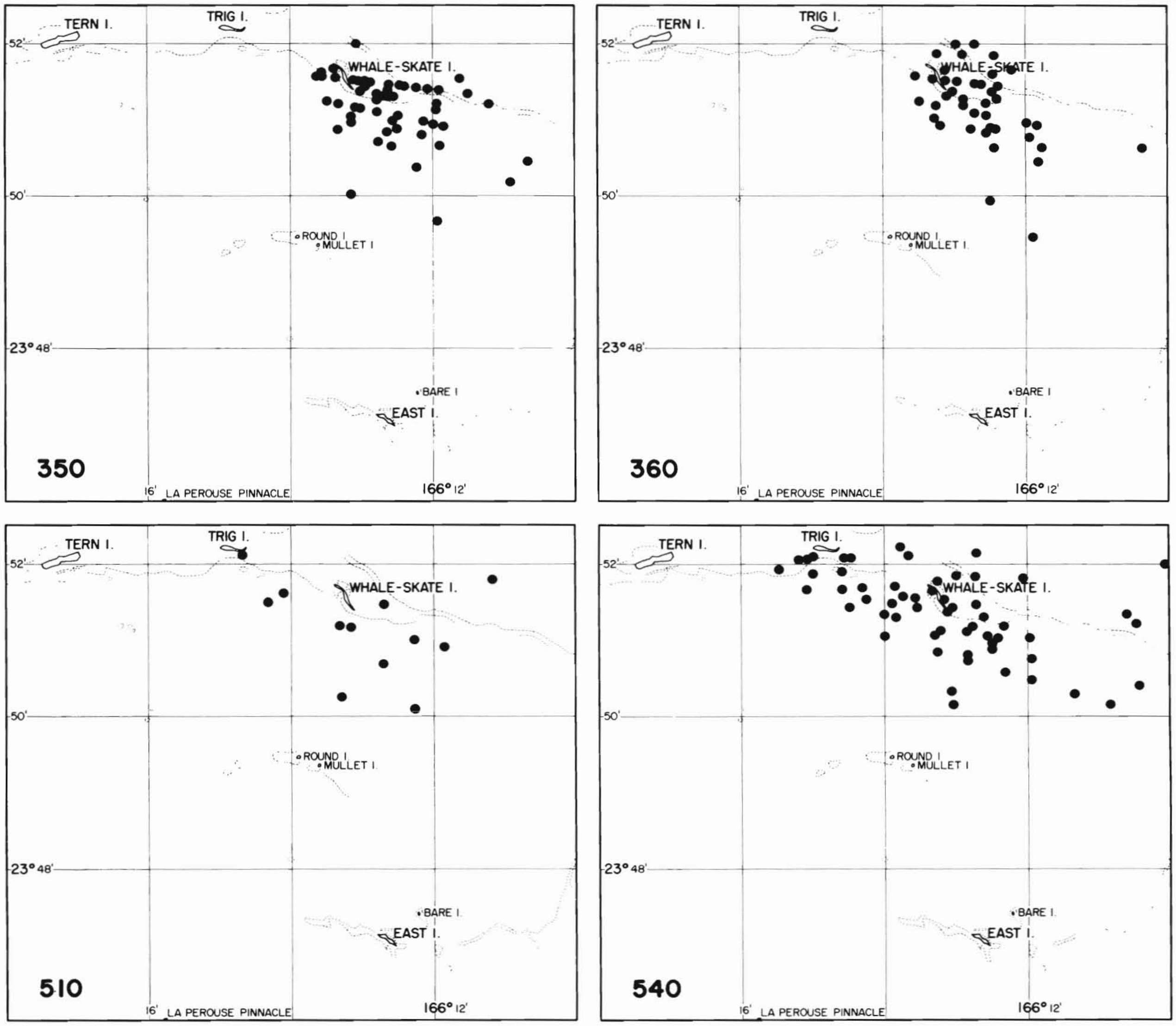



Figure 4.—Distribution of position fixes of the male turtles. Male 510 left the breeding colony about midway into the tracking period.

Female 450 was tagged first on 10 July 1970 and recovered again 5 July 1974 while nesting on East Island. The transmitter was attached on 8 June 1980 while it was basking on Whale-Skate.

Female 490 was first tagged on 19 June 1979 while it was on Whale-Skate and recovered again in the same place 10 days later. The transmitter was attached on 9 June 1980 while it was on Whale-Skate Island.

Female 530 was equipped with the transmitter on 9 June 1980. It had no previous history of tagging.

Our monitoring program was continued until 30 June 1980. Then the station at Tern Island was manned sporadically after our departure by caretaker personnel in order to see how long it was possible to maintain contact with the transmitter-equipped turtles. Of course, when a signal disappeared, it could either mean the turtle departed the colony or had shed the equipment. One transmitter (from female 490) was discovered off Whale-Skate Island in about 2 m of water in June of 1981. The screws were still in the plate and evidenced no sign of corrosion. Female 450 was found nesting on East Island in June 1981 without a transmitter; the small screw holes in the carapace were clean and without any sign of infection. So the attachment method is safe for the turtles and the equipment is eventually shed.

Table 1 also provides information on the length of time signals were heard from the turtles. The signal from male 510 disappeared first. We think it left the breeding colony because its last position was fixed on 14 June far outside the eastern fringing reef. Male 360 was last

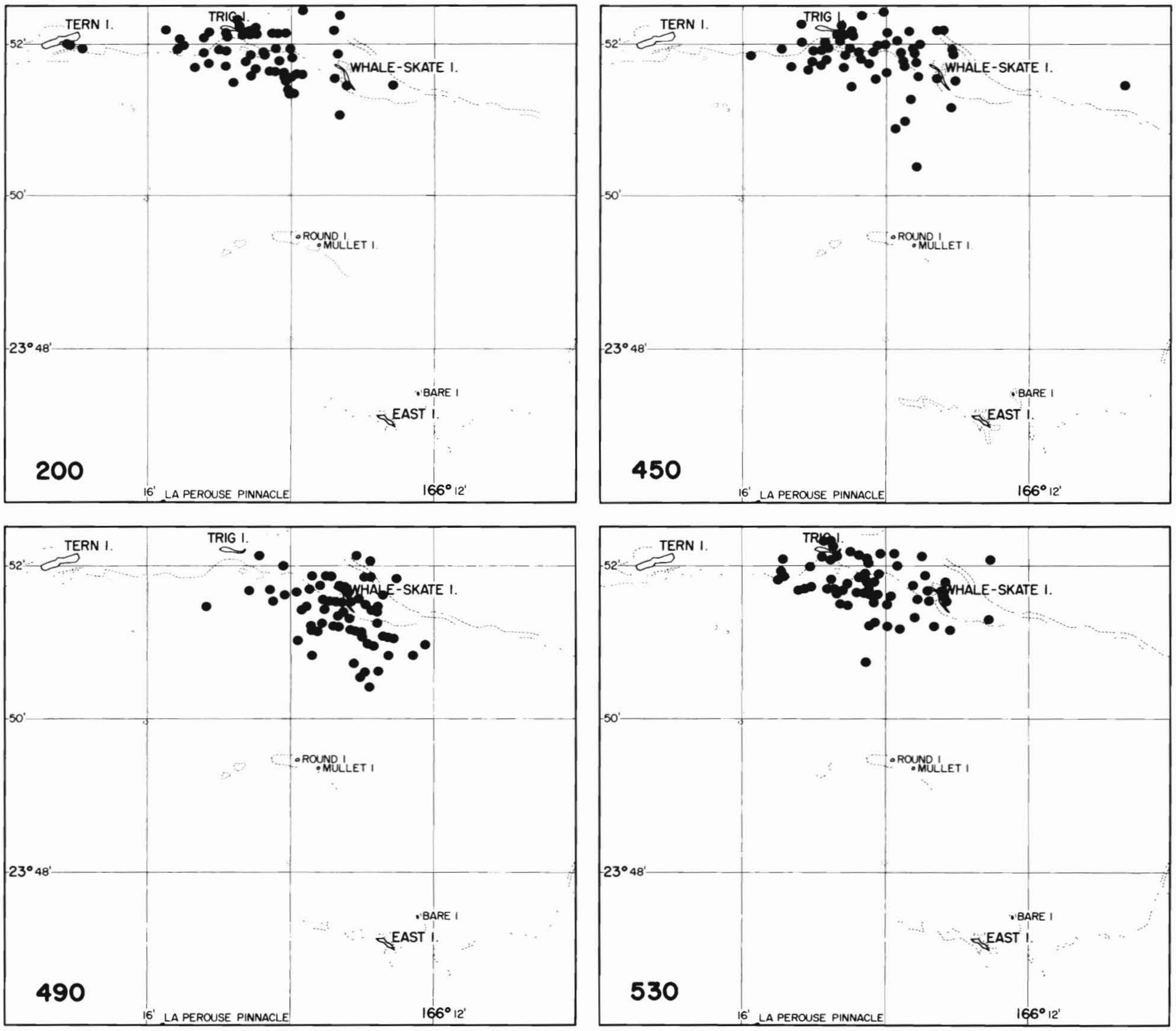



Figure 5.—Distribution of position fixes of the female turtles. Female 200 regularly came to Tern Island to nest.

heard from on 27 June. Female 200 came to Tern Island to nest twice. At the second nesting we decided to remove the transmitter and evaluate its condition and take a close look at the screw wounds. Both the turtle and the transmitter were fine. Our last transmission from her was on 30 June. She was later spotted again nesting on Tern Island on 17 July.

The other five turtles (350, 450, 490, 530, and 540) were all still transmitting when the field party left Tern Island on 30 June.

Females 490 and 530 remained in the colony until the middle of August, leaving on the 7th and 10th. Male 540 left on the 12th of the same month. Male 350 remained another month and was last heard from on 4 September. Female 450 remained the longest in the breeding colony (signals were heard until 13 November). She is likely a permanent resident of FFS.

## Habitat Utilized

Our results show that the nearshore habitat of males and females at the breeding colony is in proximity to the basking and nesting islands near where they were captured (Fig. 4, 5). While understandable perhaps for the females, it is curious that the males adhere so closely to the nesting beaches. East Island remains the nesting site for 55 percent of the FFS-breeding turtles. Nevertheless we never observed our turtles traveling the 9 km south to the East Island area. Clearly, there is a strong evolutionary bias for a female to return to the same nesting beach year after year. Since the beach was adequate for her mother and for her as a hatchling, it is highly probable it will be adequate for her and for her hatchlings. But the males have no such stake. The best strategy would be to impregnate as many females as possible regardless of which nesting beach they will eventually employ. Thus it is curious that the ranges of the males were so tightly coupled to the place they were tagged. This specificity apparently extends over the years. Male 350 was originally tagged on Whale-Skate Island in 1975 and male 540 was tagged in 1979 on Trig Island. Table 2 details previous records of year-to-year visits by males and females to the various islands. The approximately 13-20 percent straying could be due at least in part to the permanent residents. They seem, as female 450 shows, to make use of more of the reefs and beaches of FFS. She was heard from well into November and was spotted several times on the beach at East Island during the summer of 1981.

Thus, our results strongly infer that imprinting to the nesting beach and its environs occurs in both males and females and that this response seems permanent at least over several years. These results also emphasize the importance of maintaining the utilized marine habitat and the nesting beach as free from disturbing influences as possible. It is imperative for the well-being of the population that no alterations in the habitat be made since once imprinted the green turtle is unlikely to switch its breeding habitat.

**Table 2.—Specificity of returns by male and female turtles to listed areas within the French Frigate Shoals breeding grounds (Balazs, 1980). Data are based upon a tagging and subsequent recoveries from 1970 to 1980. TRIG-WS = Trig Island and Whale-Skate Island complex, EAST = East Island, and GIN = Gin Island complex (Fig. 1).**

| Item | TRIG-WS same/stray | EAST same/stray | GIN same/stray | Total same/stray |
|---|---|---|---|---|
| Males | | | | |
| Number | 33/8 | 16/2 | 0/0 | 49/10 |
| Percent stray | 24 | 12 | — | 20 |
| Females | | | | |
| Number | 15/5 | 68/3 | 0/3 | 83/11 |
| Percent stray | 33 | 4 | 100 | 13 |


## Acknowledgments

Our telemetry field team also included Causey Whittow, Howard A. Jemison III, Steven Kramer, Susan and Robert Schulmeister, Ruth Ittner, and Elizabeth Flint. Each of these individuals made valuable contributions to the project. We also want to express our appreciation to the U.S. Fish and Wildlife Service for the use of support facilities on Tern Island, and for permitting the research to be conducted within the Hawaiian Islands National Wildlife Refuge.


## Literature Cited


Amerson, A. B., Jr. 1971. The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Res. Bull. 150, 383 p.

Balazs, G. H. 1976. Green turtle migrations in the Hawaiian Archipelago. Biol. Conserv. 9:125-140.

________. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS SWFC-7, 141 p.

Baldwin, H. A. 1972. Long-range radio tracking of sea turtles and polar bear—instrumentation and preliminary results. *In* S. R. Galler, K. Schmidt-Koenig, G. J. Jacobs, and R. E. Belleville (editors), Animal orientation and navigation, p. 19-37. Nat. Aeronaut. Space Admin., Wash., D.C., SP-262.

Carr, A. 1967a. Adaptive aspects of the scheduled travel of *Chelonia*. *In* R. M. Storm (editor), Animal orientation and navigation, p. 35-55. Proc. 27th Annu. Biol. Colloq. Oreg. State Univ. Press, Corvallis.

________. 1967b. Caribbean green turtle, imperiled gift of the sea. Natl. Geogr. 131:876-890.

________. 1967c. So excellent a fishe. Natural History Press, Garden City, N.Y., 248 p.

________. 1972. The case for long-range chemoreceptive piloting in *Chelonia*. *In* S. R. Galler, K. Schmidt-Koenig, G. J. Jacobs, and R. E. Belleville (editors), Animal orientation and navigation, p. 469-483. Nat. Aeronaut. Space Admin., Wash., D.C., SP-262.

Carr, A., P. Ross, and S. Carr. 1974. Internesting behavior of the green turtle, *Chelonia mydas*, at a mid-ocean island breeding ground. Copeia 1974:703-706.

Daniel, H. 1980. Dianne, the turtle, is tracked by satellite. NOAA News 5(16):5, 8.

Feazel, C. T. 1980. The turtle run. Sea Front. 26:240-243.

Garmon, L. 1981. Tortoise marsh wallow? Sci. News 119:217.

Ireland, L. C. 1979a. Homing behavior of juvenile green turtles, *Chelonia mydas*. *In* C. J. Amlaner, Jr., and D. W. MacDonald (editors), A handbook on biotelemetry and radio tracking, p. 761-764. Pergamon Press, Oxford.

________. 1979b. Homing behavior of immature green turtles (*Chelonia mydas*). (Abstr.) Am. Zool. 19:952.

Meylan, A. B. 1978. The behavioral ecology of the west Caribbean green turtle (*Chelonia mydas*) in the internesting habitat. Master's Thesis, Univ. Fla., 131 p.

________. In press. The behavioral ecology of the west Caribbean green turtle (*Chelonia mydas*) in the internesting habitat. *In* K. A. Bjorndal (editor), The conservation and biology of sea turtles. Smithson. Press.

Mortimer, J. A. 1981. Reproductive ecology of the green turtle, *Chelonia mydas*, at Ascension Island. Ph.D. Diss., Univ. Fla., 162 p.

Murphy, T. M., Jr. 1979. Sonic and radio tracking of loggerhead turtles. Mar. Turtle Newsl. 11:5.

Pritchard, P. C. H. 1980. Report on United States/Mexico conservation of Kemp's ridley sea turtle at Rancho Nuevo, Tamaulipas, Mexico in 1979. Final rep., U.S. Fish Wildl. Contract 14-16-0002-80-2. U.S. Fish Wildl. Serv., Albuquerque, N.M., 27 p.

Standora, E. A., J. R. Spotila, and R. E. Foley. 1979. Telemetry of movement and body temperature data from green turtles, *Chelonia mydas*, at Tortuguero, Costa Rica. (Abstr.) Am. Zool. 19:981.

Stoneburner, D. L. 1979. Satellite telemetry of internesting movements of loggerhead sea turtles at Cumberland Island national seashore. U.S. Dep. Inter., Natl. Park Serv., Southeast Reg. Off., Atlanta, Ga., 7 p.

Timko, R. E., and D. DeBlanc. 1981. Radio tracking juvenile marine turtles. Mar. Fish. Rev. 43(3):20-24.

World Conference on Sea Turtle Conservation. 1979. Sea turtle conservation strategy. World Conference on Sea Turtle Conservation, 26-30 November, 1979, Wash., D.C., 38 p.