Satellite Tracking Manual for the Visiting Sea Turtle Researcher and Information Exchange Program

Host: Pacific Islands Fisheries Science Center
NOAA, National Marine Fisheries Service

Location: Pacific Islands Fisheries Science Center
NOAA, National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

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Exchange Program

Sponsored by:

Pacific Islands Fisheries Science Center
NOAA, National Marine Fisheries Service
Marine Turtle Research Program

Host:

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NOAA, National Marine Fisheries Service
Pacific Islands Fisheries Science Center
2570 Dole Street
Honolulu, Hawaii 96822-2396
Phone: (808) 983-5733; Cell phone: (808) 286-2899
Fax: (808) 983-2902
Email: gbalazs@honlab.nmfs.hawaii.edu

Lodging for Workshop Participants:

Lincoln Hall
East-West Center
1821 East-West Road
Honolulu, Hawaii 96848-1821
(808) 944-7816
(808) 944-7960 after 9:30pm

Lincoln Hall is a 5 minute walk from the NMFS Pacific Islands Fisheries Science Center where most training activities will be conducted.

Abstract of presentation for "Seminaire Tortues Marine-Ocean Indien 1999." December 1999, Reunion Island, France.

SEA TURTLE SATELLITE TRACKING: BRINGING PEOPLE TOGETHER FOR CONSERVATION

George H. Balazs

National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822-2396 USA

An amazing increase has been witnessed this past decade in the effective use of satellite telemetry to map the movements of sea turtles to learn more about their life in the ocean. At the same time, educators working closely with researchers have skillfully utilized these marine trackings to build awareness as a force for conservation. The process of tracking sea turtles by satellite using the global Argos System (CLS-France/NOAA-USA) can be described briefly as follows: A small watertight transmitter with sufficient battery reserve is safely attached to the back of a turtle, usually at the time of nesting. When the animal returns to the water and surfaces to breathe, data transmissions are sent to sensitive receivers aboard polar-orbiting satellites. This information is rapidly relayed to ground processing stations that calculate the turtle's location with varying levels of accuracy. The results are then sent to the researcher over the Internet on a daily basis for evaluation and mapping.

As the ultimate wildlife tagging tool of the 20th Century, no other single research activity has generated such widespread interest and value to promote regional cooperation on behalf of sea turtles. Several favorable factors have come together in recent years to make this happen, including 1) the availability of suitable transmitters and their high rate of success when properly programmed and deployed; 2) an increased need for timely information on the international movements of sea turtles for management purposes; 3) a greater willingness to devote the money and other resources necessary to conduct satellite tracking; 4) more people with experience who are willing to share their skills in successful tracking, thereby building capacity in others; and 5) the lightning speed and versatility of the Internet and the proliferation of conservation education websites providing ease of access to millions worldwide.

This paper will elaborate on the above elements and provide examples of successful projects, as part of a broad overview of the subject. Considerable potential exists for the expanded use of satellite telemetry for sea turtles in the Indian Ocean and other important world regions.

ST-14 Sea Turtle Satellite Transmitter Attachment Instructions

Prepared Specifically For

Pacific Region Hawksbill Research - Satellite Tracking Project 2000
and
Caribbean Hawksbill Research - Satellite Tracking Project 1998/1999/2000

Instructions Compiled by:

Barbara Schroeder
George Balazs
Michelle Rogers
National Marine Fisheries Service

With improvements and modifications, this instruction manual is based on detailed attachment techniques first published in:

Balazs, G. H., R. K. Miya, and S. C. Beavers.
1996. Procedures to attach a satellite transmitter to the carapace of an adult green turtle, *Chelonia mydas*. *In* J.A. Keinath, D.E. Barnard, J.A. Musick, and B.A. Bell (comps.), Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation, February 20-25, 1995, Hilton Head, South Carolina, p. 21-26. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SEFSC-387.

PREPARING THE TRANSMITTER PRIOR TO ATTACHMENT:

- Ensure that the saltwater switch metal screw heads are covered with small pieces of masking tape. The external components of the saltwater switch are located on the end of the transmitter nearest to the antenna (SEE FIGURE 1). These screw heads serve as electrical contacts for the unit's saltwater switch and must not be covered with resin, fiberglass cloth, or any other material during transmitter attachment. The screw heads will be taped prior to the shipment of the transmitters, but double check to make sure they have not been dislodged in any way. If you need to recover them, the easiest way is to cut a piece of masking tape in a small circle and press the tape firmly over the screw head to completely (and individually) cover it.

- The transmitter i.d. number, factory serial number, and duty cycle will be etched (scratched) on the outside housing. Record all of this information and double-check the transmitter serial number, which is located on a metal plate with the TELONICS company identification, on the edge of the transmitter opposite the antenna (SEE FIGURE 2). These data must be recorded on the field data sheet you are using to record all pertinent details about the turtle and the attachment/deployment process.

- NOTE that the magnet (which turns the transmitter on/off) will have already been removed in accordance with specific instructions given previously.

NOTE:

It is necessary, once the carapace is cleaned and dried, to keep the working area completely dry. This can be done by erecting a waterproof tarp to work under (which also provides shade) or, at a minimum, having a tarp ready to cover the box should it begin to rain.

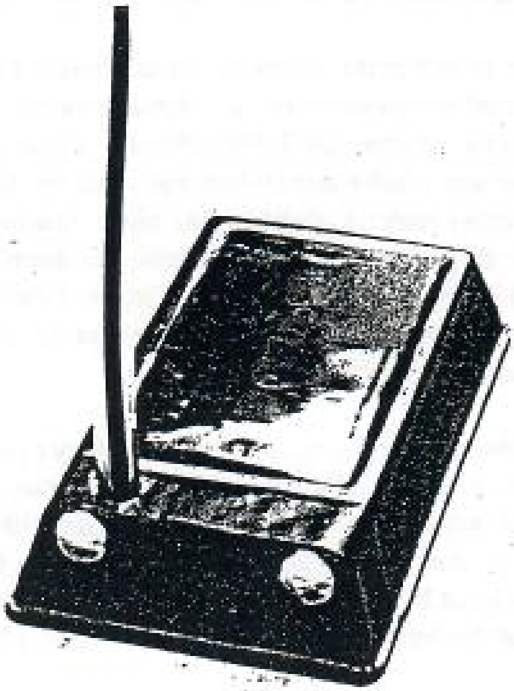


Figure 1. Salt-water switch terminal screw heads have been covered with masking tape to prevent resin from coating the screw heads.

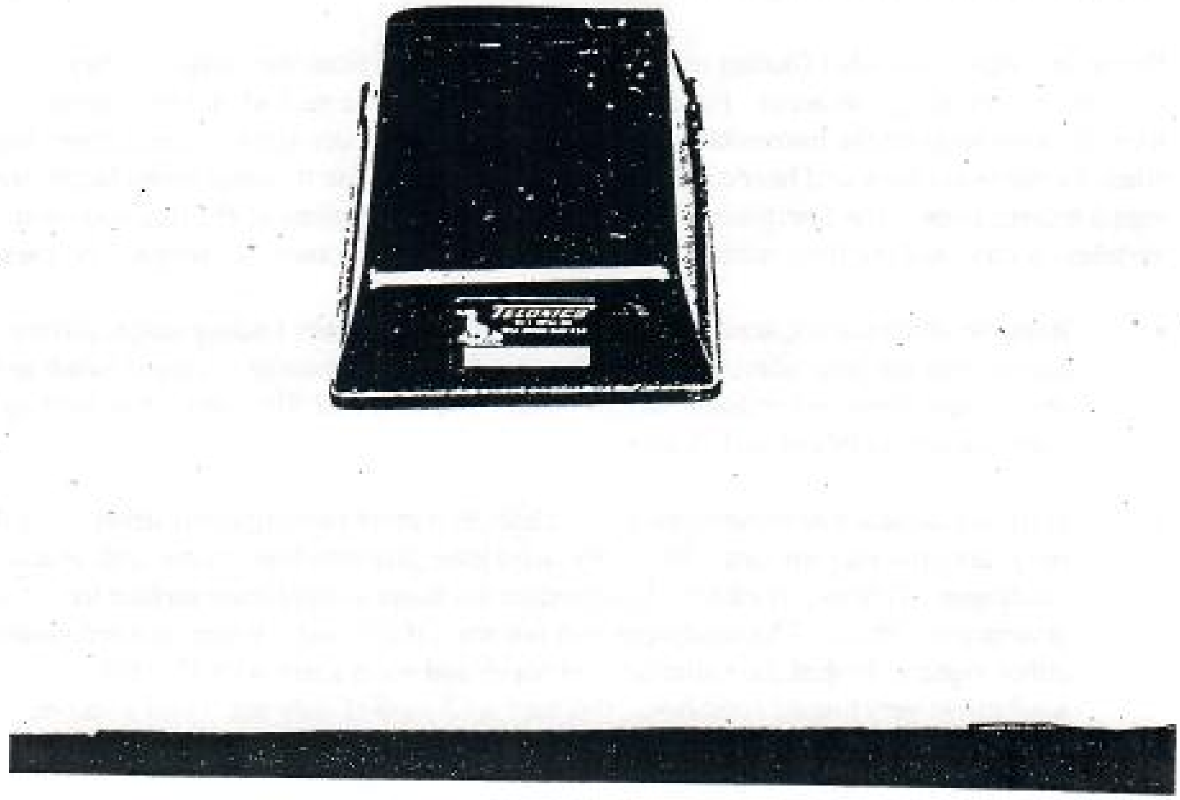


Figure 2. Record the serial number of the transmitter before applying the transmitter to the carapace. The serial number is located on the TELONICS identification plate on one end of the unit.

STEP 1: PREPARING THE CARAPACE

Barnacles, algae, and other fouling material must be removed from the carapace where transmitter mounting will occur. For adult hawksbill turtles, the second vertebral scute is the ideal location to place the transmitter. This section of the carapace rises to a maximum height when the turtle surfaces and hence, allows the antenna to also rise to a maximum height for signal transmission. The fiberglass bonding will encompass sections of the first and third vertebral scutes, and the first, second, and possibly third costal scutes. To prepare the carapace:

- Remove all barnacles, scrub off algae, and remove any other fouling material from the carapace in the area where the transmitter application will occur. A scrub brush and green, mild abrasive scrubbers are provided. Use only FRESH water when wetting the carapace for scrubbing and cleaning.

- Once the carapace has been thoroughly cleaned, it must be completely dried using the terry cloth towels provided. When dry, sand the entire attachment area with coarse sandpaper. This step is extremely important to ensure a roughened surface for attachment. NOTE: The sandpaper will not work if it is wet! When finished sanding, either vigorously dust the entire area, or scrub and wash again with FRESH water. If working in very humid conditions, you may wish to dust only and avoid a second application of water. The carapace should now be free of sanding dust.

- When dry and thoroughly dusted, lightly wipe the entire area with an isopropyl alcohol dampened cloth. Allow to dry COMPLETELY before moving on to the next step.

STEP 2: MOUNTING THE TRANSMITTER ON THE CARAPACE

The transmitter will be mounted to the carapace using a base of silicone elastomer. This product is used primarily in human medicine as a splinting agent. The elastomer is NOT an adhesive, but forms a molded, level platform against the carapace. Because the elastomer is not an adhesive, care must be taken not to dislodge the transmitter from the carapace once the elastomer has cured and before the fiberglass cloth and resin have bonded to the carapace. Unlike epoxy products or mixed polyester resin, elastomer does NOT generate heat as it cures. This is extremely important and ensures that no possibility of thermal damage to the turtle exists. Mount the transmitter using the silicone elastomer as follows:

- Note that the elastomer product comes with instructions concerning optimum ambient temperatures for successful use. You should consult these instructions to ensure that the conditions you are working under fall within the specified temperature regimes. Under certain conditions, you may need to use more or less elastomer base and/or more or less catalyst.

- Place the transmitter on the carapace, on the second vertebral (=central) scute where it will eventually be bonded. This will enable you to judge the "fit" and make any small adjustments in placement to obtain the best "fit". NOTE: Do not select a different location to mount the transmitter. The antenna will not be directly centered along the midline, but the transmitter WILL be. Only slight adjustments over the second vetebral scute will be necessary. Wipe the transmitter very lightly with isopropyl alcohol and allow it to dry.

- Experience has shown that 4 oz of elastomer base should yield a sufficient quantity of silicone elastomer to place on the bottom of the transmitter in order to mold and mount the unit firmly against the curved and/or irregular surface of the carapace. Use 10 drops of elastomer catalyst with 4 oz of elastomer base (different temperatur and humidity conditions may dictate slightly different catalyst amount needed). Drop the catalyst in a random pattern around the elastomer as you count the drops going into the cup. The elastomer catalyst is in a small glass jar, DO NOT confuse the resin catalyst with the elastomer catalyst. Vigorously and thoroughly mix the two parts together, using a mixing stick, for at least 20-30 seconds. The mixture should be workable, but not runny, if it is still very runny, continue mixing. The elastomer has a working time of 2-3 minutes, so it must be quickly spread on the bottom of transmitter using your mixing stick. Spread the elastomer out evenly on the bottom of the unit.

- Immediately press the transmitter firmly against the carapace on the second vertebral scute to form a LEVEL platform - the unit should not be tipped forward or backward. Ensure that the elastomer forms a base along the entire length and width of the unit. The elastomer should "ooze" out slightly along all sides of the transmitter. As the elastomer is setting up, the transmitter may tend to slide around a little bit, have someone stand either directly in front or behind the turtle to ensure that the transmitter is along the vertical midpoint of the carapace. Remember, the antenna will be slightly off center, due to its' location on the unit. If the elastomer does not "fill" all areas under the transmitter, use your finger or mixing stick to drag the elastomer and push it where it is needed. You have limited time to do this, as the hardening process is well underway. A second batch of elastomer can always be mixed up to fill in any gaps that might be left, this product bonds to itself, so adding in additional elastomer in a second step is not a problem.

- When the elastomer has completely cured (approximately 10 minutes), use a knife to trim the excess material flush with the edges of the transmitter, taking care not to cut into the carapace scutes. Do not pull the elastomer away from the transmitter if a clean cut has not been made. This could cause the elastomer to be pulled out from under the transmitter where it is needed. Once the elastomer is trimmed away, re-sand and then dust the area where the elastomer contacted the carapace and then wipe this area lightly with an isopropyl alcohol dampened cloth. Allow to thoroughly dry.

Sammons Preston Rolyan
An AbilityOne Company
4 Sammons Court
Bolingbrook, IL 60440-5071
(800) 323-5547
Fax: (800) 547-4333
Web site: www.sammonsprestonrolyan.com
Email: spr@abilityone.com

Product number: A643-1K, Silicone elastomer 1# kit, ~$60

STEP 3: BONDING THE TRANSMITTER TO THE CARAPACE, FIRST APPLICATION

There are three separate applications of resin over fiberglass cloth to bond the transmitter to the carapace. Follow the instructions below for the first application:

- The amount of catalyst to use will vary depending on the ambient temperature and the temperature of the resin prior to mixing. Begin by using 40 drops of resin catalyst (MEK catalyst) with 4 oz of polyester "laminating" resin. Spread the drops of catalyst over the surface of the resin in the mixing cup while counting the drops. Mix thoroughly for 60-90 seconds. Surgical gloves should be worn at ALL times when working with the resin and fiberglass cloth.

- Note that under very cool conditions the resin may take a long time to cure, conversely, under very hot conditions the resin may cure faster. You may want to experiment beforehand to determine the amount of catalyst needed under your ambient temperature so that the resin cures neither too fast or too slow or, as noted above, you can start with 40 drops and make adjustments for the subsequent steps if necessary. Fewer drops of the catalyst will cause the resin to cure more slowly and more drops will cause the resin to cure more quickly. A rapidly catalyzing mixture is NOT desirable because of the short working time and the more rapid release of heat. Polyester resin does generate heat, however, this application technique uses only very thin layer of resin over fiberglass cloth, and thermal stress is not a problem. Do NOT rush the resin/curing process.

- After mixing the resin, lightly brush a coat on the transmitter and carapace, where the first cloth set will be applied. Use the four cloth pieces provided in the bag marked "CLOTH SET 1". The two longer pieces are placed along the length of the transmitter, even with the top edges and the two shorter pieces along the width of the transmitter (SEE FIGURE 3 and 4). The "cut" end of the shorter pieces should be aligned with the vertical axis of the carapace. The posterior piece must be place immediately BELOW the saltwater switch terminals, do NOT cover the taped screw heads. Use the remaining resin to liberally soak the cloth until it is no longer white but has a transparent appearance. Use the tip of the brush to "push" the resin into the cloth, do not use broad painting style strokes as this will cause the cloth to slide around. You want to get the resin into the cloth, by "pushing". Use your brush to pull the resin back up toward the cloth if it is runny. As the resin cures, it will "stay in place" better. Fold the extra "corner" pieces of cloth and resin them as flat as possible at the corners of the transmitter. You must work quickly as the working time of a properly mixed batch of resin will be relatively short (5-15 minutes). Once the resin begins to gel, it will no longer be workable, do not continue applying the resin after it beings to gel. NOTE: Use the tip of your brush to "push" the resin into the cloth, the more traditional painting method will NOT work well to get the resin into the cloth but will cause the resin to be pulled away from the cloth. You must push it in through the cloth fibers.

- IMPORTANT: Have one or two members of your team standing by with cloths to catch any drips that may run toward the turtles' skin. Use a cloth rag to wipe away these drips, if the "painters" can't pull the dripping resin back into the attachment area. It is a VERY GOOD idea to have a towel over the head of the turtle during the resin application to ensure that there is NO chance of getting resin in the eyes. This often serves to calm the turtle as well.

- Allow this first layer to dry until fine threads of resin no longer form when the sticky surface is lightly touched with your paintbrush. Ideally, this hardening stage will take approximatley 15 minutes, but may take longer depending on circumstances. The resin will remain tacky, but you are ready to apply the next layer.

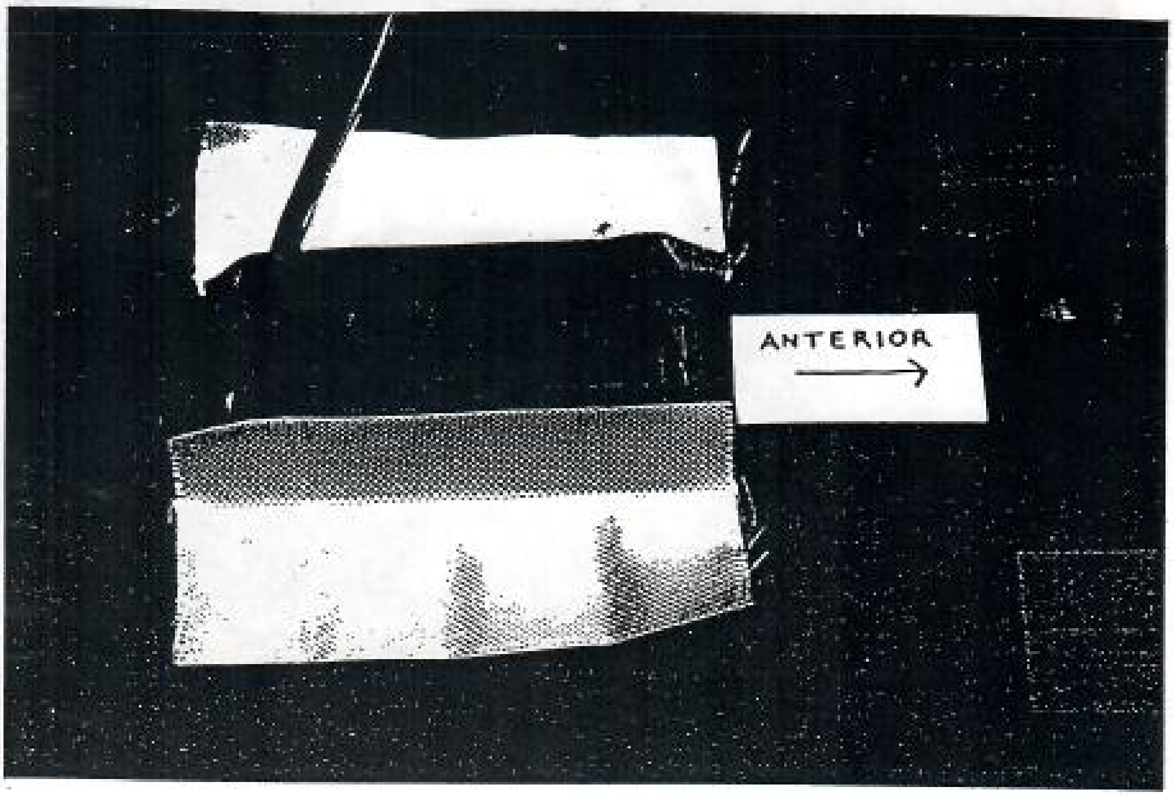


Figure 3. Cloth/resin - first application. Using cloth set #1, apply the two longest pieces of cloth lengthwise on the transmitter.

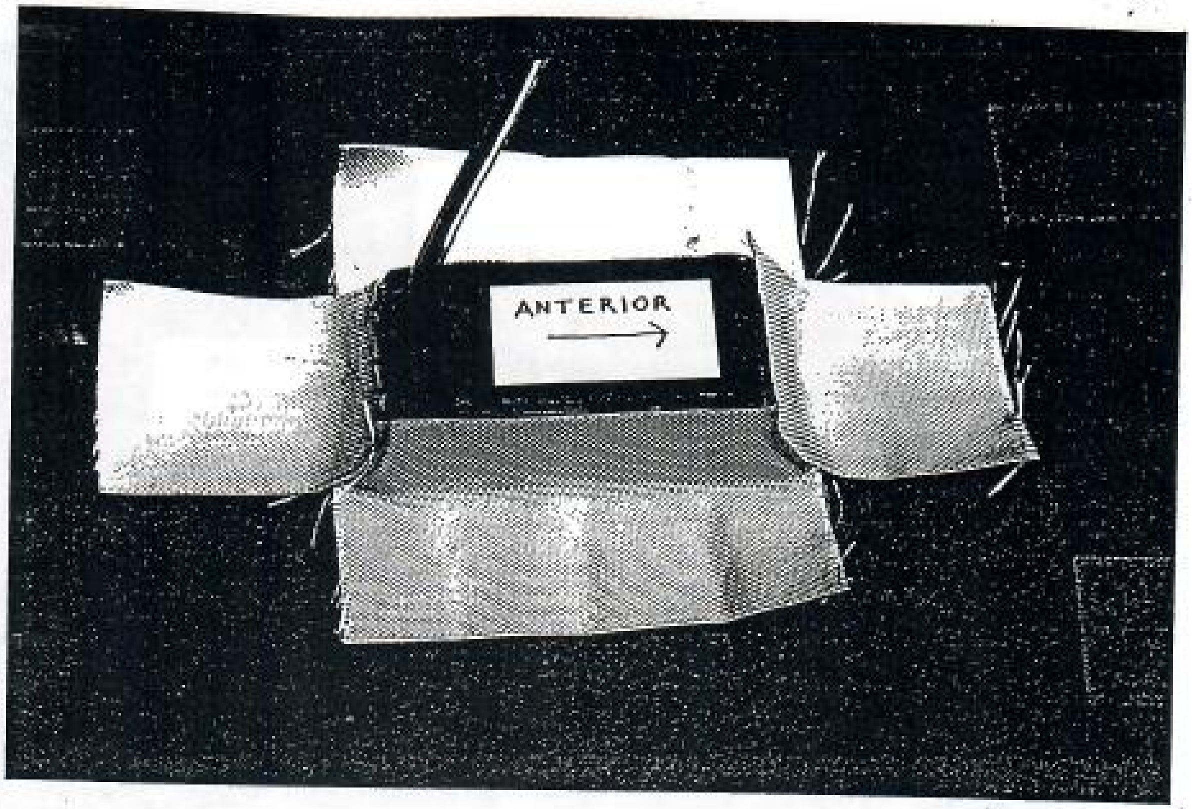


Figure 4. Cloth/resin - first application. Using cloth set #1 continue this step by applying the two shorter pieces of cloth to the anterior and posterior end of the unit. MAKE SURE the posterior piece does NOT cover the salt water switch screw heads, it should be placed just beneath them.

STEP 4: BONDING THE TRANSMITTER TO THE CARAPACE, SECOND APPLICATION

Follow the instructions below for the second application of the three-step bonding process:

- This is the step during which the identification card is laminated on the transmitter. Have the card ready BEFORE the resin and catalyst are mixed. The identification card is place OVER the first lengthwise strip of cloth noted below.

- Mix a second cup of catalyst and resin, using 40 drops of catalyst (or an amount adjusted based on results of the first coat) with 4 oz of resin. Mix thoroughly for 60-90 seconds. Brush this fresh coat of resin on the transmitter and carapace, where the second layer of cloth will be applied.

- Use the four pieces of fiberglass cloth from the bag labeled "CLOTH SET 2". Apply the longest piece of cloth, marked with an "X", along the length of the transmitter extending from anterior to posterior (SEE FIGURE 5). The "X" serves only to identify this piece from the others, it is not necessary to orient it one way or the other. You may need to cut small notches in this piece so as not to cover the saltwater switch terminals. After soaking the lengthwise piece of cloth with resin, place the i.d. card on the transmitter, make sure it will be visible anterior to the buffer tube that will be place in front of the antenna during the last cloth/resin step.

- Apply two of the remaining pieces of equal length cloth crosswise on the transmitter and extending down the sides of the unit and onto the carapace (SEE FIGURE 5). Thoroughly soak all cloth with resin until it becomes transparent. Apply the last remaining strip of cloth crosswise over the center of the unit, overlapping the two crosswise pieces just applied (SEE FIGURE 6). Ensure that all cloth is soaked until transparent. Use the resin liberally and push it into the cloth.

- Allow this layer to dry to a tacky stage, as described in Step 3, above.

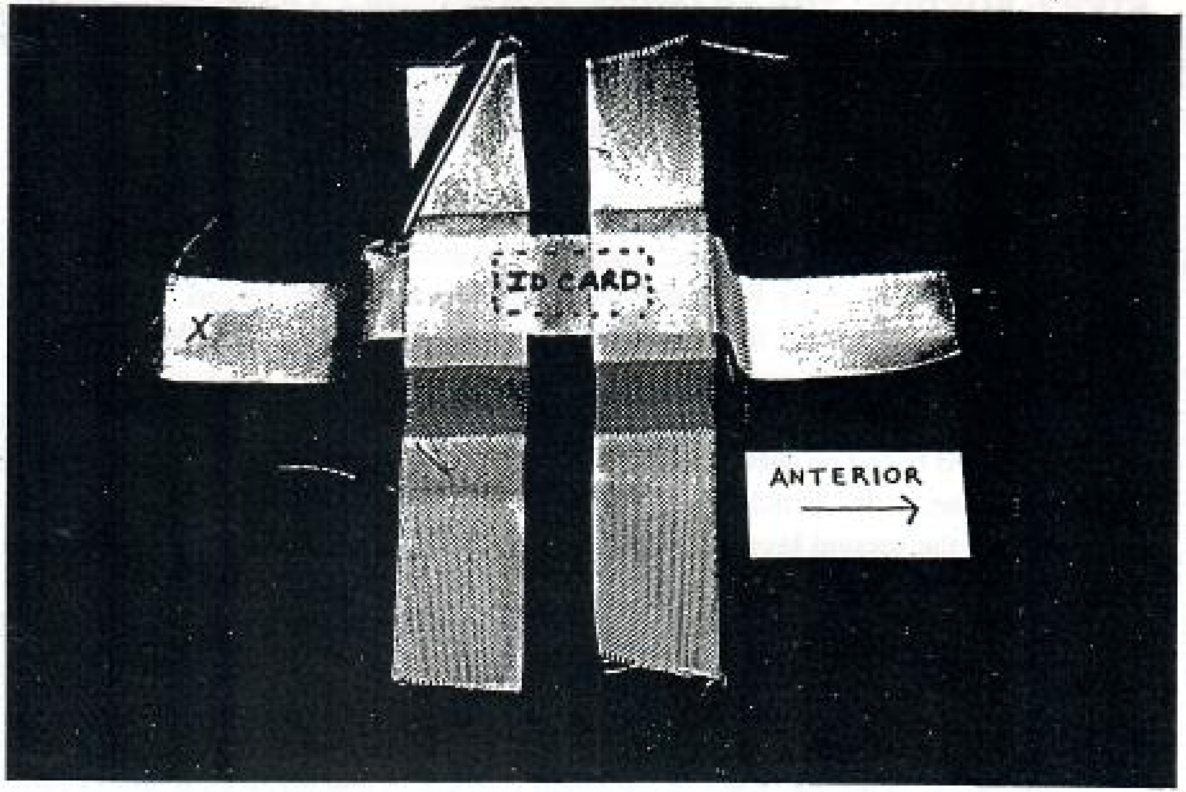


Figure 5. Cloth/resin - second application. Using cloth set #2 apply the longest piece of cloth (marked with an "X") lengthwise on the transmitter. Next place the i.d. card on the transmitter, over the piece of cloth marked with an "X". Next, apply two of the remaining pieces of cloth crosswise, as shown.

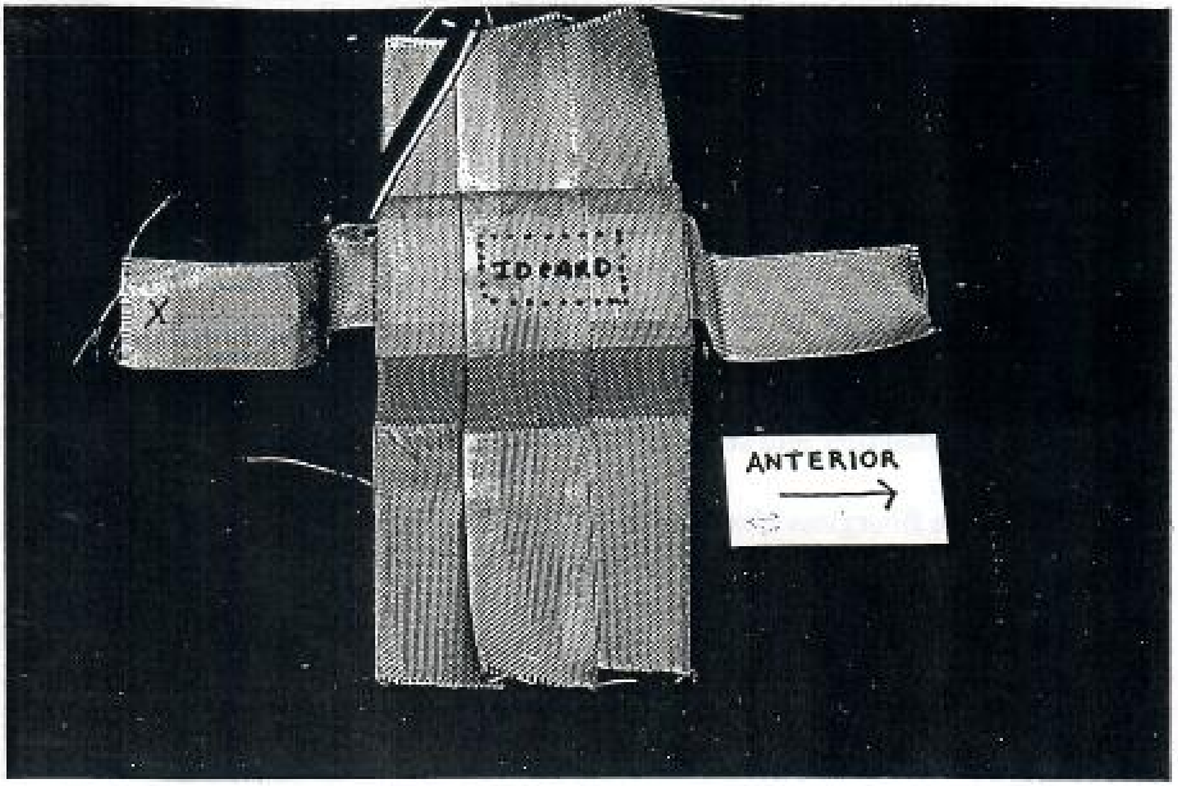


Figure 6. Cloth/resin - second application. Using cloth set #2, continue with this step by applying the last piece of cloth crosswise on the transmitter overlapping the two previously placed pieces.

STEP 5: BONDING THE TRANSMITTER TO THE CARAPACE, THIRD APPLICATION

Follow the instructions below for the third and final application of the three-step bonding process:

- Mix a third cup of catalyst and resin, again using 50 drops of catalyst with 5 oz of resin. Mix vigorously and thoroughly for 60-90 seconds. As soon as the resin is mixed, place the buffer tube ("cigar") into the cup and allow it to start soaking up resin, turn it over after it has soaked for a few minutes, you can also drip some resin down the center of tube to help soak it from the inside out. Brush the resin on the transmitter and carapace, where the third layer of cloth will be applied.

- Using the fiberglass cloth contained in "CLOTH SET 3", apply the widest (and shortest) piece of cloth to the anterior end of the transmitter, overlapping the top and extending down and anterior on the carapace. Place one of the two long strips of cloth crosswise toward the anterior end so that it overlaps the "raw" edge of the anterior-most piece, just placed in this step (SEE FIGURE 7).

- Place the rolled fiberglass cloth antenna "buffer" tube (cigar) directly anterior to the antenna (SEE FIGURE 7). Soak the tube with resin and use the remaining long strip crosswise over the tube to hold it in place. The tails of this cloth strip should be pulled slightly posterior to "anchor" the buffer tube in place.

- Soak all the cloth thoroughly until it is transparent. Just as the resin remaining in the cup begins to gel, "goop" it on the top and anterior side of the buffer tube to provide additional protection. This thicker application of resin is to occur only on top of the transmitter, and never on the carapace where it will generate significantly more heat than the thin painted layers we are using.

- Allow the resin to cure as noted in STEPS 3 and 4. Do not be in a hurry to release the turtle.

Figure 7. Cloth/resin - third application. Use cloth set #3 and consult the instructions under STEP 5. Note that in this photograph the cloth strips for this step have already been soaked with resin, but they are still visible for instructive purposes.

STEP 6: PREPARING THE TURTLE FOR RELEASE

After the final coat of resin and cloth has cured in accordance with the directions above, several steps must be taken to ensure that the turtle is ready for release.

- Remove the masking tape from the saltwater switch terminals to ensure that they are clear and free of residue. Lightly sand the terminals to ensure they are free of residue.

- Double check your field notes to ensure that the transmitter serial number is documented and that the message on the handwritten identification card has been recorded.

- Double check field notes to ensure that all measurements and biological samples have been obtained from the turtle. Obtain a tissue sample for genetic analysis.

- The turtle can now be released by lifting the box over and away from her. Be sure you don't bang into the transmitter with the box. NOTE: Do not allow the turtle to crawl into any body pits or deep holes on the beach as this can cause flexing and "pop" the cloth/resin layers in one or more places.

- Note the time of release and, if possible, obtain a GPS recording of the release location.

- Ensure that all used equipment from the attachment are properly disposed of and that all equipment which can be re-used for the next attachment is collected and stored.

LIST OF ITEMS BEING PROVIDED

ST14 transmitters
Scrubber pad
Putty knife
Cloth towels
Coarse sandpaper
Silicone Elastomer kit
Trash bags
Mixing cups
Stirring sticks
Empty plastic dropper bottles
Scissors
Rubber gloves
Fiberglass cloth kits
"Castro Cigar" cylinder kits
Indelible pen
Card for message on transmitter
Camera (one-time use)

Items That Need to be Obtained in Your Country

1. Polyester laminating resin (= marine or surfboard laminating resin)
2. MEK Peroxide catalyst for resin
3. Rubbing alcohol (such as 70% isopropyl)
4. Lumber to construct a turtle holding container
5. Awning for shade and rain protection

PROTOCOL FOR COLLECTION OF TISSUE FOR GENETIC ANALYSIS

Send to:
Dr. Peter Dutton
NOAA-NMFS/SWFSC
La Jolla Laboratory
8604 La Jolla Shores Drive
La Jolla, CA 92037, USA

Phone: 858-546-5636
FAX: 858-546-7003
Email: peter.dutton@noaa.gov

MATERIALS

-Salt preservative: saturated NaCl with 20% DMSO
-razor blade, scalpel or biopsy tool[2]
-screw-cap polypropylene tubes
-disposable gloves, labels, marker

TISSUE SOURCE

Live animals: skin or muscle biopsy
Dead animals: if fresh, heart and liver; if dead more than 2 hours, skin and muscle
Fresh eggs and whole embryos from non-viable intact eggs

METHOD

1.) Collect 0.5-5.0 grams of tissue (0.5-2.0 cm dia. skin biopsies, or 2-3 strips of tissue (1.5x4cm). Wearing gloves while handling the tissue, and changing gloves in between samples from different individuals, is ideal. **Use a new blade or biopsy tool when collecting from each different individual.**

2.) Chop the tissue a few times with a razor blade to increase penetration of the preservative.

3.) Add tissue to the tube with preservative. On the small piece of bond paper, **write in pencil** the ID number, species, location and date. Put the piece of paper in the vial with each sample.

4.) Label each vial (cap and side of the vial) using the enclosed **Sharpe permanent pen** with the species, location and a field ID number, this number should be the one you use as reference in your field records to any other information you collect.

5.) Wrap parafilm around the cap and the top of the vial by stretching the parafilm as you wrap. This will prevent leaking while the sample is in transport. Double wrap in an airtight plastic bag for shipping.

6.) Samples can be stored at ambient temperature for at least 1 year. Avoid extended exposure to heat or sunlight.

7.) Ship samples by air freight or express mail. Please include copies of permits (if required) and data sheets or stranding report on the samples collected.

[2]Acu-Punch 6mm disposable biopsy punch available from Acuderm, Inc., Fort Lauderdale, Florida 33309, USA.

Thank you for contributing to our research efforts

LIST OF APPENDICES:

1. Example of polyester laminating resin and MEK peroxide catalyst needed for satellite transmitter attachment.

2. Diagrams for constructing a sea turtle holding container that can be used for satellite transmitter attachment.

3. Example and explanation of Argos ADS (Automatic Distribution Service) data - DIAG Format for ST14 satellite transmitter.

4. Descriptive literature for the Argos global tracking system.

5. Examples of sea turtle migration maps obtained from Argos satellite tracking using ST14 transmitters.

6. Color photographs showing various aspects of deploying satellite transmitters on sea turtles.

7. Satellite overpass predictions for your specific study site showing the two times each day your transmitter may be turned on (magnet taken off) in order to synchronize with the satellites.

8. Selected publications relating to sea turtle satellite tracking.

Ellis, D. M., G. H. Balazs, W. G. Gilmartin, S. K. K. Murakawa, and L. Katahira.
2000. Short-range reproductive migrations of hawksbill turtles in the Hawaiian Islands as determined by satellite telemetry.

Garduno, M., A. Maldanado, R. Marquez-M., B. A. Schroeder, and G. H. Balazs.
2000. Satellite tracking of an adult male and female green turtle from Yucatan in the Gulf of Mexico.

Mortimer, J. A. and G. H. Balazs.
2000. Post-nesting migrations of hawksbill turtles in the Granitic Seychelles and implications for conservation.

Polovina, J. J., D. R. Kobayashi, D. M. Parker, M. P. Seki, and G. H. Balazs.
2000. Turtles on the edge: Movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts in the central North Pacific, 1997-1998.

Schroeder, B. A. and G. H. Balazs.
2000. Design and field testing of an internal helix antenna satellite transmitter for sea turtles.

Cheng, I.-J. and G. H. Balazs.
1998. The post-nesting long range migration of the green turtles that nest at Wan-An Island, PengHu Archipelago, Taiwan.

Ellis, D. M. and G. H. Balazs.
1998. The use of the generic mapping tools program to plot ARGOS tracking data.

Balazs, G. H., D. M. Ellis, W. G. Gilmartin, and L. K. Katahira.
1997. Use of satellite telemetry to determine the migratory routes and resident foraging habitats of nesting hawksbill turtles: A case study in the Hawaiian Islands.

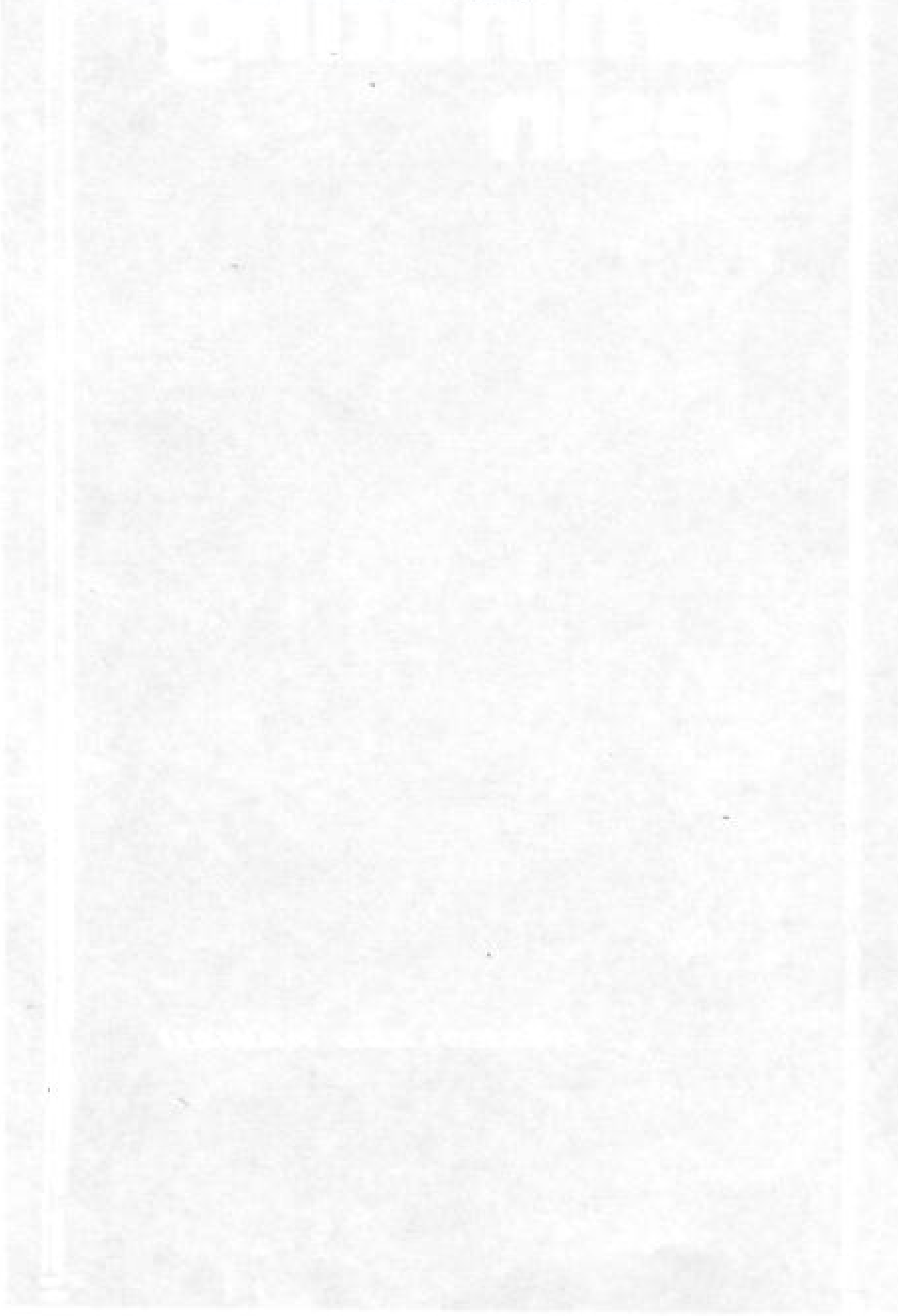
Dutton, P. H. and G. H. Balazs.
1996. Simple biopsy techniques for sampling skin for DNA analysis of sea turtles.

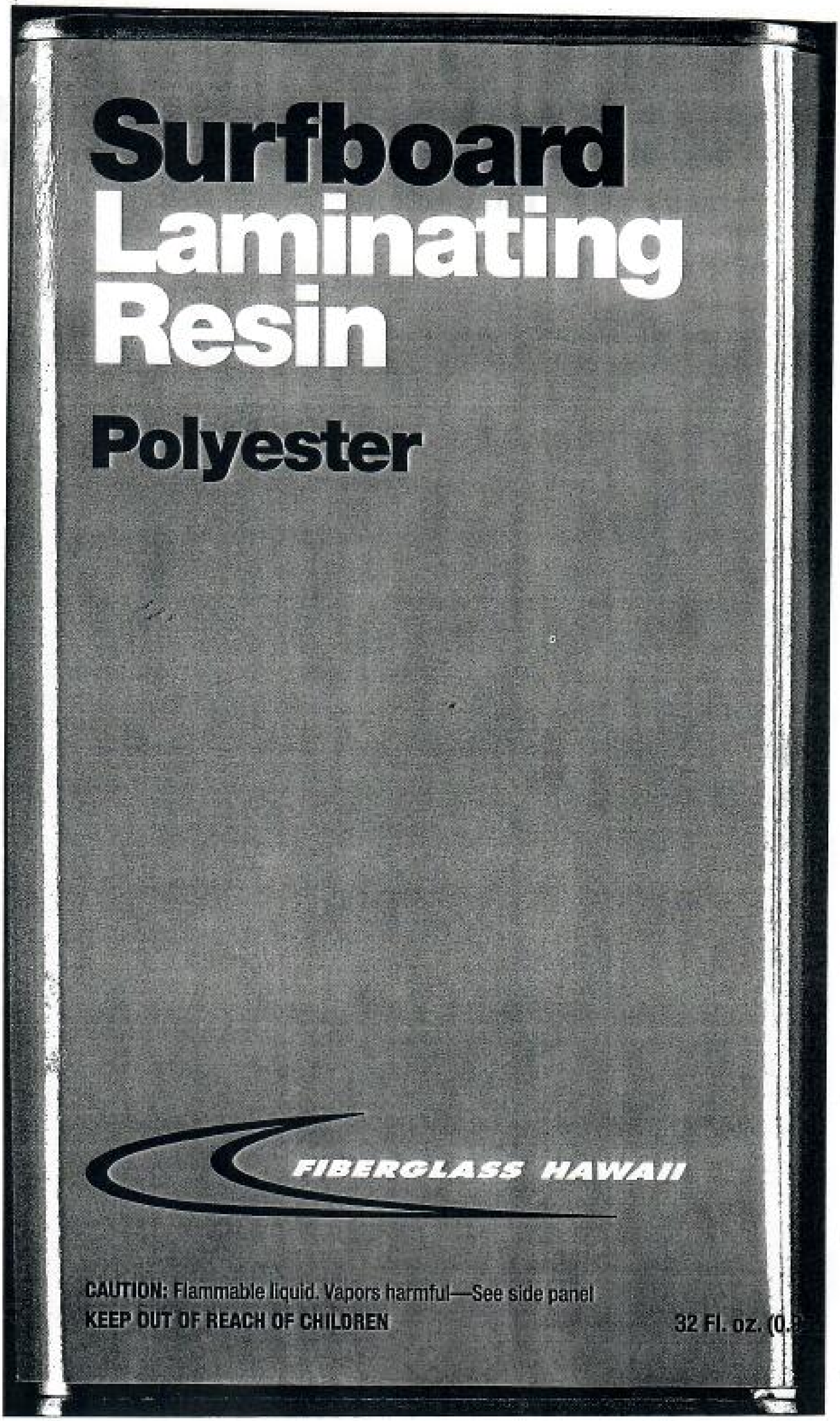
Schroeder, B. A., L. M. Ehrhart, and G. H. Balazs.
1996. Post-nesting movements of Florida green turtles: Preliminary results from satellite telemetry.

Balazs, G. H.
1994. Homeward bound: Satellite tracking of Hawaiian green turtles from nesting beaches to foraging pastures.

Balazs, G. H., P. Craig, B. R. Winton, and R. K. Miya.
1994. Satellite telemetry of green turtles nesting at Rose Atoll, American Samoa, and French Frigate Shoals, Hawaii.

APPENDIX 1. Example of polyester laminating resin and MEK peroxide catalyst needed for satellite transmitter attachment.




Surfboard
Laminating
Resin
Polyester
FIBERGLASS HAWAII
CAUTION: Flammable liquid. Vapors harmful—See side panel
KEEP OUT OF REACH OF CHILDREN
32 Fl. oz.

Surfboard Laminating Resin

Polyester

A wax free, water clear, UV inhibited laminating resin designed for laminations which require a transparent resin system. Ideal for bonding single or multiple layers of fiberglass cloth to foam, most woods, and fiberglass surfaces. Do not use on polystyrene. Do not use in direct sunlight. Working time of catalyzed resin is approximately 10 minutes.

Preparation

Surface must be clean, dry and free of oil based paint, oil, wax, dust, and other contaminants. Sand thoroughly and round all sharp corners as fiberglass will not readily make a sharp bend. Do not wipe with a tack cloth.

Mixing

Add Fiberglass Hawaii MEKP catalyst to resin using the guide below.

Note: Air temperature will affect catalyst level. It is always recommended to check gel times before adding catalyst to large amounts of resin. Resin will react faster when left in a large mass.

Application

To avoid waste, mix only the volume of resin that can be applied in 10-15 minutes. Using a brush or squeegee, apply resin to surface. After fabric is thoroughly saturated use resin roller or squeegee to remove wrinkles, air bubbles, and any excess resin.

Sanding

This material will remain tacky and is not formulated to be sanded. To sand surface you must apply Fiberglass Hawaii Surfboard Sanding resin after all laminating is completed. This allows the laminate to be sanded smooth and prepared for finish coating or painting.

Clean-Up

Use Fiberglass Hawaii Acetone for clean up of tools and equipment. Wash hands thoroughly after using with soap and water only.

% OF CATALYST TEMPERATURE	OUNCE of Resin	QUART of Resin	GALLON of Resin
1.0% 80 +	10 drops per ounce	9 cc 0.04 oz.	37 cc 1.4 oz.
1.5% 70 – 80 F	15 drops per ounce	14 cc 0.54 oz.	56 cc 2.2 oz.
2.0% 60 – 70 F	20 drops per ounce	18 cc 0.72 oz.	75 cc 2.9 oz.

Fiberglass Hawaii

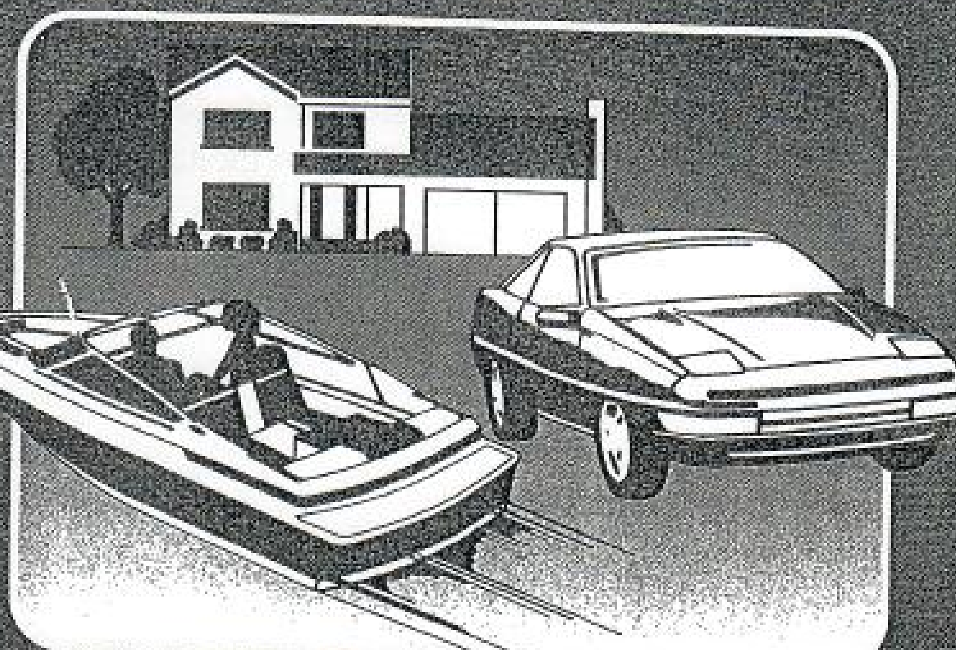
MEK PEROXIDE
CATALYST

WARNING FLAMMABLE
HARMFUL IF SWALLOWED
SEVERE EYE IRRITANT
SEE BACK PANEL

½ FL. OZ.

EVERCOAT® 100561

Laminating Resin



Remains tacky to hold fiberglass fabric in place on vertical surfaces. Low viscosity for fast glass wet-out. Non-thixed and non-waxed.

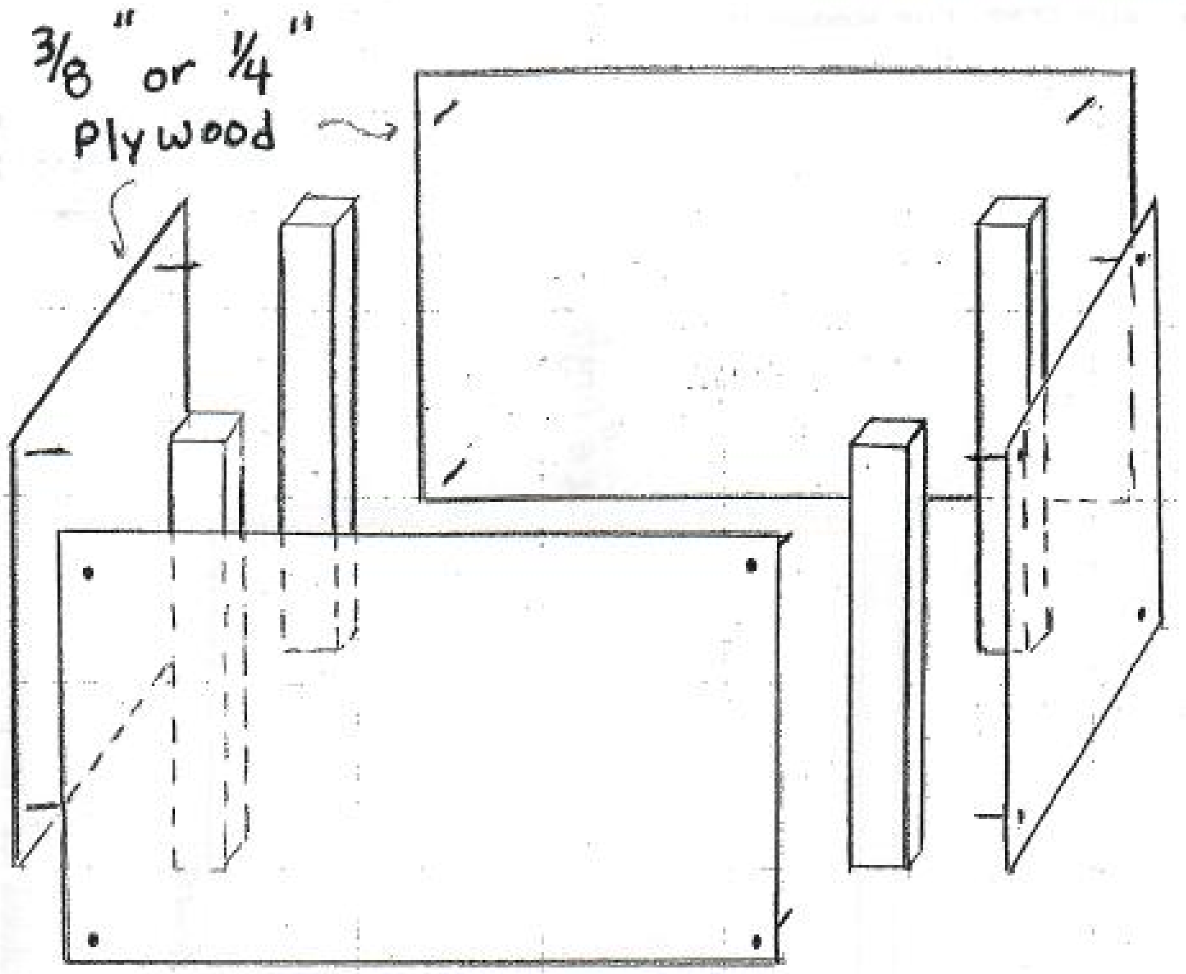
DANGER! FLAMMABLE LIQUID AND VAPOR. HARMFUL OR FATAL IF SWALLOWED. This kit contains: Styrene and Methyl Ethyl Ketone Peroxide. Read cautions on individual containers carefully. Keep out of reach of children.

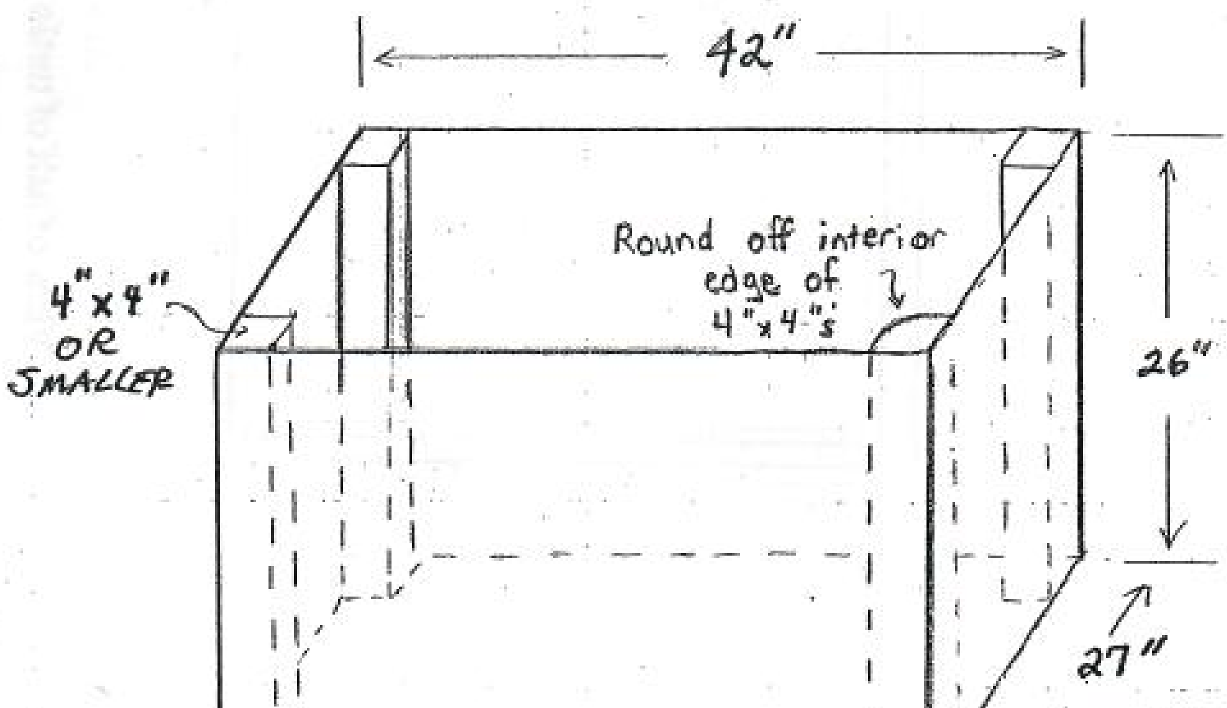
CONTENTS: 32 Fl. Oz. (1 Quart) .946 Liter Resin
11 cc (.37 Fl. Oz.) Liquid Hardener

APPENDIX 2. Diagrams for constructing a sea turtle holding container that can be used for satellite transmitter attachment.

Important NOTE: The size of the box (length and width) will depend upon the size of nesting hawksbills in your area. The dimensions shown in the following diagrams are for a medium-sized adult hawksbill. The width of the box must be narrow enough to prevent the turtle from being able to turn around.

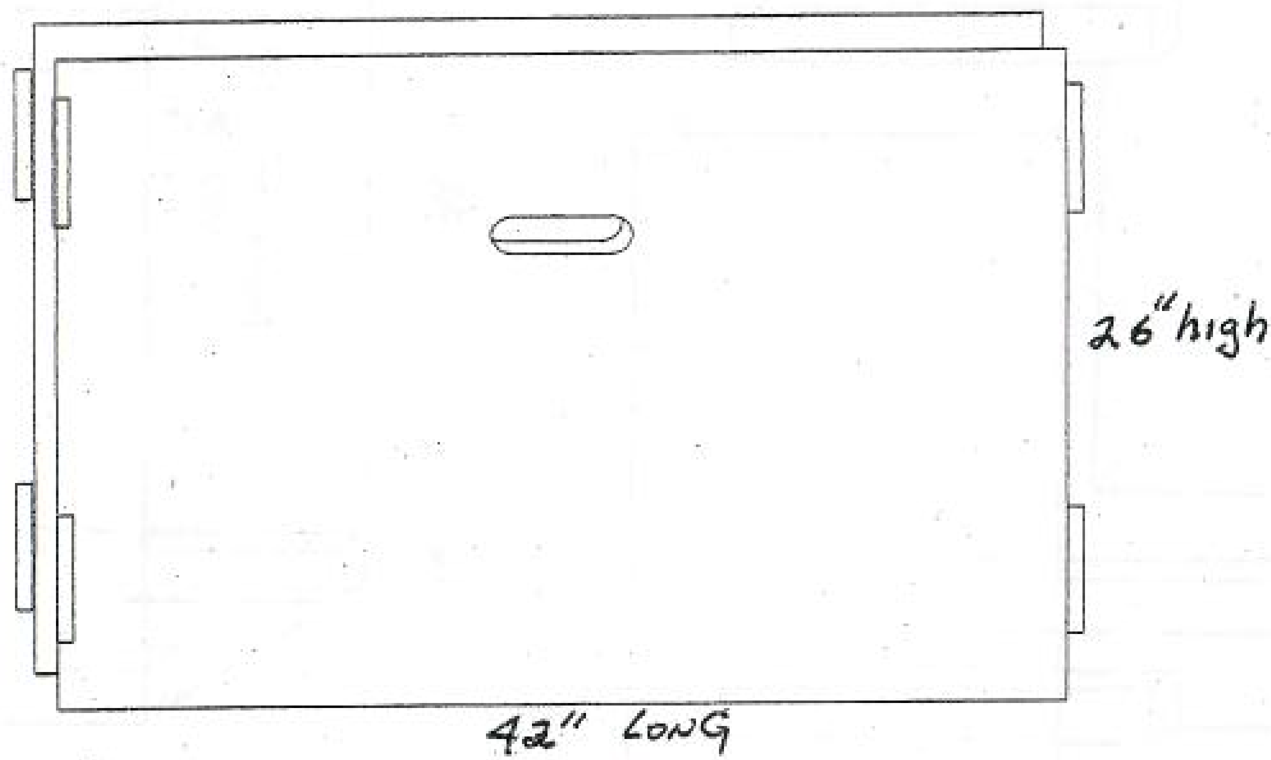
Carpet or thick cloth should be stapled to the interior surfaces of the container to prevent abrasion to the turtle.





Marine Turtle Research
NMFS HONOLULU LAB
2570 Dole Street
Honolulu, HI 96822-2396

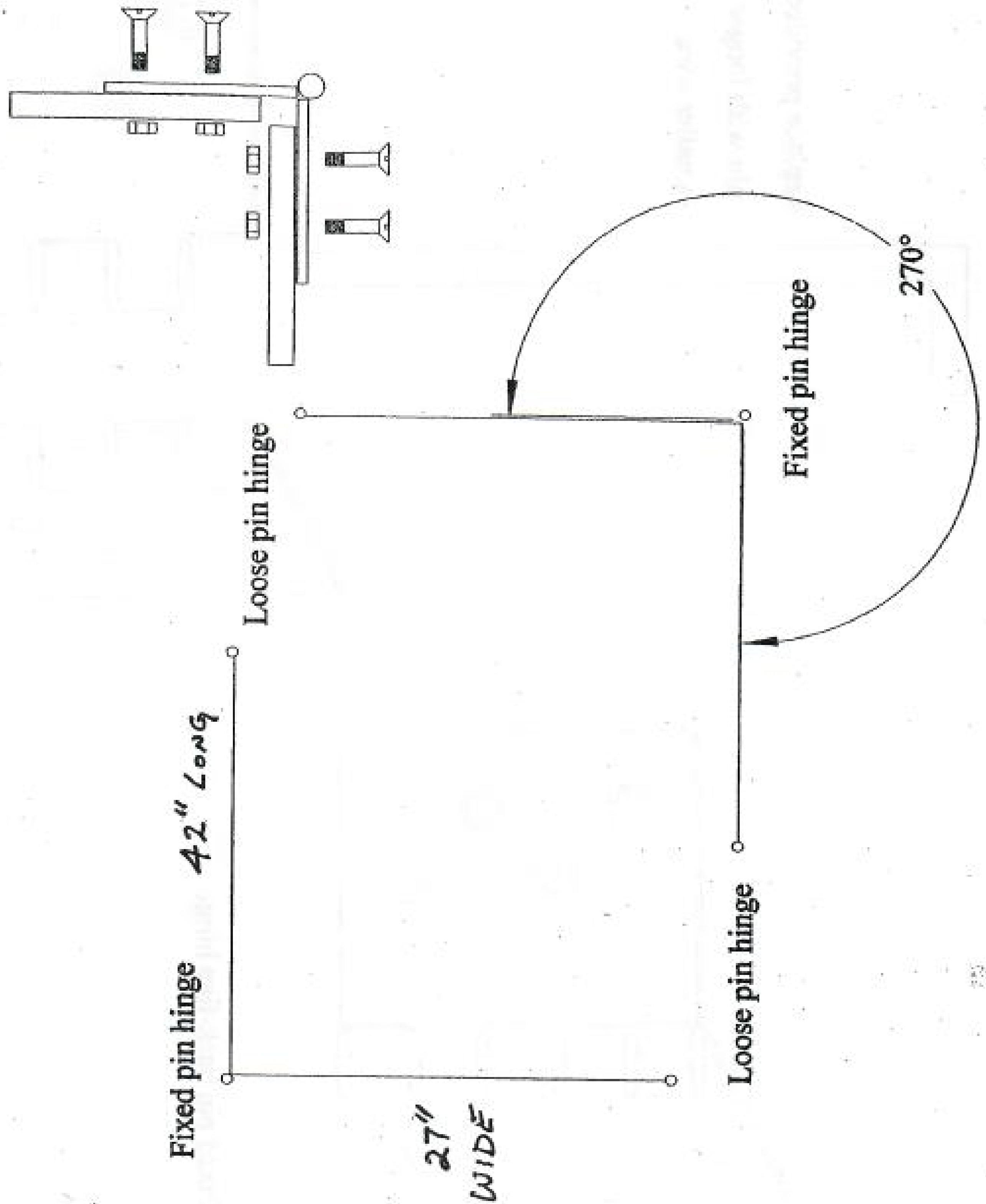
Drawing by: Shandell Eames
1997



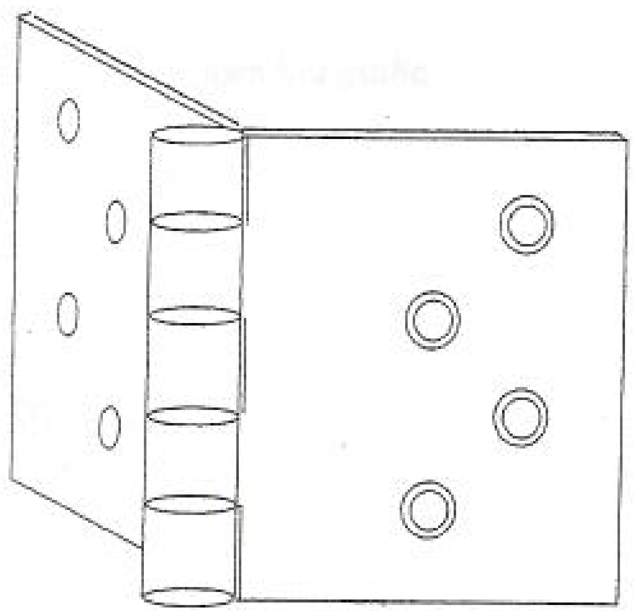
View of half of turtle corral folded for transport--

Note congruent handle holes which allow sides

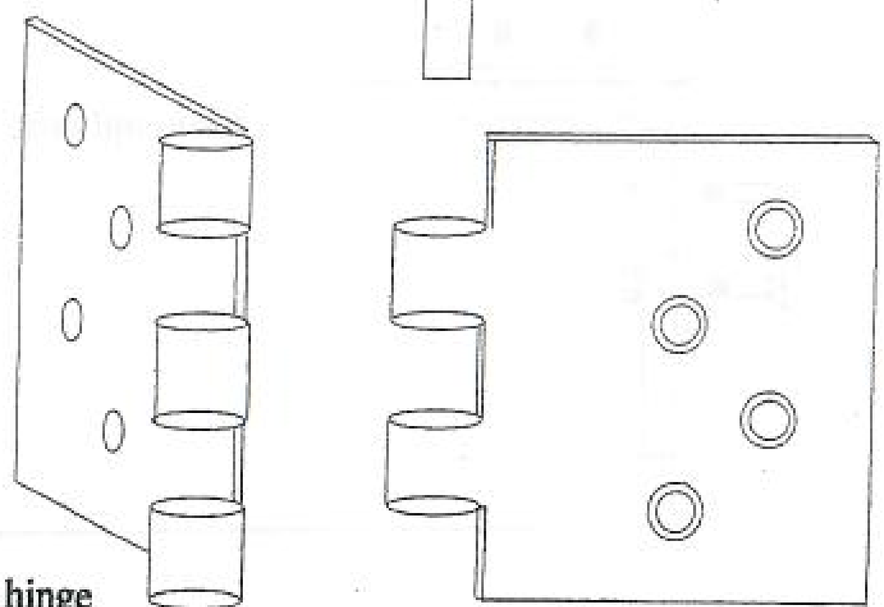
to be held closed while unit is being carried.


270°
Fixed pin hinge
Loose pin hinge
42" LONG
Fixed pin hinge
Loose pin hinge
27" WIDE

Replace provided hinge pin with longer slightl smaller wire.



Fixed pin back-flap hinge



Loose pin backflap hinge

APPENDIX 3. Example and explanation of Argos ADS (Automatic Distribution Service) data - DIAG Format for ST14 satellite transmitter.

ID OF TRANSMITTER

LOCATION CLASS

```
24192  Date : 04.09.98 19:54:22  LC : Z  IQ : 00
  Lat1 : ???????  Lon1 : ????????  Lat2 : ???????  Lon2 : ????????
  Nb mes : 001  Nb mes>-120dB : 000  Best level : -133 dB
  Pass duration : ?  s   NOPC : ?
  Calcul freq : 401 650000.0 Hz   Altitude :    0 m
       164          828          155          68
        00           00
24192  Date : 05.09.98 13:46:17  LC : 0  IQ : 58
  Lat1 : 23.844N  Lon1 : 166.225W  Lat2 : 21.013N  Lon2 : 153.702W
  Nb mes : 004  Nb mes>-120dB : 000  Best level : -129 dB
  Pass duration : 632s   NOPC : 4
  Calcul freq : 401 650018.4 Hz   Altitude :    0 m
       162          260          224          92
        00           00
24192  Date : 05.09.98 15:26:31  LC : 2  IQ : 68
  Lat1 : 23.791N  Lon1 : 166.218W  Lat2 : 31.797N  Lon2 : 157.945E
  Nb mes : 004  Nb mes>-120dB : 000  Best level : -130 dB
  Pass duration : 362s   NOPC : 4
  Calcul freq : 401 650006.6 Hz   Altitude :    0 m
       161           08          224          92
        00           02
24192  Date : 05.09.98 16:26:18  LC : B  IQ : 00
  Lat1 : 23.763N  Lon1 : 166.339W  Lat2 : 17.928N  Lon2 : 142.356W
  Nb mes : 002  Nb mes>-120dB : 000  Best level : -128 dB
  Pass duration : 176s   NOPC : 2
  Calcul freq : 401 650018.4 Hz   Altitude :    0 m
       162          105          224          92
        00           00
24194  Date : 05.09.98 13:47:10  LC : 3  IQ : 60
  Lat1 : 23.869N  Lon1 : 166.285W  Lat2 : 21.072N  Lon2 : 153.810W
  Nb mes : 009  Nb mes>-120dB : 000  Best level : -129 dB
  Pass duration : 450s   NOPC : 3
  Calcul freq : 401 649669.2 Hz   Altitude :    0 m
       164           00           00          00
        00           00
24194  Date : 05.09.98 19:40:23  LC : Z  IQ : 00
  Lat1 : ???????  Lon1 : ????????  Lat2 : ???????  Lon2 : ????????
  Nb mes : 001  Nb mes>-120dB : 000  Best level : -133 dB
  Pass duration : ?  s   NOPC : ?
  Calcul freq : 401 650000.0 Hz   Altitude :    0 m
       170           70           00          00
        00           00
24194  Date : 06.09.98 06:06:11  LC : 0  IQ : 50
  Lat1 : 23.869N  Lon1 : 166.265W  Lat2 : 25.189N  Lon2 : 160.037W
  Nb mes : 006  Nb mes>-120dB : 000  Best level : -128 dB
  Pass duration : 584s   NOPC : 3
  Calcul freq : 401 649689.8 Hz   Altitude :    0 m
       167         2053          100         136
        00           00
25694  Date : 12.09.98 19:40:15  LC : 2  IQ : 68
  Lat1 : 22.968N  Lon1 : 164.326W  Lat2 :  0.056S  Lon2 :   0.524E
  Nb mes : 004  Nb mes>-120dB : 000  Best level : -128 dB
  Pass duration : 440s   NOPC : 4
  Calcul freq : 401 649453.9 Hz   Altitude :    0 m
       178           61          153         133
        00           16
25694  Date : 12.09.98 19:54:13  LC : 0  IQ : 56
  Lat1 : 22.970N  Lon1 : 164.317W  Lat2 : 22.707N  Lon2 : 163.181W
  Nb mes : 005  Nb mes>-120dB : 000  Best level : -126 dB
  Pass duration : 674s   NOPC : 1
  Calcul freq : 401 649453.2 Hz   Altitude :    0 m
       178          115          153         133
        00           00
```

"FAILSAFE" MODE IN EFFECT IF 03 CONSISTENTLY APPEARS HERE

NUMBER OF DIVES OVER THE PAST 12 HOURS

AVERAGE DIVE TIME FOR PAST 12 HOURS = THIS VALUE X 2 SECONDS = 224 X 2 = 448 ÷ 60 = 7.5 MINUTES

FIT THIS VALUE TO UNIQUE GRAPHIC WITH EACH ST14 TO ESTIMATE APPROX. TEMPERATURE

DURATION OF LAST DIVE = THIS VALUE X 2 SECONDS = 2053 X 2 = 4106 ÷ 60 = 68 MINUTES

```
25694  Date : 13.09.98 07:06:06  LC : Z  IQ : 10
     Lat1 : 22.743N  Lon1 : 163.528W  Lat2 : 23.918N  Lon2 : 158.024W
     Nb mes : 003  Nb mes>-120dB : 000  Best level : -123 dB
     Pass duration : 079s   NOPC : 0
     Calcul freq : 401 649450.3 Hz   Altitude :    0 m
             176           21           586         18643
              01           36
25694  Date : 13.09.98 08:55:30  LC : Z  IQ : 00
     Lat1 : ???????  Lon1 : ????????  Lat2 : ???????  Lon2 : ????????
     Nb mes : 001  Nb mes>-120dB : 000  Best level : -135 dB
     Pass duration : ?  s   NOPC : ?
     Calcul freq : 401 650000.0 Hz   Altitude :    0 m
             176           978           98          209
              00           00
25694  Date : 13.09.98 15:36:55  LC : Z  IQ : 10
     Lat1 : 32.789N  Lon1 : 150.513E  Lat2 : 22.916N  Lon2 : 163.825W
     Nb mes : 003  Nb mes>-120dB : 000  Best level : -133 dB
     Pass duration : 080s   NOPC : 0
     Calcul freq : 401 649450.3 Hz   Altitude :    0 m
             178           07           139          147
              00           00
25694  Date : 13.09.98 16:51:41  LC : 2  IQ : 60
     Lat1 : 22.885N  Lon1 : 163.873W  Lat2 : 21.514N  Lon2 : 157.560W
     Nb mes : 005  Nb mes>-120dB : 000  Best level : -130 dB
     Pass duration : 315s   NOPC : 2
     Calcul freq : 401 649456.6 Hz   Altitude :    0 m
             176           46           139          147
              00           00
25694  Date : 13.09.98 17:39:28  LC : B  IQ : 00
     Lat1 : 22.861N  Lon1 : 163.842W  Lat2 : 16.474N  Lon2 : 133.869W
     Nb mes : 002  Nb mes>-120dB : 000  Best level : -127 dB
     Pass duration : 379s   NOPC : 2
     Calcul freq : 401 649450.3 Hz   Altitude :    0 m
             177           153           139          147
              00           00
25694  Date : 13.09.98 19:19:49  LC : 3  IQ : 60
     Lat1 : 22.847N  Lon1 : 163.812W  Lat2 : 26.739N  Lon2 : 178.129E
     Nb mes : 004  Nb mes>-120dB : 000  Best level : -128 dB
     Pass duration : 679s   NOPC : 3
     Calcul freq : 401 649453.5 Hz   Altitude :    0 m
             178           40           139          147
              00           00
25694  Date : 13.09.98 19:42:19  LC : 2  IQ : 58
     Lat1 : 22.843N  Lon1 : 163.811W  Lat2 : 21.453N  Lon2 : 157.684W
     Nb mes : 011  Nb mes>-120dB : 000  Best level : -124 dB
     Pass duration : 684s   NOPC : 4
     Calcul freq : 401 649449.1 Hz   Altitude :    0 m
             181           17           139          147
              00           01
```

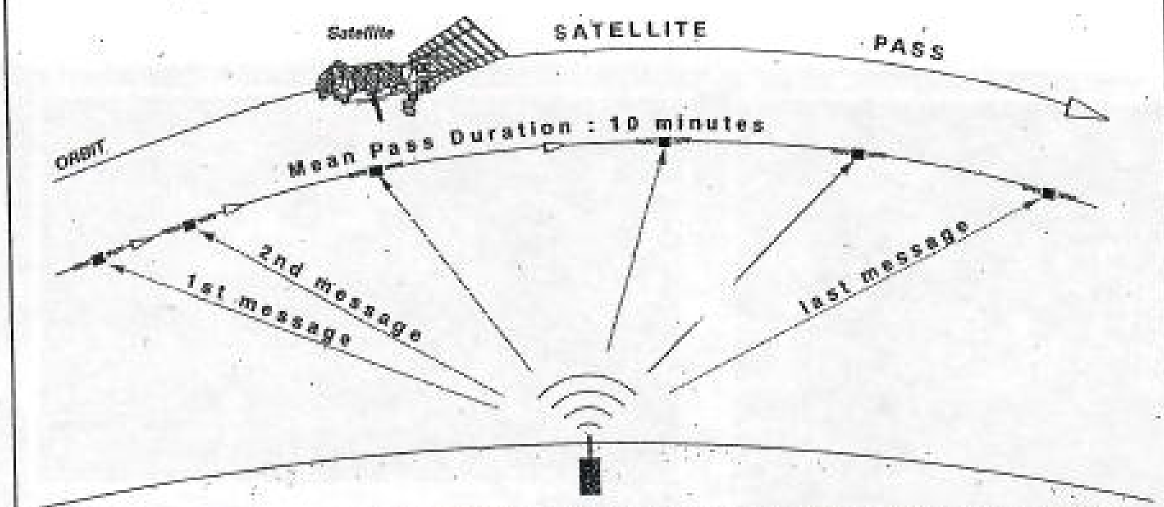
LATITUDE LONGITUDE

"USUALLY THE "Lat1" and "Lon1" are the correct positions

APPENDIX 4. Descriptive literature for the Argos global tracking system.

New Argos Location

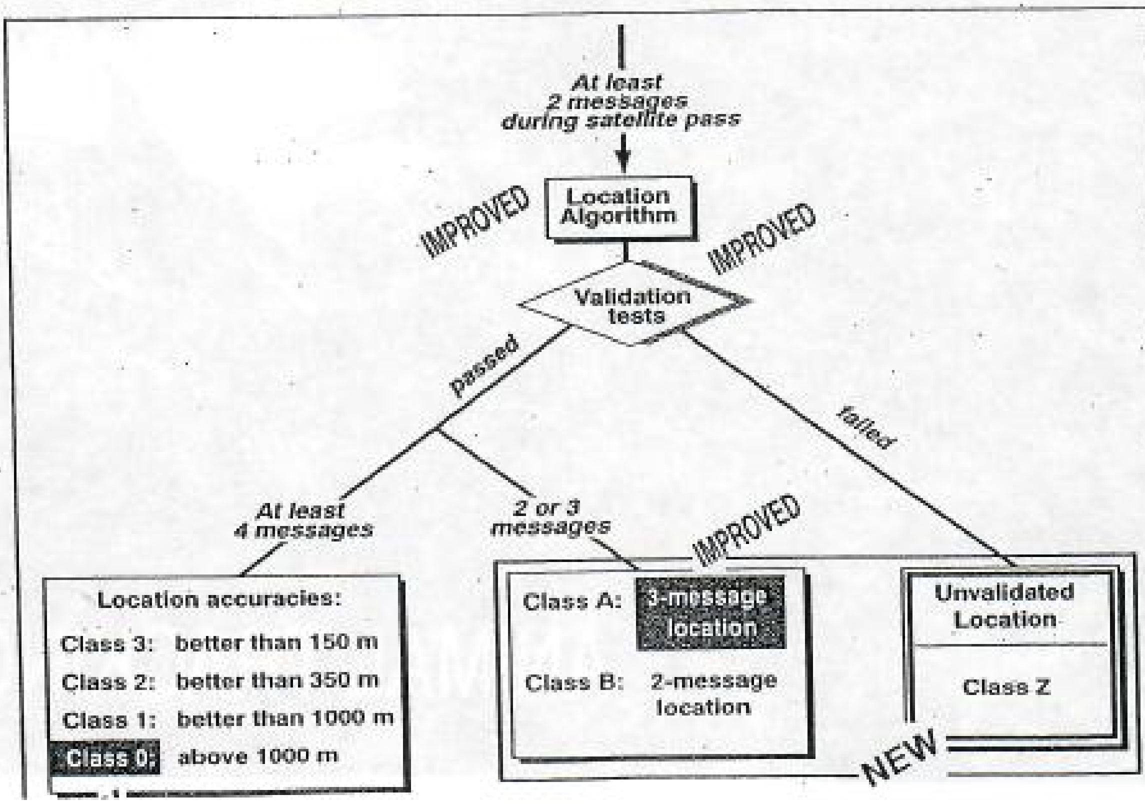
1 • What is a Message?



During a pass over a transmitter, the number of messages the satellite receives depends on:

- the pass duration
- the transmitter repetition period

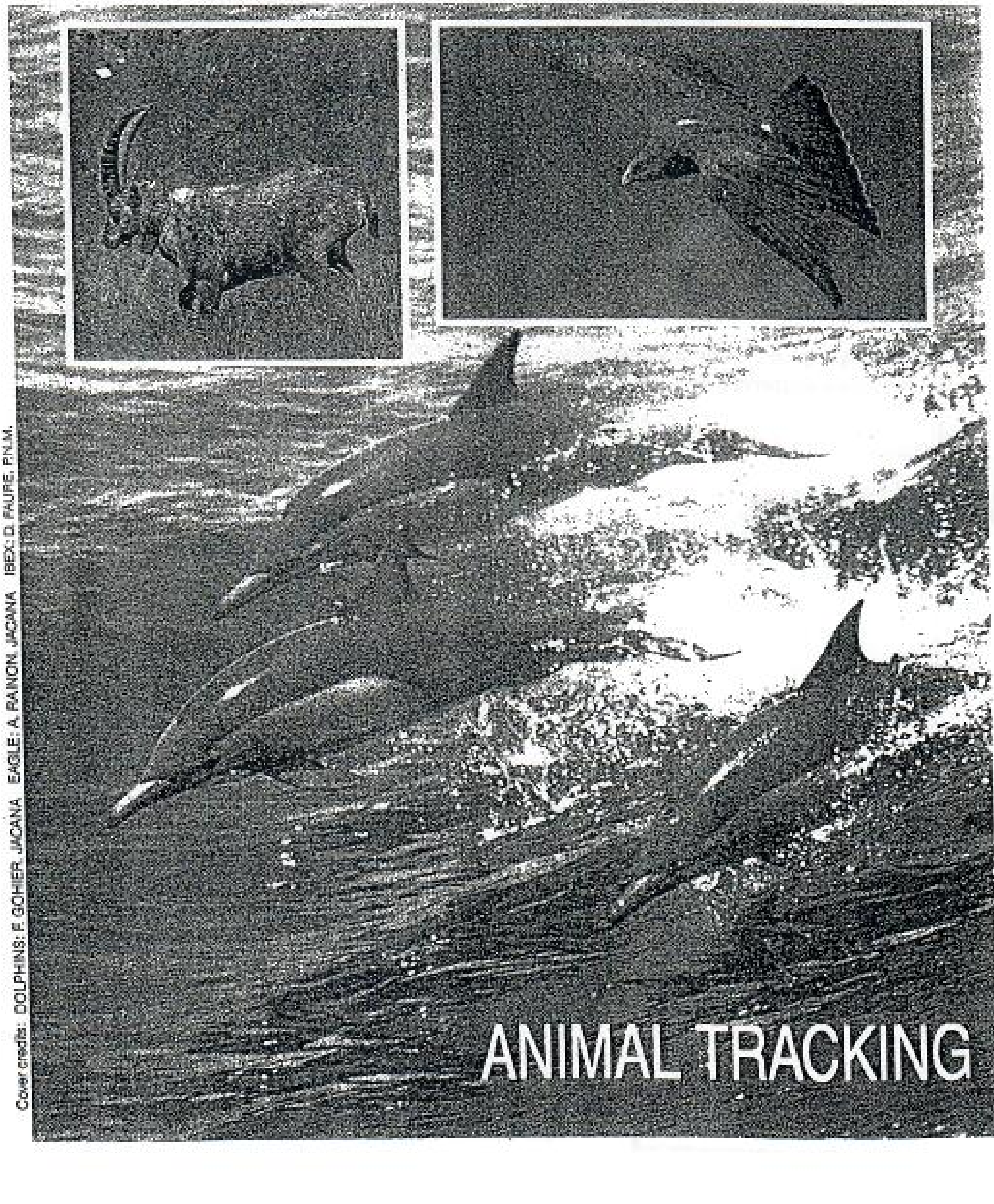
2 • What is new?



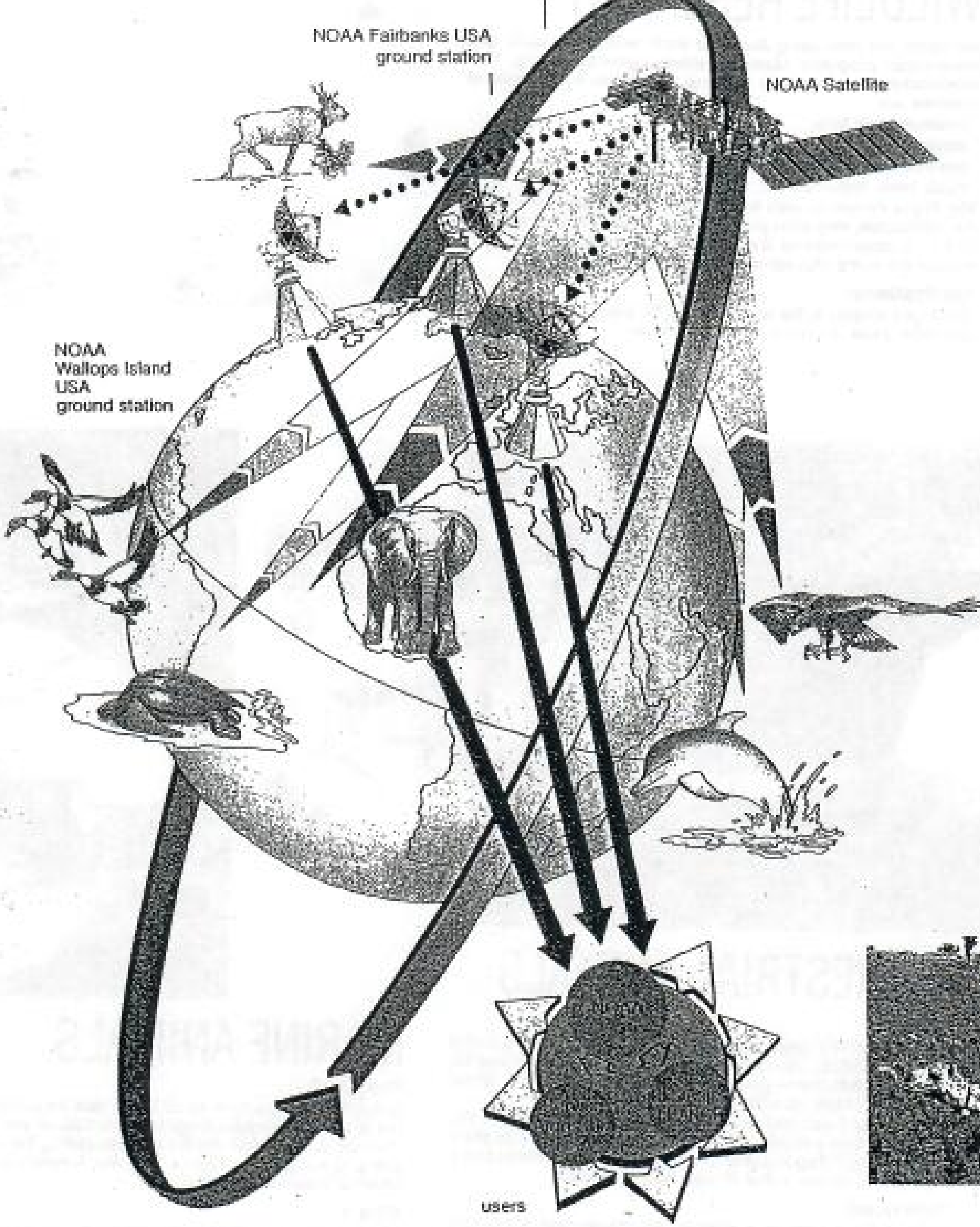
ARGOS

CLS

COLLECTE LOCALISATION SATELLITES



Cover credits: DOLPHINS: F. GOHIER, JACANA EAGLE: A. RAINON, JACANA IBEX: D. FAURE, P.N.M.



F. GOHIER JACANA

THE ARGOS SYSTEM

Argos is a satellite-based location and data collection program conducted by France and the United States. It is dedicated to environmental studies.

Proven operational system

Argos has been operational since 1978 and is scheduled to continue through 2000. During that time, at least 15 satellites will have been launched.

Worldwide coverage

Argos is carried on board National Oceanic and Atmospheric Administration (NOAA) satellites. Two are simultaneously in service on polar orbits, altitude 850 km, providing complete global coverage.

Automatic centralized location system

Platform positions are calculated several times a day and supplied to users at the Argos Global Processing Centers in Toulouse, France and Landover, MD, USA. Traditionally, the user community has consisted largely of oceanographers, meteorologists and hydrologists. But during the late 1980s and early 90s, dedicated equipment has been developed for wildlife researchers and interest has grown enormously.

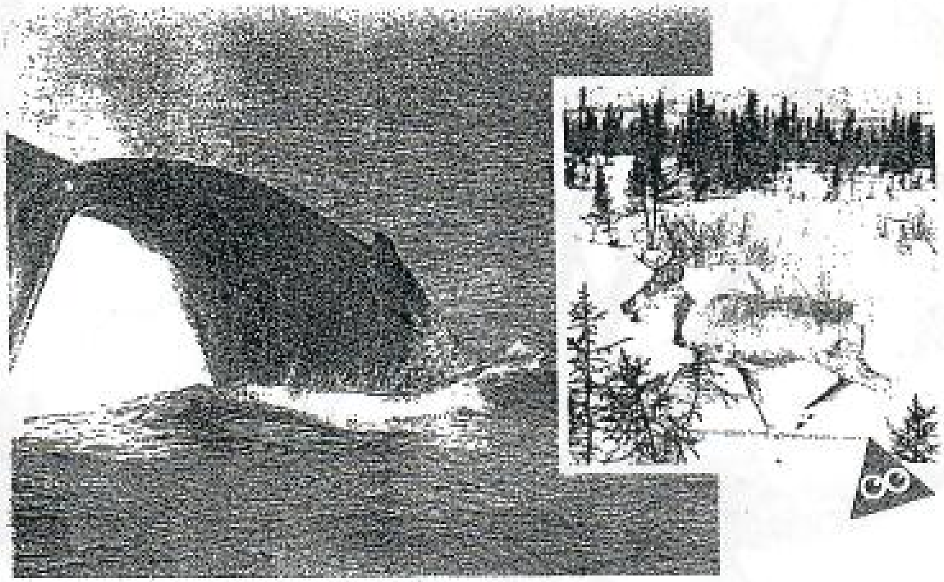
WILDLIFE RESEARCH

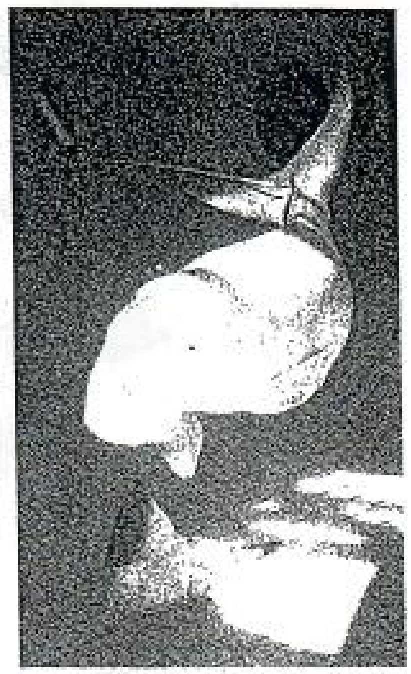
Biologists are now using Argos to track animals in study and preservation programs. Methods include sightings, ringing, VHF radiotracking, and satellite tracking. The main advantages of satellites are:
- continuity over time,
- accurate location,
- capability for remote monitoring,
- vastly lower logistics costs.

The Argos system is used to track individual animals and study the distribution, migration patterns, and vulnerability of the species to human-induced disturbances. Argos is also used to monitor the re-introduction of endangered species.

Applications

The Argos system is the essential tool for many animal tracking programs. Here are some of the main ones:





TERRESTRIAL ANIMALS

Bear

American wildlife researchers have used Argos data to define seasonal habitats, develop census techniques, and assess the size and distribution of polar bear stocks in the Beaufort, Bering and Chukchi seas, as well as Canadian grizzly bears.
Female polar bears and cubs are being tracked in Hudson's Bay during ice-free periods. Answers are being sought to many questions regarding foraging and hunting, and the distribution of their habitat relative to that of male bear predators.

Wildebeest

In Botswana, a program is studying the movements of the Kalahari wildebeest in search of water-holes. When their pathways are known, wells will be sunk to avoid the many deaths which occur in very dry years.

Caribou, Reindeer

Programs have been conducted in Alaska to study the impact of oil drilling on caribou and reindeer movements. The Canadians are studying the likely effect of installing hydro-electric reservoirs north of Quebec on the behavior of caribou herds, whose annual range stretches some 600,000 km2.

Elephant

An American program to track African forest elephant *(Loxodonta africana cyclotis)* in Korup National Park, Tanzania will yield invaluable information on spatial use in the park, the elephants' social activity, and conflicts with local villagers.

Deer

Under a program to enhance areas abandoned by farming and encourage extensive breeding, the Argos system will be used to track tame deer and help understand what makes them migrate.

MARINE ANIMALS

Penguins

Scientific institutes have used Argos mini-transmitters in a number of penguin tracking programs. Australians and New Zealanders are studying the Adelie penguin during the breeding season and winter. The French and the Americans are studying emperor penguin's behavior.

Whale

Right whales and humpback whales are being studied during the migrations from the Bay of Fundy in Canada to Florida. In this program, biologists are both tracking the animals and studying their physiology. Norwegians are studying the migration of minke whales in the North Atlantic.

Seal, Sea-lion

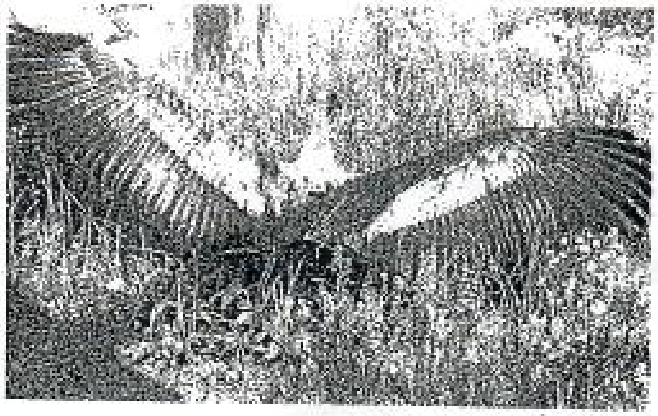
The Argos system is being used to study the lifestyle of a small seal population *(Phoca hispida saimensis)* in the Lake Saimaa region of Finland. The Japanese are investigating seal migrations and the impact of deep sea fishing on seals. The Americans are also studying the behavior of a number of the northern sea-lion and other pinnipeds.

Manatee, Dugong

Since 1984, a proven tagging method has contributed significantly to the fight to save manatees and dugongs.

Turtle

Argos turtle-tracking programs are complementing conventional tagging techniques. Argos is being used to collect data on behavior during diving, migratory pathways, and the preferred water masses of leatherback turtles *(Dermochelys coriacea agassizi)*.



BIRDS

Bird tracking programs have been among those to benefit the most from the development of dedicated mini-Argos transmitters. Ornithologists have studied the migrations of many species including Bewick swans *(Cygnus columbianus)*, Brent geese *(Branta bernicla)*, and white storks *(Ciconia ciconia)*. Studies are conducted on Jabiru stork populations in central Brazil. In Saudi Arabia, Argos is being used to aid the re-introduction of Houbara bustards *(Chlamydotis undulata)*. Swiss researchers are studying the behavior of the royal eagle in the Alps.

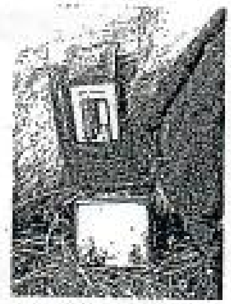
ARGOS TRANSMITTERS

Thousands of Argos transmitters around the world have demonstrated their efficiency and reliability. Dedicated models have been developed with the following features:

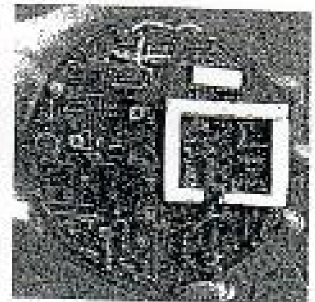
• Capability to withstand harsh environments
The transmitter is treated harshly. Often, it must be watertight, seawater-resistant, pressure-resistant (whale and turtle tags must withstand several hundred hectopascals), shock-resistant, and so on.

• Matching to animal
To avoid interfering with natural behavior patterns, the transmitter weight must not exceed 3 to 5% of the animal's. Models weighing as little as 45 g are now available. The shape and size of the transmitter packaging must be aerodynamically or hydrodynamically compatible with the animal, and must not disturb its temperature regulation system. Attachment systems include harnesses, collars, floats, bonding and darting.

• Transmitter power supply
Several operational long-duration power supply systems have been developed, including:
- batteries with favorable capacity/weight tradeoff, e.g. lithium type,
- solar cells with cadmium-nickel batteries,
- duty cycles using a timer which switches on the transmitter at fixed intervals, e.g. one day in two, or seawater switches which turn the transmitter off when the animal is diving.



Terrestrial mammal PTT



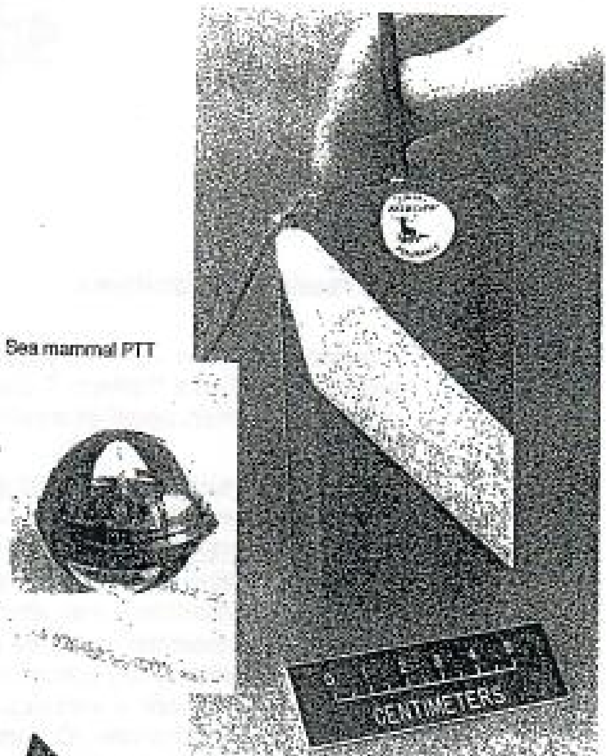
Bird PTT

COST OF USING THE ARGOS SYSTEM

The Argos system is far less expensive than conventional VHF radiotracking and visual sighting. The great advantage for wildlife researchers is that you do not need any capital infrastructure and will avoid the usual heavy logistics burden.

CLS AND ANIMAL TRACKING

As well as operating the Argos system, CLS can provide you with information on the current market offerings, or supply suitable models.
Also note that CLS has developed a user-friendly PC program, ELSArgos, by which you can connect into the Argos center, and download and display your platform locations on customized maps.



Sea mammal PTT

Terrestrial mammal PTT

We have plenty more information. Please ask !

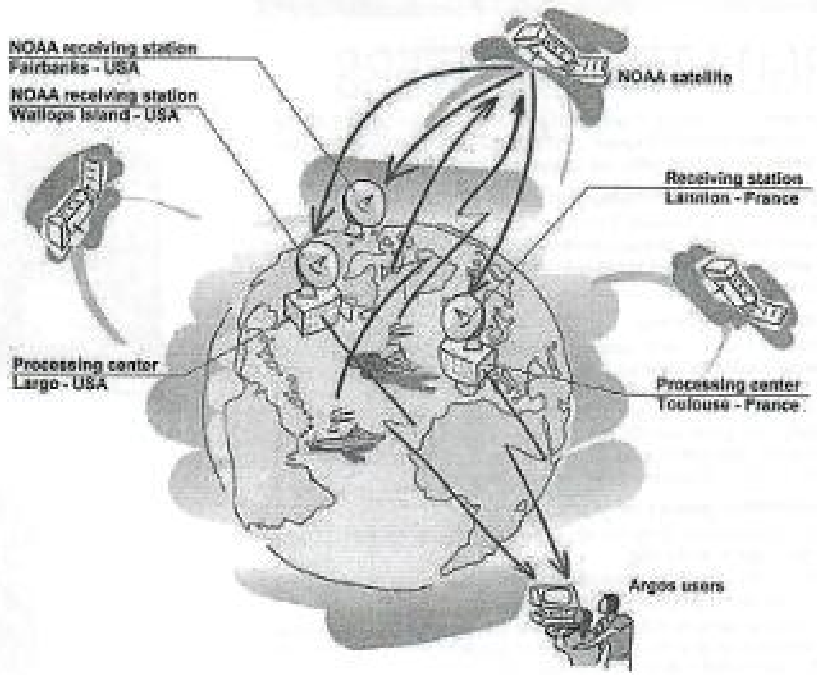
C.L.S./Service Argos
18, avenue Edouard Belin
31055 Toulouse CEDEX
France
Tel. : (+33) 61 39 47 00
Telex : 531 752 F
Fax : (+33) 61 75 10 14

NACLS
9200 Basil Court, Suite 306,
Landover, MD 20785
USA
Tel. : (301) 341 18 14
Fax : (301) 341 21 30

Service Argos Inc.
Suite 10, 1801 Mc Cormick Drive
Landover MD 20785
USA
Tel. : (301) 925 44 11
Telex : 898 146
Fax : (301) 925 89 95

Service Argos Inc.
2150 N. 107* Suite 345
Seattle, WA 98133
USA
Tel. : (206) 367 94 77
Fax : (206) 367 96 24

Appendix 1: Argos system segments



1. Users' transmitters

A transmitter is any station equipped for transmission via the Argos system. Each transmitter, sometimes called a Platform Transmitter Terminal, or PTT, has an individual identification number. The main signal characteristics are:

- Transmit frequency: 401.650 MHz ± 4 kHz. This must remain stable, as the Argos location calculation is based on measurements of the Doppler effect on the signal (see Appendix 2: Argos location).
- Repetition period, assigned by Service Argos according to the application; for example data collection transmitters are assigned periods over 200 seconds.
- The transmitter message includes:
  - a preliminary synchronization sequence,
  - statement of message length, which can be 32 to 256 bits,
  - the transmitter ID number,
  - the sensor data or other message data, 32 to 256 bits.

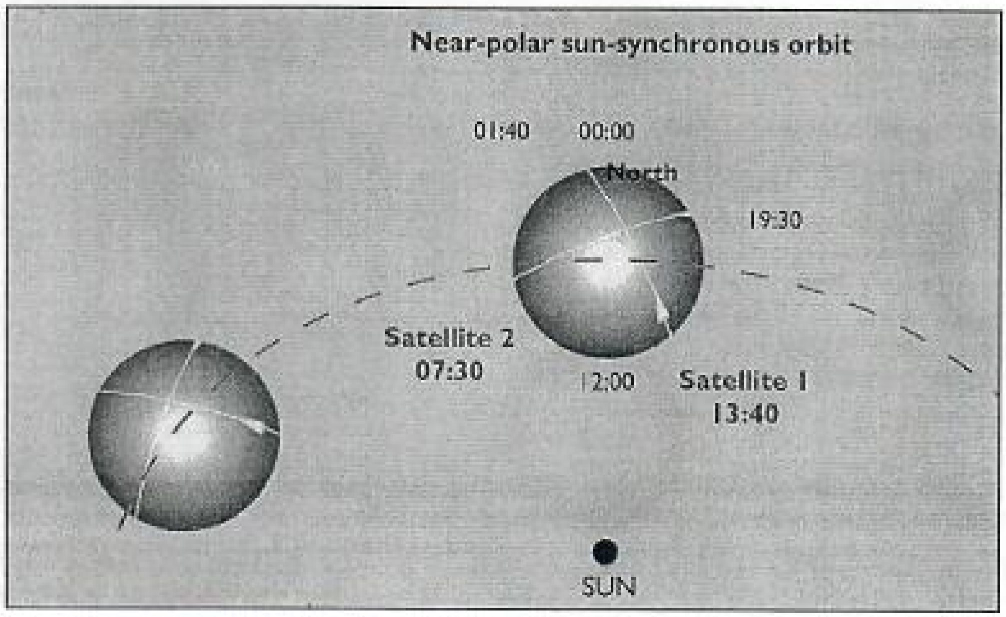
Each message lasts 360 to 920 milliseconds, according to the number of message bits.

2. Satellites

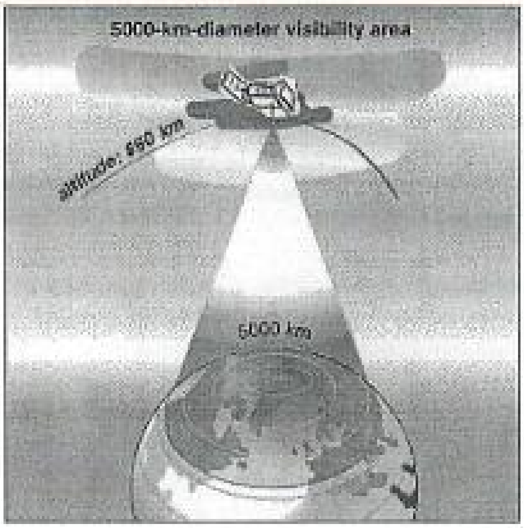
The Argos instruments are flown on board the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES). At least two satellites are operational at any time. Launches are scheduled through 2010. From around the turn of the century Argos instruments will also be flown on satellites operated by the Japanese space agency NASDA and the European Meteorological Satellite organization, Eumetsat.

The satellites receive the Argos messages from users' transmitters and relay them to ground in real time. They also store them on tape recorders and read out ("dump") the messages every time they pass over one of the three main system ground stations:

- Wallops Island, Virginia, USA
- Fairbanks, Alaska, USA,
- Lannion, France.

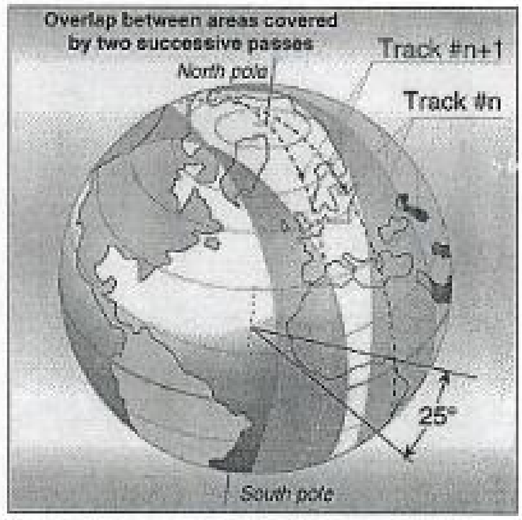


The POES satellites see the North and South Poles on each orbital revolution. Their orbital planes rotate about the polar axis at the same rate as the Earth about the Sun, or one complete revolution per year. Each orbital revolution transects the equatorial plane at fixed local solar times. Therefore, each satellite passes within visibility of any given transmitter at almost the same local time each day. The time taken to complete a revolution around the Earth is approximately 100 minutes.



At any given time, each satellite simultaneously "sees" all transmitters within an approximate 5000-kilometer-diameter "footprint", or visibility circle. As the satellite proceeds in orbit, the visibility circle sweeps a 5000 kilometer swath around the Earth, covering both poles.

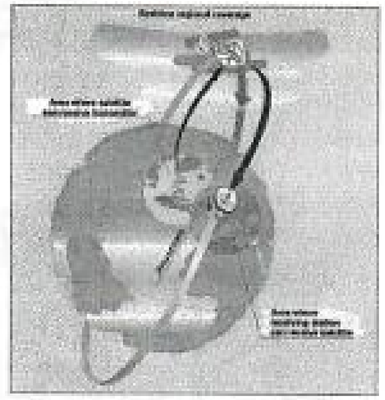
Due to the Earth's rotation, the swath shifts 25° west (2800 km at the Equator) about the polar axis on each revolution. This results in overlap between successive swaths (see below). Since overlap increases with latitude, the number of daily passes over a transmitter also increases with latitude. At the poles, the satellites see each transmitter on every pass, a total of roughly 28 times a day for two satellites.



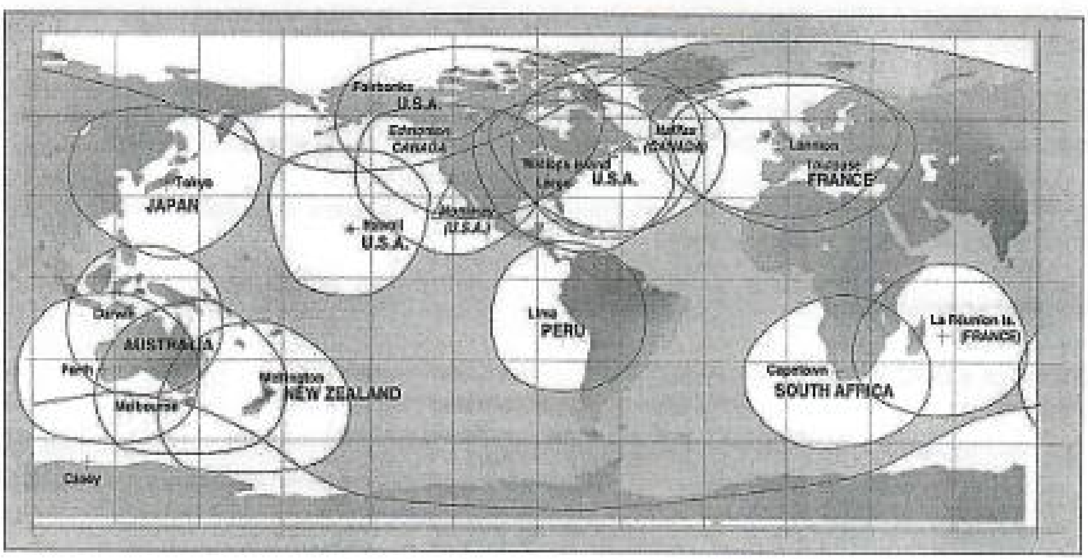
The duration of transmitter visibility by the satellite (or of the pass duration over the transmitter) is the "window" during which the satellite can receive messages from the transmitter. It lasts about up to 14 minutes (10 minutes on average).

3. Receiving stations

The three main ground stations receive all messages recorded by the satellite during a complete orbital revolution, providing complete global coverage. The stations are at Wallops Island, Virginia, USA; Fairbanks, Alaska, USA; and Lannion, France. Regional receiving stations receive transmitter data from the satellites in real time whenever the satellite is within station visibility. The main ground stations also serve as regional receiving stations.



Regional receiving stations operate in Largo, Hawaii and Monterey in the USA; Halifax and Edmonton in Canada; Toulouse in France; Casey in Antarctica; Cape Town in South Africa; Tokyo in Japan; Darwin, Melbourne and Perth in Australia; Wellington in New Zealand; Reunion Island (FR); Lima in Peru. More regional stations are planned.

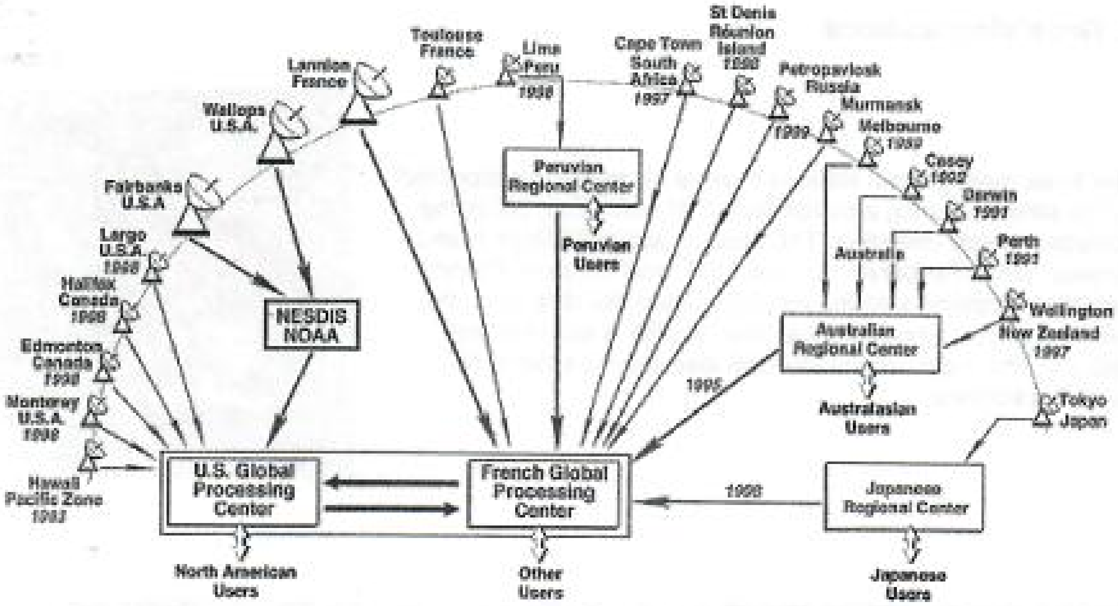


4. Processing centers

Processing centers receive raw Argos data extracted from the satellite datasets relayed by the ground stations. They then locate the transmitters and process the sensor data.

Global centers

The Global Processing Centers (GPCs) in Largo, MD, USA and Toulouse, France process all data received from the receiving stations. They archive all the results and make them available to users on line. Each center can back up the other in the event of a failure.



Regional centers

Regional Processing Centers (RPCs) provide users in a region with local access to results. For example, Japanese users can connect to the Argos RPC in Tokyo to download locations and sensor data from transmitters around the world.

The RPCs are connected to one or more regional receiving stations. This means they can process data received in real time from transmitters in visibility of the receiving stations.

Each RPC is also connected to a GPC so that it can provide its users with global coverage, i.e. data received in other parts of the world.

Telemetry acquisition

The work of a GPC includes:

- quality control, including checking of message time-tagging, signal level, transmitter ID number, length of sensor data message, and the receive frequency for use in the Doppler location calculation.
- time-tagging in Coordinated Universal Time (UTC).
- message classification by transmitter, in chronological order.

Location

See Appendix 2: Argos location.

Sensor data processing

The data from each sensor on a given transmitter is processed separately from the other sensors. Users can therefore choose different processing options.

The Argos processing centers offer two types of processing:

- **type A**, which outputs the raw sensor data as numerical values,
- **type B**, which converts raw sensor data into physical values using a different calibration curve for each sensor.

Appendix 2: Argos location

1. Overview

Your transmitters can be located in two independant ways:

- Conventional Argos location. Transmitter positions are calculated by measuring the doppler effect on the transmission frequencies.
- Global Positioning System (GPS) location. On request, a dedicated processing module extracts GPS positions from Argos data collection messages, validates them, and makes them available int the same format as Argos positions.

The latitudes and longitudes of the Argos and GPS positions are expressed in degrees and thousandths of a degree. The reference system is the World Geodetic System (WGS 84).

2. Argos location

Introduction

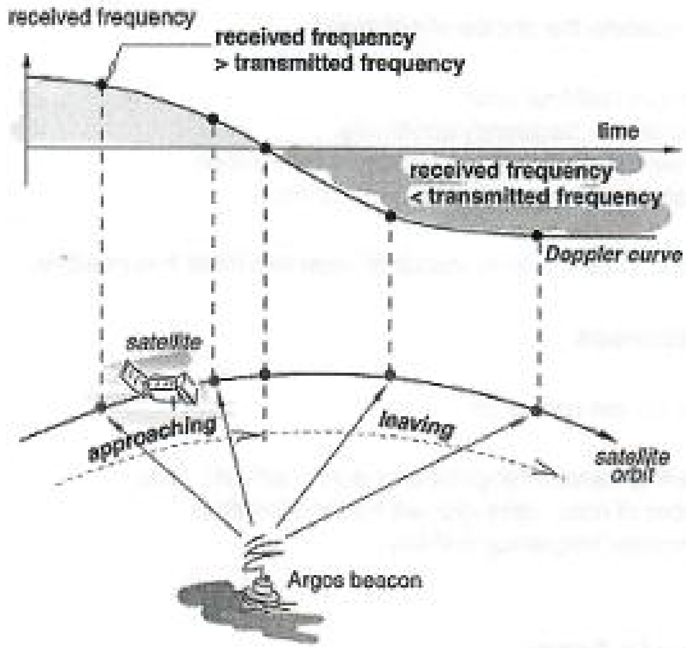
Locations are calculated from all messages received during a satellite pass over a transmitter. Various calculations are done, according to your request:

- Standard locations are calculated on reception of four or more messages.
- Users who have requested Location Service Plus (Auxiliary Location Processing in North America) also receive locations calculated from two or three messages. This service was developped to increase the number of locations for transmitters sending weak signals, or at irregular times, or in difficult environments such as steep-sided valleys. Typical users are animal trackers operating miniaturized transmitters.

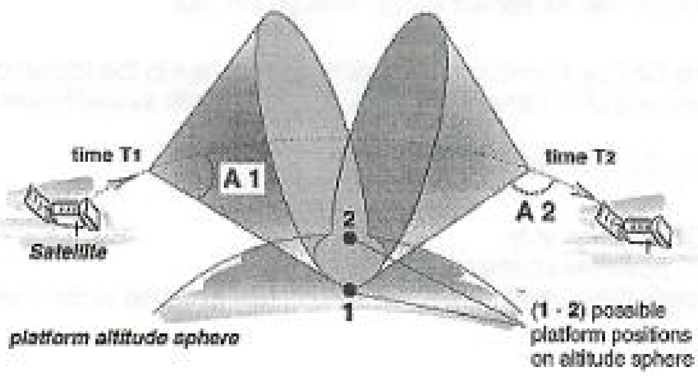
Each location is assigned to a location class. The classes vary according to the estimated accuracy of the location, for standard locations, or the number of messages received, for Location Service Plus / Auxillary Location Processing.

How the locations are calculated

Argos locations are calculated by measuring the Doppler shift on the transmitter signals. This is the change in frequency of a sound wave or electromagnetic wave when a source of transmission and an observer are in motion relative to each other. The classic case is when an observer notices a change in the sound when a train approaches and moves away. Similarly, when the satellite "approaches" a transmitter, the frequency of the transmitted signal measured by the onboard receiver is higher than the actual transmit frequency and lower when it moves away.



Each time the satellite instrument receives a message from a transmitter, it measures the frequency and time-tags the arrival. The Argos processing center computes the locus of possible positions for the transmitter, a cone defined by:
- a vertex at the position of the satellite when it received the message
- the angle at the vertex, a function of the difference between the frequency measured on board the satellite and the transmitter frequency.



The processing center calculates an initial estimate of the transmitter's position from the first and last messages collected during the pass and the most recent calculated frequency. The intersection of the cones for these two messages with the terrestrial radius + the height declared for the transmitter (altitude sphere) gives two possible positions.

For each position, least-squares analysis is used on the equations to refine the estimate of the transmitter's position and transmit frequency. The position with the better frequency continuity is chosen, and its plausibility checked.

Plausibility tests

Four checks validate the choice of solution:

- minimum residual error,
- transmission frequency continuity,
- shortest distance covered since latest location,
- plausibility of velocity between locations.

For the location to be made available at least two must test positive.

Location classes

Location classes are based on:

- satttellite/transmitter geometry during satellite pass,
- number of messages received during the pass,
- transmitter frequency stability.

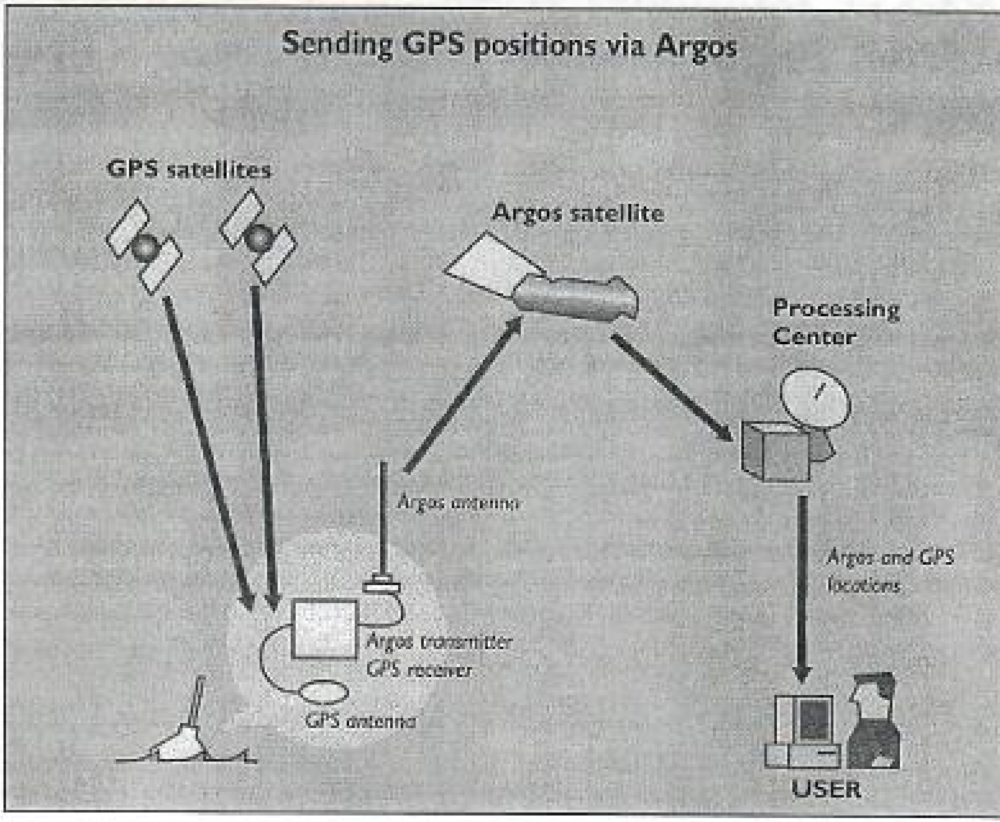
3. GPS positions via Argos

The advantages of sending GPS positions via the Argos system are that:

- having two location systems is more reliable than just one,
- GPS positions can be generated as often as you want,
- accuracy is higher (within 100 meters) and does not depend on the transmitter quality,
- positions can be spread evenly through the day.

Providing the GPS positions in the Argos messages are in the format defined by CLS, they are output in latitude and longitude, and made available just like Argos locations.
Various Argos/GPS formats are available:

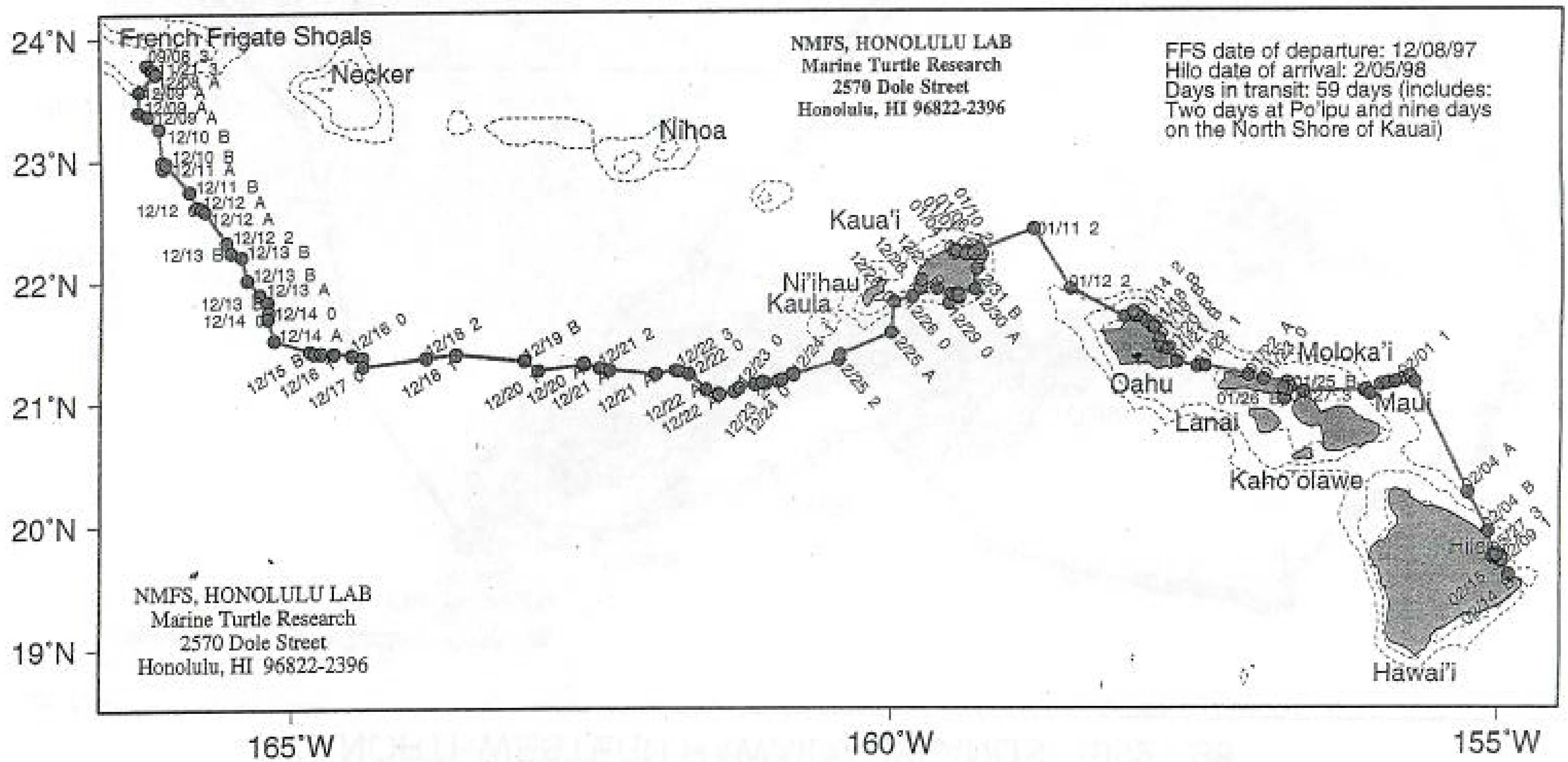
- GPS positions only,
- GPS positions interlaced with sensor data,
- a single GPS position with the sensor data acquired at the same time.



Sending GPS positions via Argos
GPS satellites
Argos satellite
Processing
Center
Argos antenna
Argos and GPS
locations
Argos transmitter
GPS receiver
GPS antenna
USER

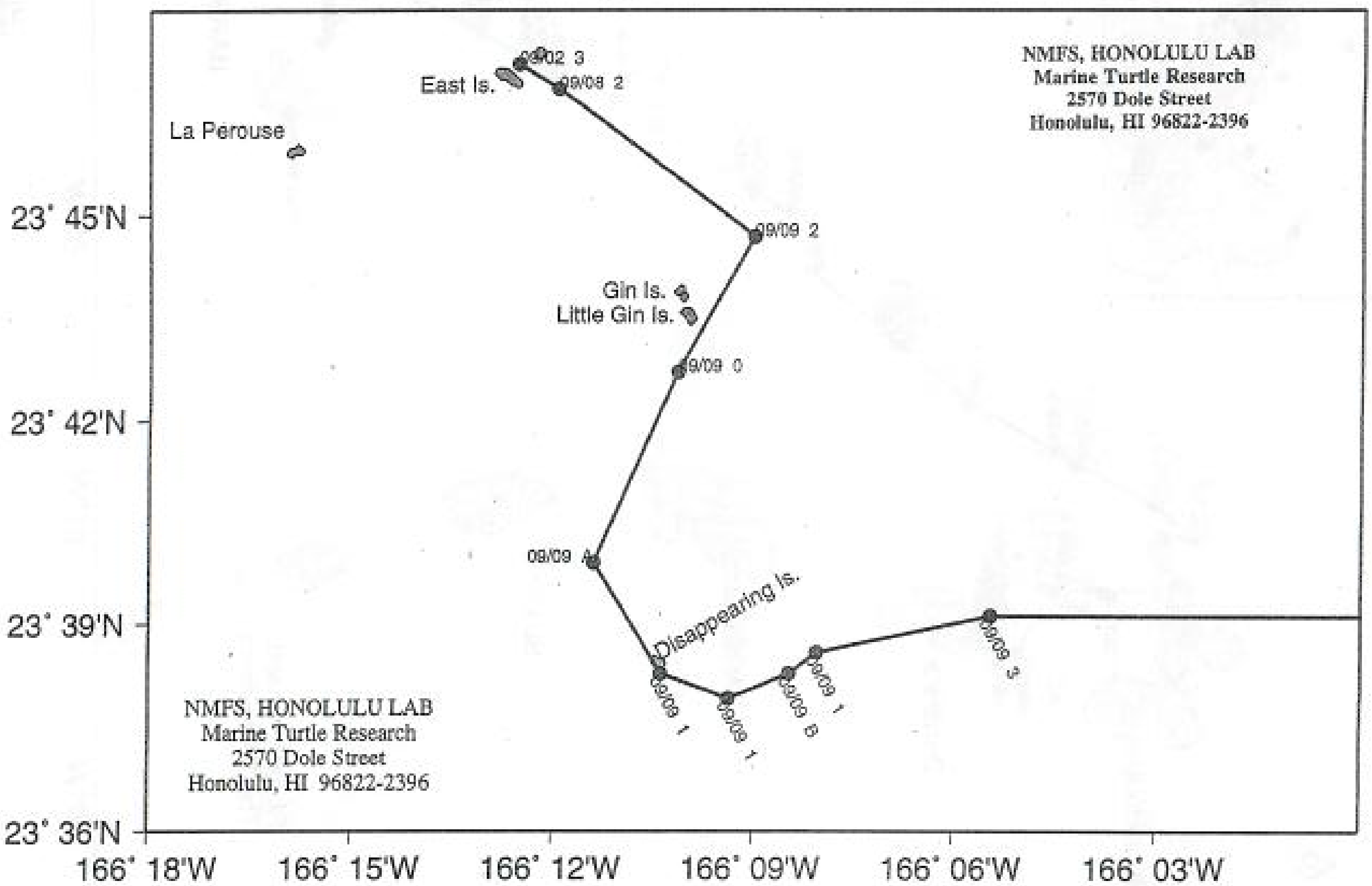
APPENDIX 5. Examples of sea turtle migration maps obtained from Argos satellite tracking using ST14 transmitters.

1997-98 Post-nesting migration of green turtle 24196 from French Frigate Shoals to the Main Hawaiian Islands



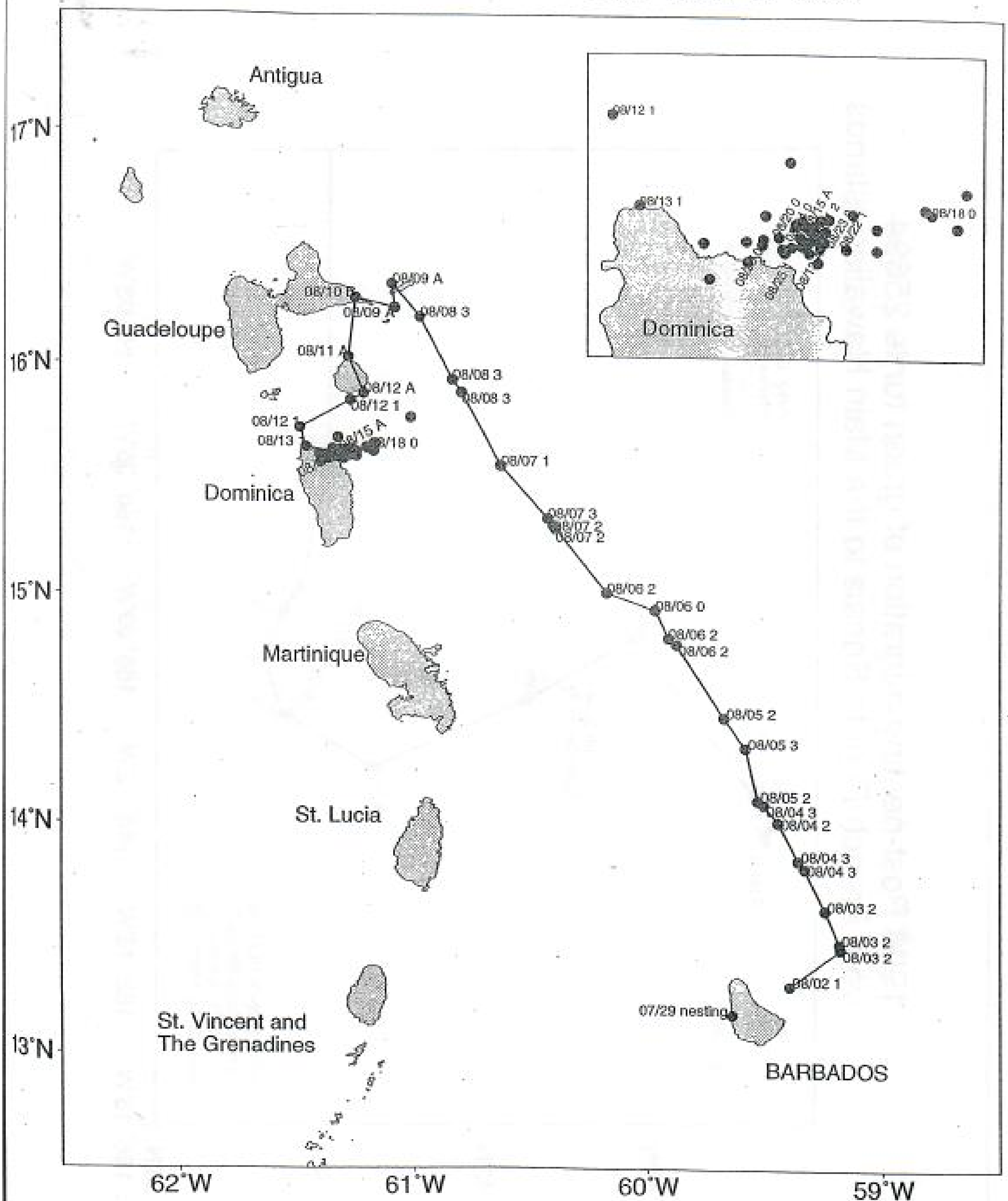
GMT map created by Denise Ellis 09/11/98

1998 Post-nesting migration of green turtle 25694 from French Frigate Shoals to the Main Hawaiian Islands



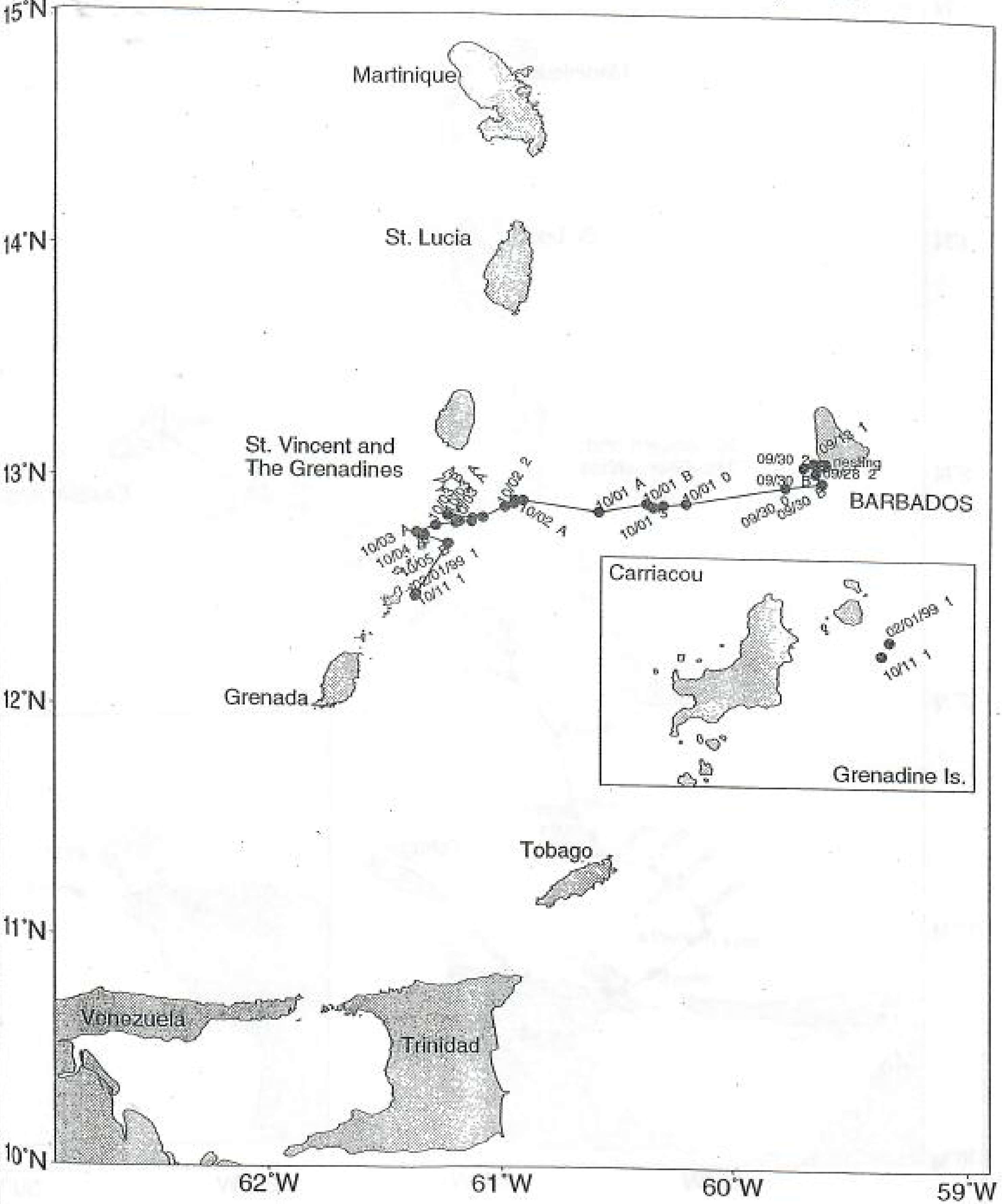
GMT map created by Denise Ellis 09/11/98

Barbados Hawksbill "Julia" #8179, 1998



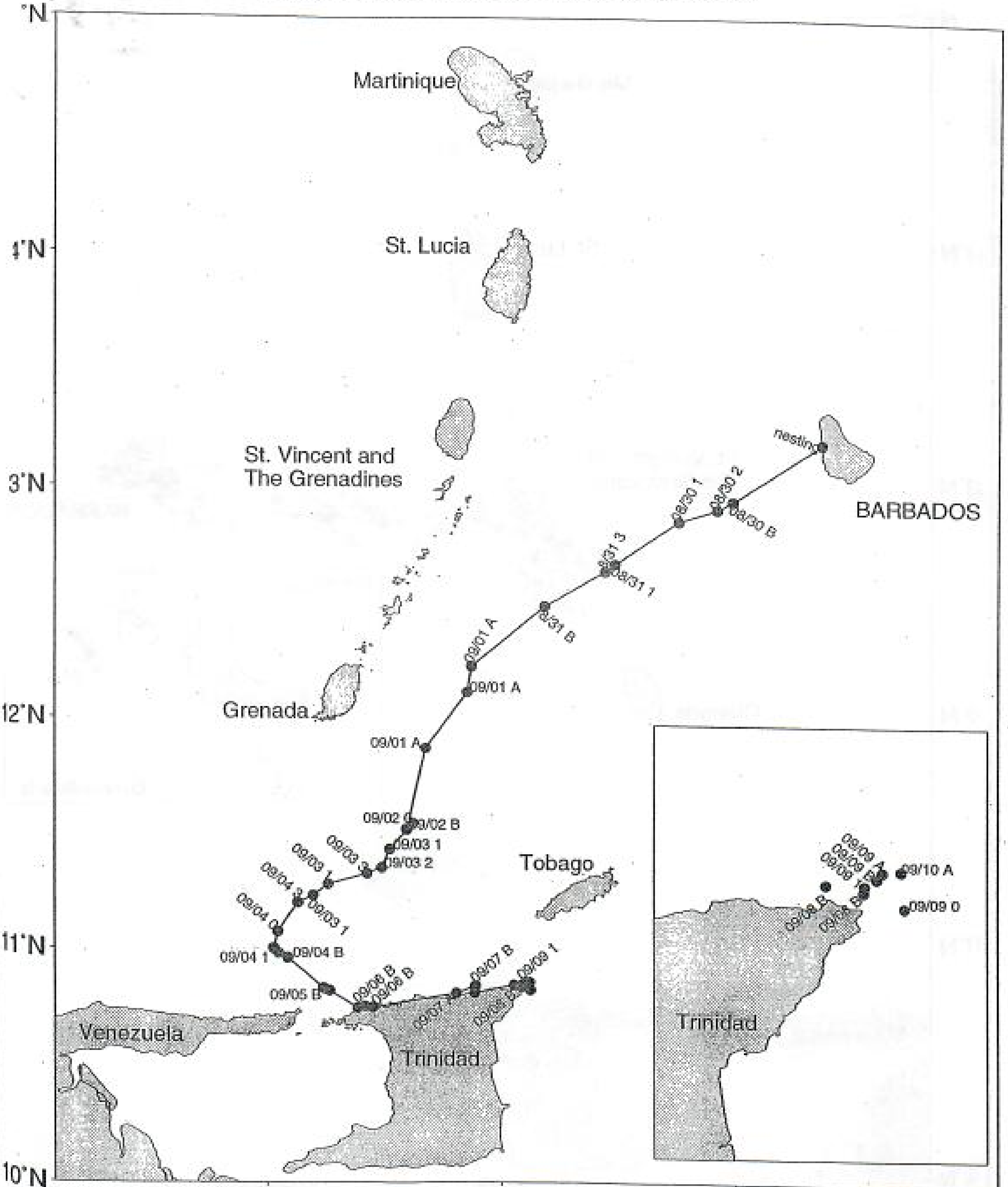
GMT map by Denise Ellis 9/30/98
Marine Turtle Research Program
National Marine Fisheries Service

Barbados Hawksbill "Lotus" #8180, 1998



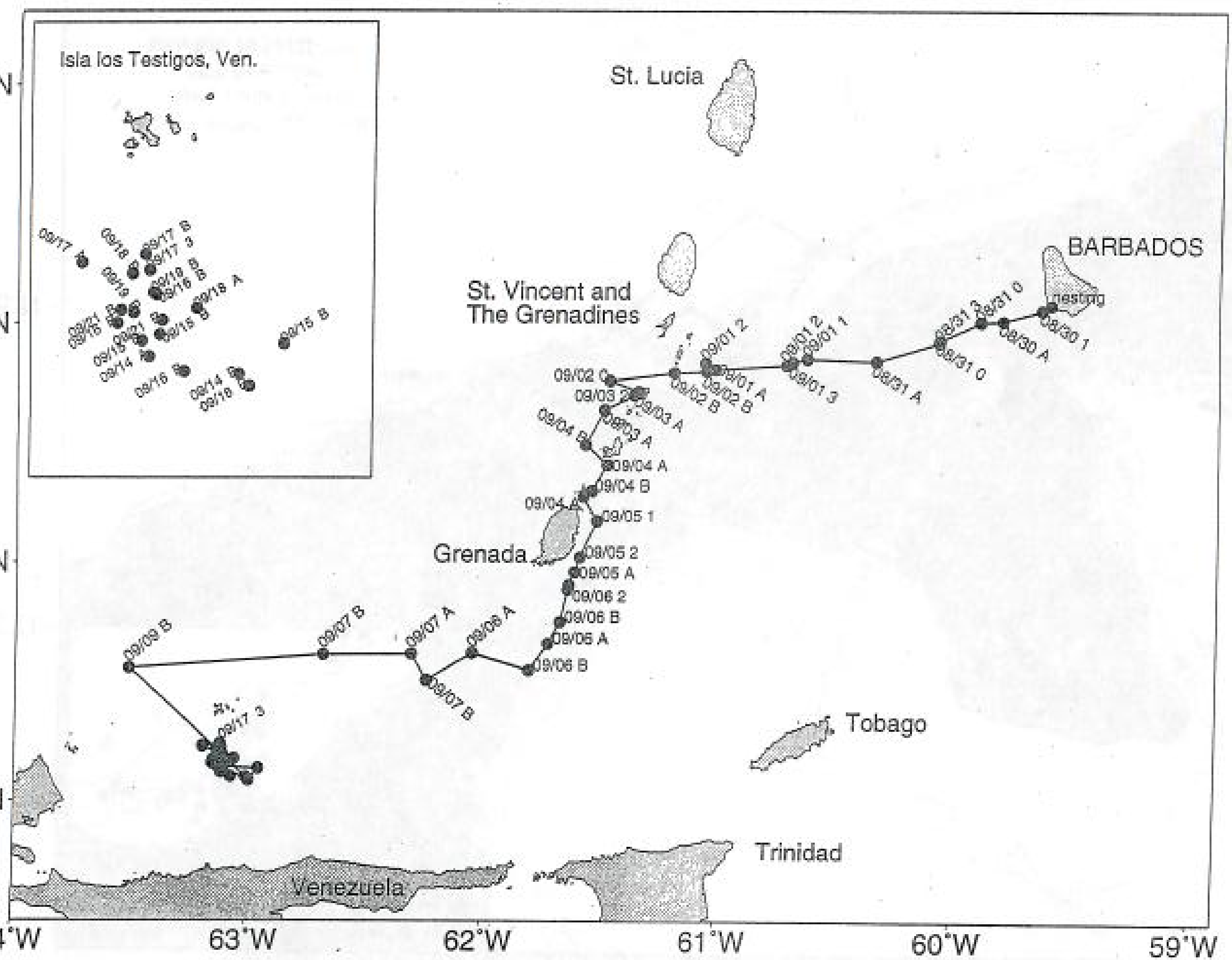
GMT map by Denise Ellis 10/07/98
Marine Turtle Research Program
National Marine Fisheries Service

Barbados Hawksbill #8207, 1998



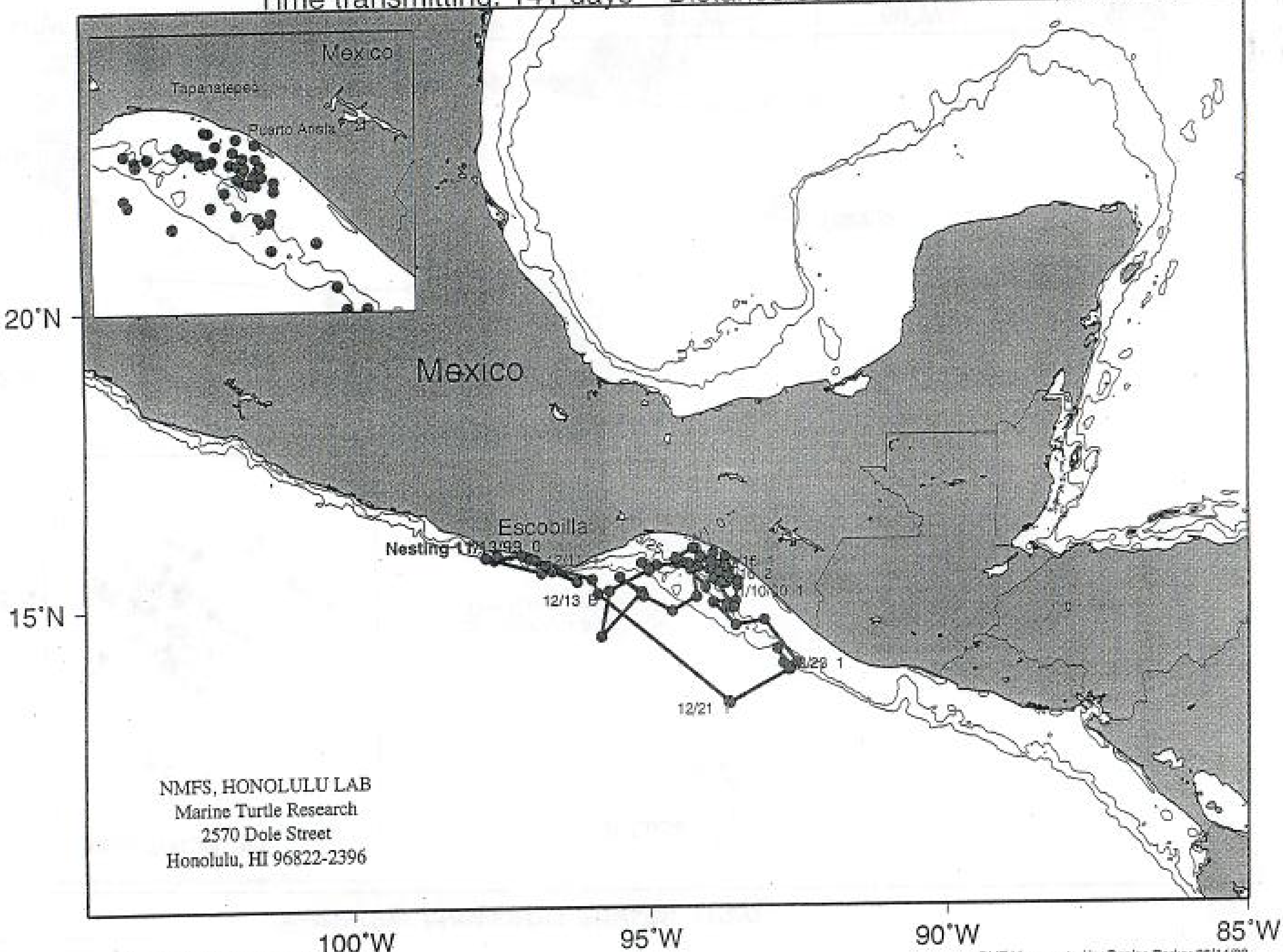
GMT map by Denise Ellis 9/10/98
Marine Turtle Research Program
National Marine Fisheries Service

Barbados Hawksbill #8208, 1998



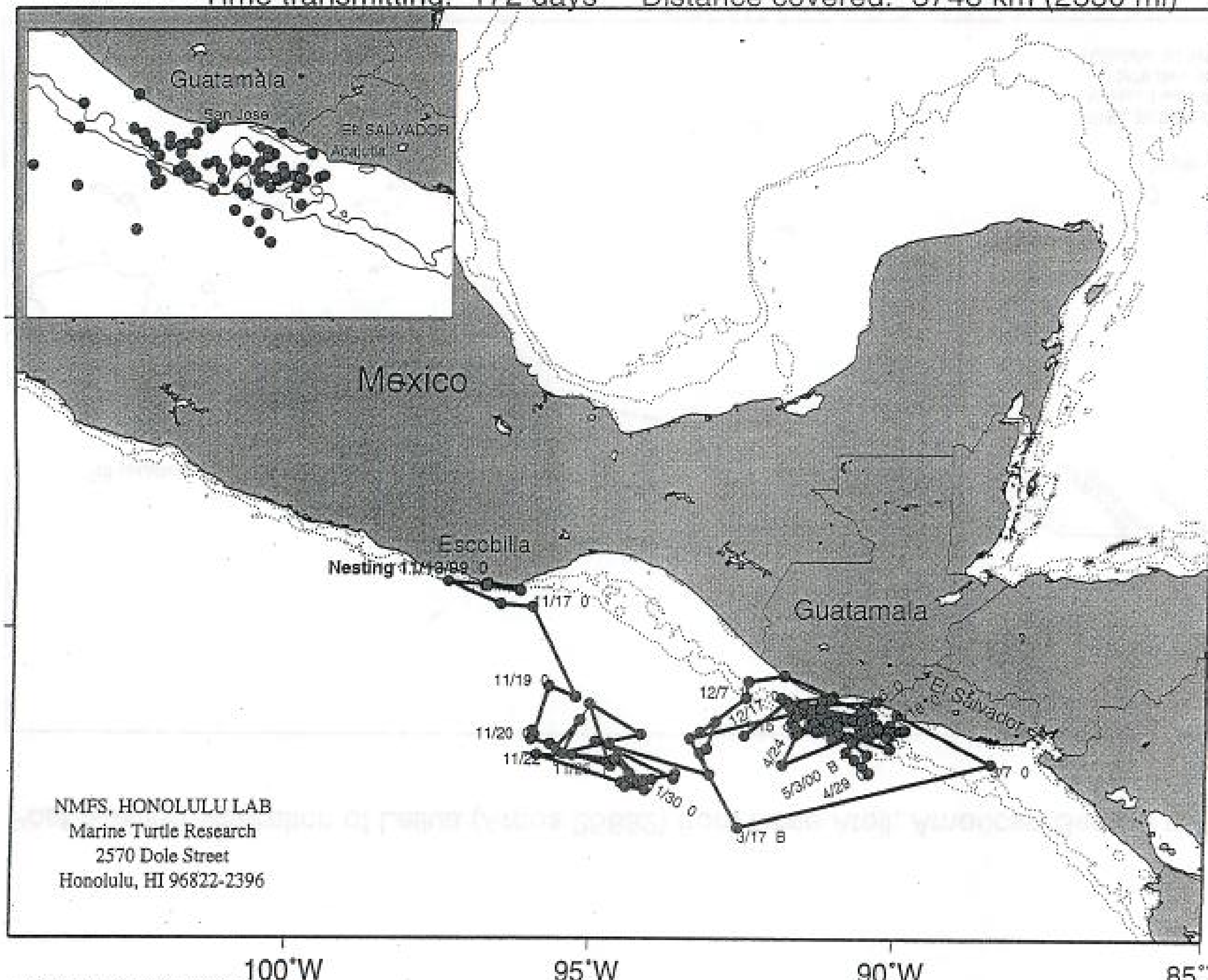
GMT map by Denise Ellis 9/22/98
Marine Turtle Reserch Program
National Marine Fisheries Service

1999-2000 Post-nesting satellite-tracked movements of female olive ridley
from Escobilla Beach, Oaxaca, Mexico to the Gulfo de Tehuantepec, Mexico
Time transmitting: 141 days   Distance covered: 2650 km (1647 mi)



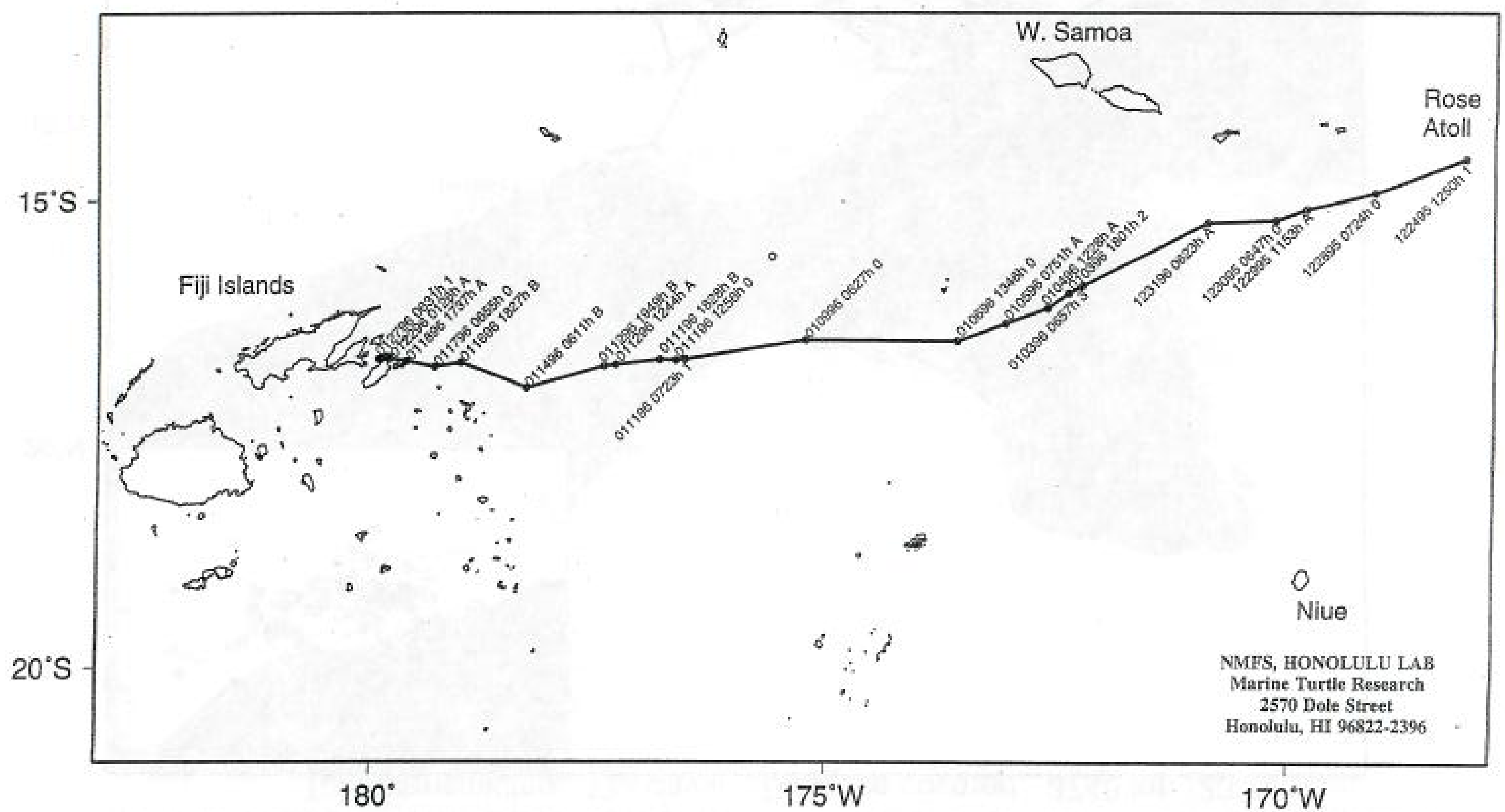
** DATE CEASED TRANSMITTING

1999-2000 Post-nesting satellite-tracked movements of female olive ridley (ID 24187)
from Escobilla Beach, Oaxaca, Mexico to offshore of Guatamala and El Salvador
Time transmitting: 172 days Distance covered: 3748 km (2330 mi)

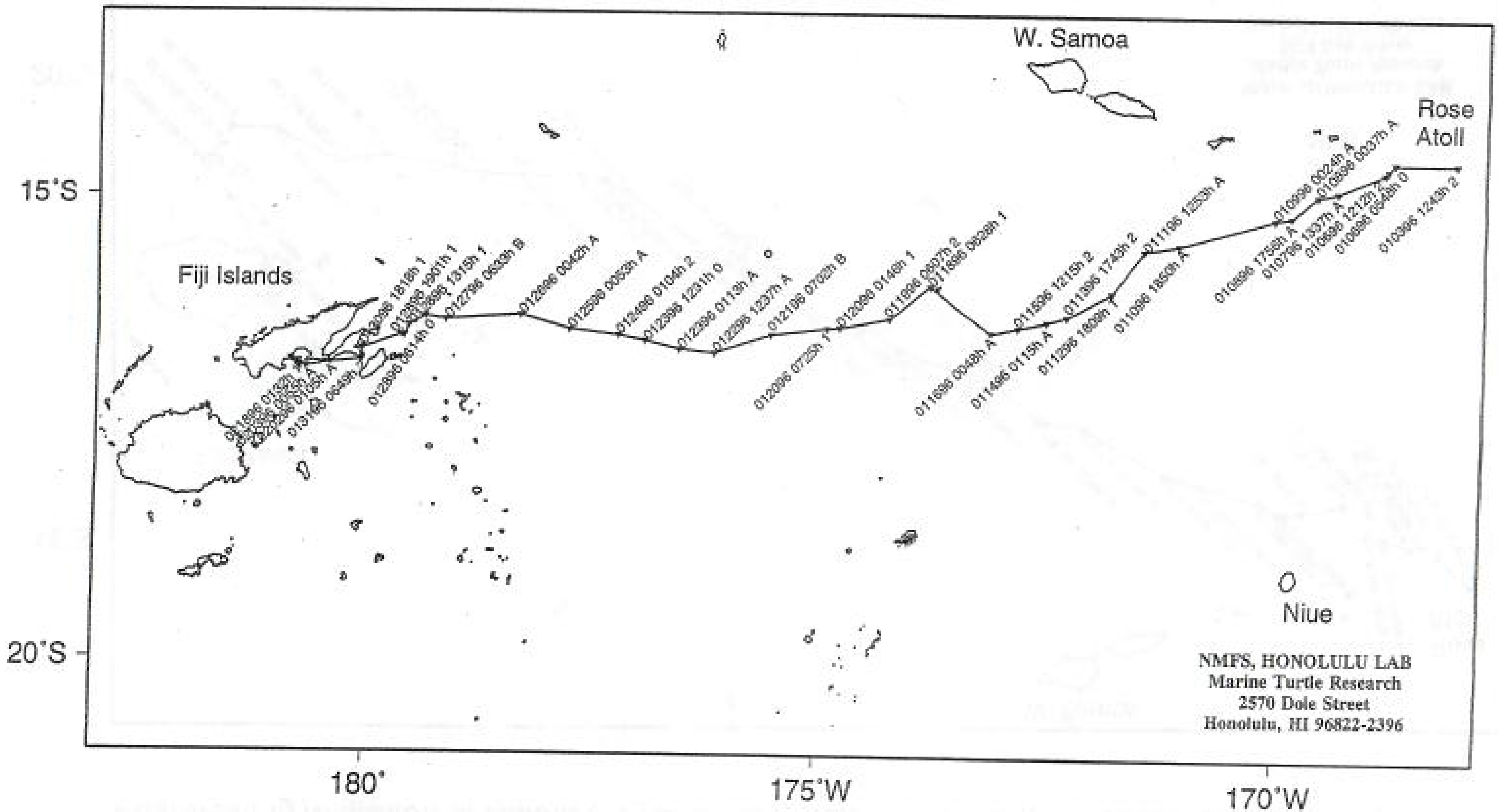


** DATE CEASED TRANSMITTING

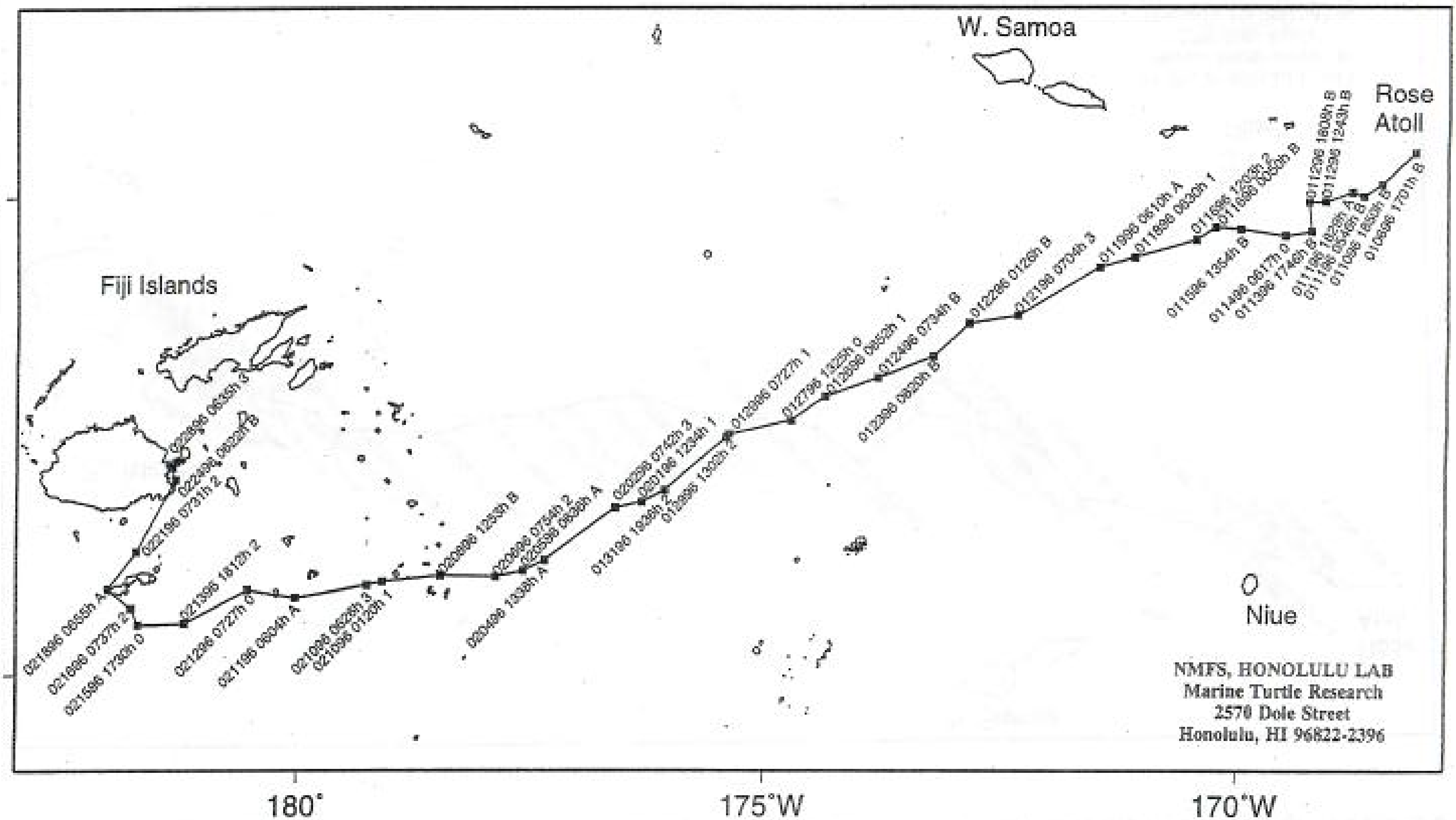
Post-Nesting Mirgration of Leilua (Argos 25692) from Rose Atoll, American Samoa to Fiji, 1995-96



Post-nesting Migration of Isalei (Argos 25693) from Rose Atoll, American Samoa to Fiji, 1995-96

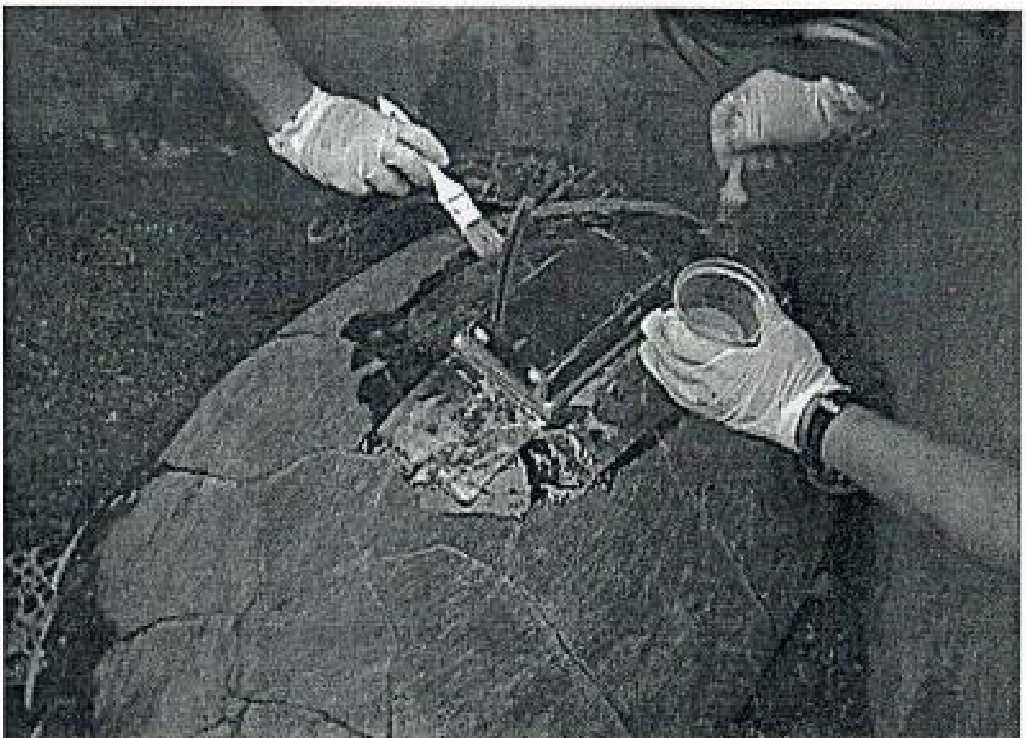


Post-nesting Migration of Aulotu (Argos 25694) from Rose Atoll, American Samoa to Fiji, 1995-96

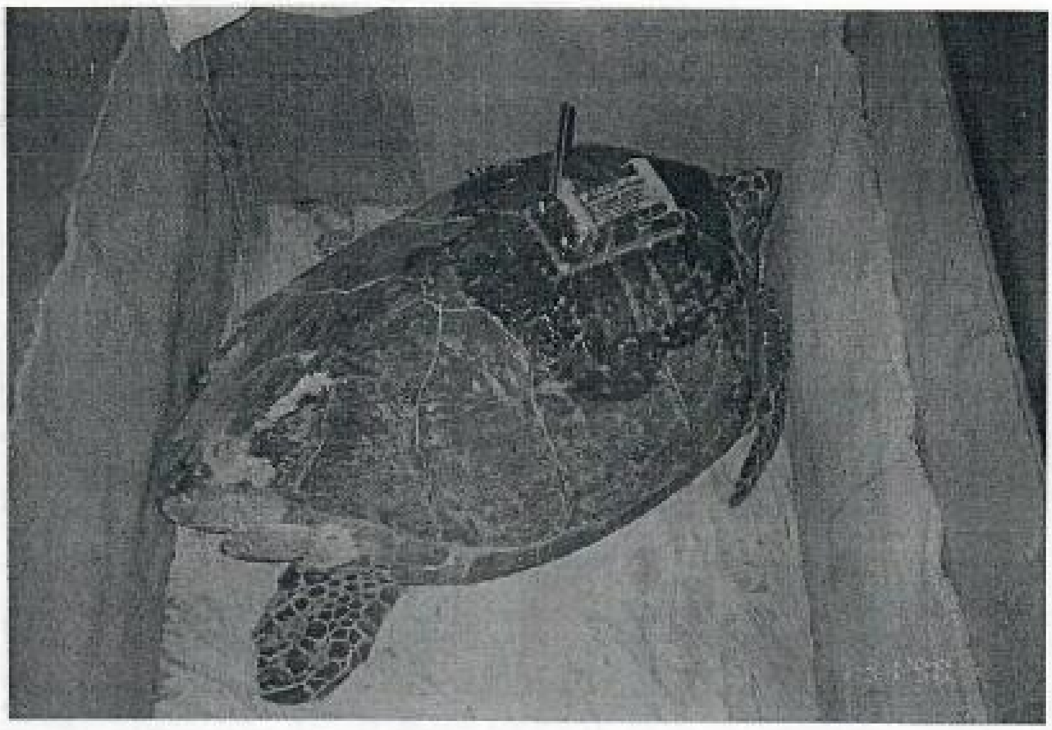


APPENDIX 6. Photographs showing various aspects of deploying satellite transmitters on sea turtles.

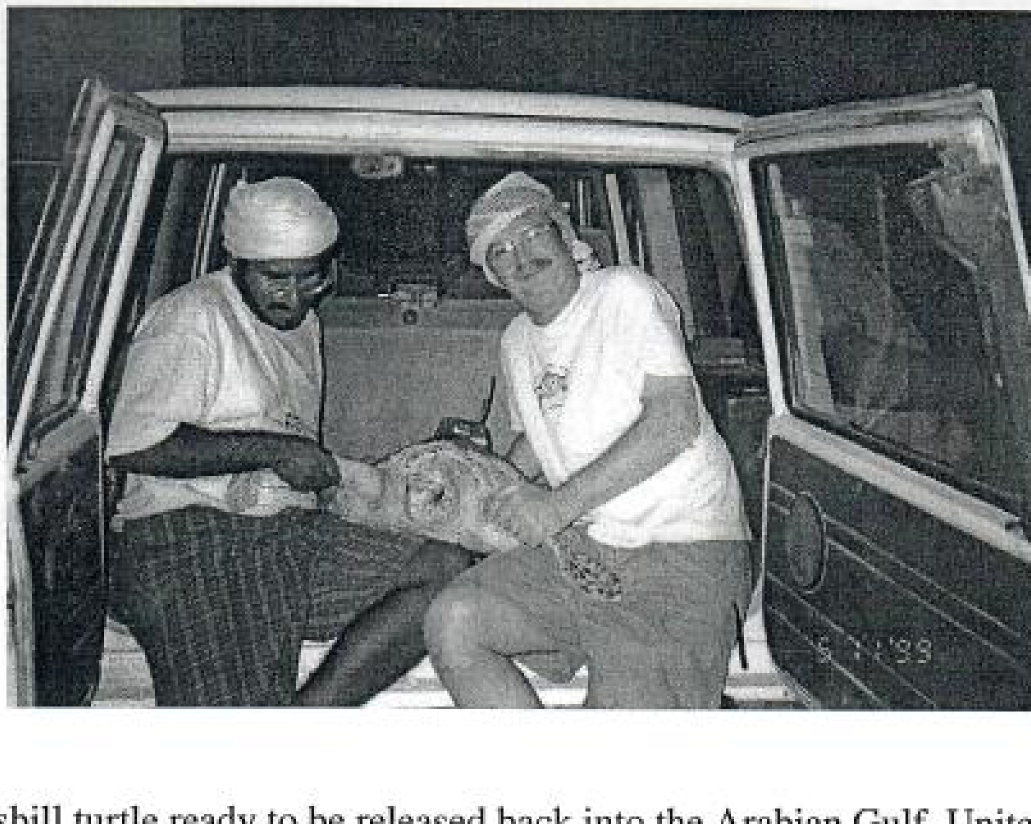
Satellite tracking training workshop in Tortuguero, Costa Rica (July 2000). Note that an awning is essential to provide shade and protection from rain for both the turtle and the researchers.



Application of the first layer of fiberglass cloth and laminating resin (Barbados 1998).

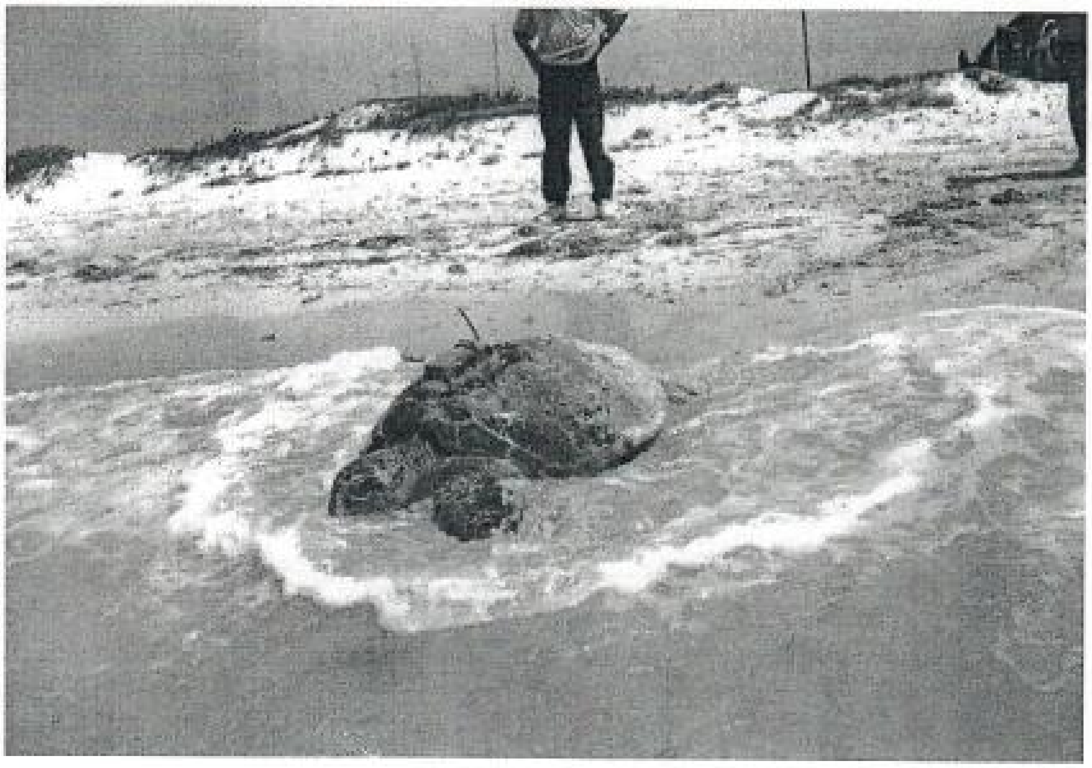


Hawksbill turtle in Barbados ready to be released.

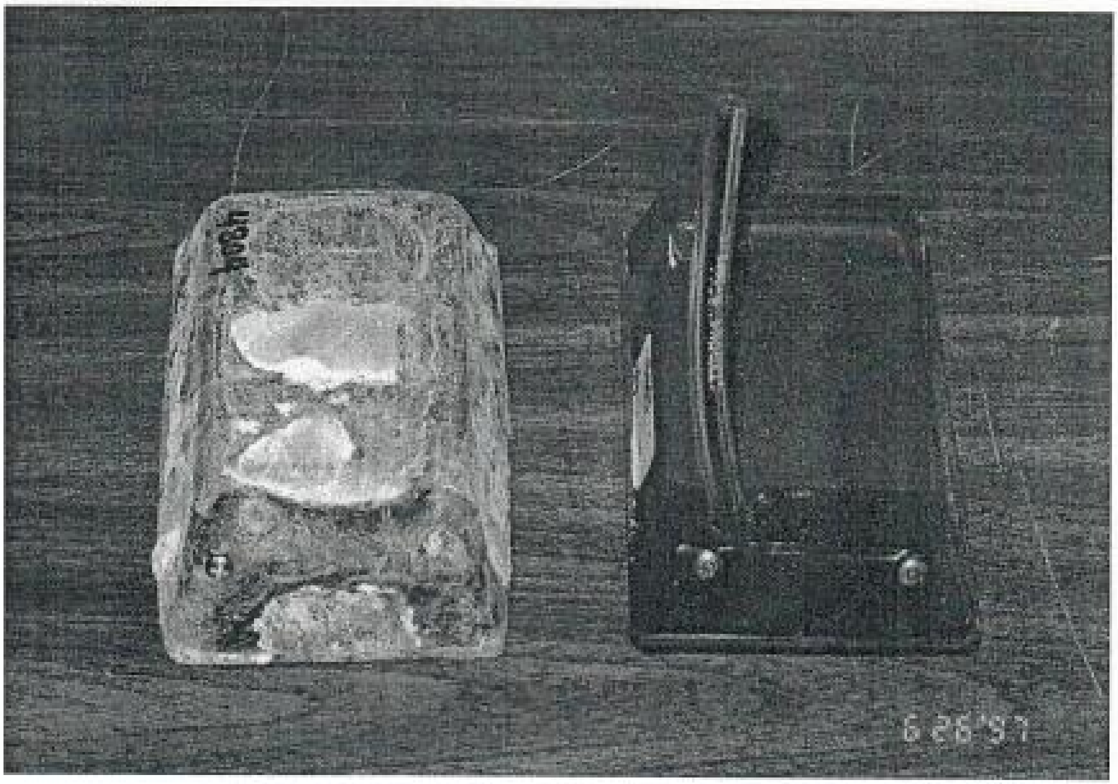


Hawksbill turtle ready to be released back into the Arabian Gulf, United Arab Emirates.

Hawksbill turtle being released at Cousin Island, Republic of Seychelles (1998).



Hawksbill turtle being released in Yucatan, Mexico (1999).



ST14 Telonics satellite transmitters. The one on the right is brand new, while the one on the left was recovered from a live healthy hawksbill after two years.

APPENDIX 7. Selected publications relating to sea turtle satellite tracking.

SHORT-RANGE REPRODUCTIVE MIGRATIONS OF HAWKSBILL TURTLES IN THE HAWAIIAN ISLANDS AS DETERMINED BY SATELLITE TELEMETRY

Denise M. Ellis[1], George H. Balazs[2], William G. Gilmartin[3], Shawn K. K. Murakawa[1], and Lawrence K. Katahira[4]
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[2]National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822-2396 U.S.A.
[3]Hawaii Wildlife Fund, P.O. Box 70, Volcano, Hawaii 96785 U.S.A.
[4]Hawaii Volcanoes National Park, P.O. Box 52, Hawaii National Park 96718 U.S.A.

Five hawksbill turtles, *Eretmochelys imbricata*, nesting in the Hawaiian Islands during 1995-97 were tracked by satellite using the Argos system. The purpose of this study was to locate resident foraging pastures utilized by the turtles, and to determine the routes taken to reach these sites. The hawksbill is a rare and endangered species in the Hawaiian Islands where it has recently been the focus of increased research and recovery efforts. Nesting is confined to only a few beaches on the islands of Oahu, Molokai, Maui and Hawaii in the southeastern segment of the archipelago. Sightings by ocean users of immature or adult hawksbills are uncommon in marine habitats of the Hawaiian Islands. In contrast, green turtles, *Chelonia mydas*, are numerous and routinely encountered by divers and tour operators promoting the underwater viewing of sea turtles.

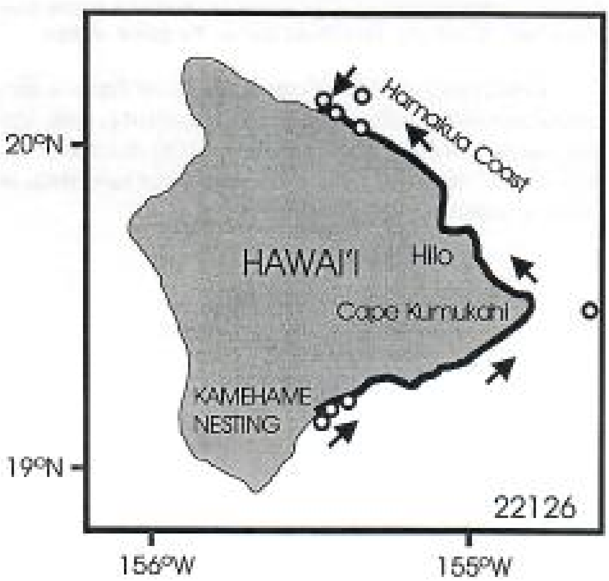

Figure 1. 1995 post-nesting migration of Hawksbill 22126 from Kamehame beach 180 km in a counter-clockwise direction to Honoka'a on the Hamakua coast.

A knowledge of the marine habitats used by Hawaiian hawksbills, especially adult females, is essential for effective protection and management. The flipper tagging of 38 nesting hawksbills since 1991 has only yielded resightings on or near the beaches where the turtles were originally tagged. The Hawaiian Archipelago extends for 2450 km across the North Pacific (19°N, 155°W to 28°N, 178°W) and is among the most isolated of all island groups. Prior to the satellite tracking reported herein, distant migrations by hawksbills to destinations both within the archipelago, and to international areas beyond, were considered as possibilities.

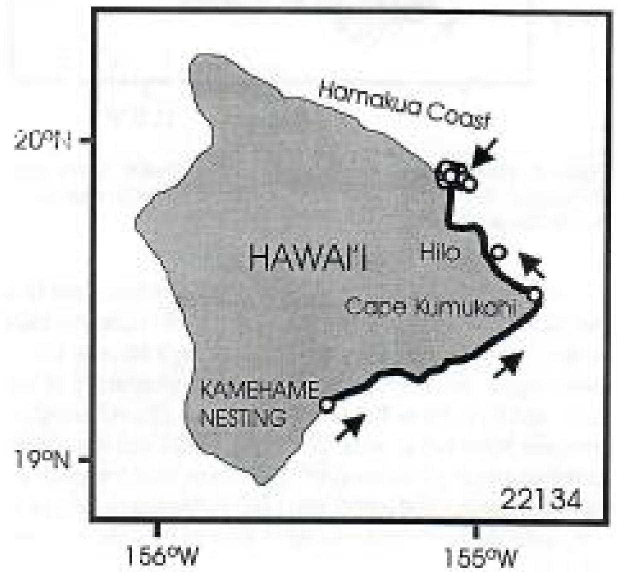

Figure 2. 1995 post-nesting migration of Hawksbill 22134 from Kamehame Beach 135 km in a counter-clockwise direction to Honomu on the Hamakua coast.

ST3/ST14 one-watt UHF satellite-linked transmitters made by Telonics (Mesa, Arizona U.S.A.) were safely and securely attached with polyester resin and fiberglass cloth to the carapaces of four hawksbills nesting at Kamehame on the island of Hawaii (two in 8/95, two in 8/96) and one nesting at Kealia, Maui in 9/97. The three turtles tracked in 1996-97 were also equipped with Telonics MOD-225 VHF transmitters to allow auxiliary monitoring using a portable receiver and antenna at nearby coastal sites.

Three of the turtles tracked from Kamehame and the one tracked from Kealia migrated to the nearshore waters of the Hamakua Coast, a windswept shoreline of cliffs on the island of Hawaii that is inhospitable for recreational use (Figures 1-4). The routes taken were mainly coastal involving estimated distances of only 135-255 km traveled in 7-10 days.

The fourth turtle tracked from Kamehame migrated to Kahului Bay on the windward side of Maui, a distance of 315 km (Figure 5). The route of this migration was again mainly along the coastline taking an estimated 18 days.

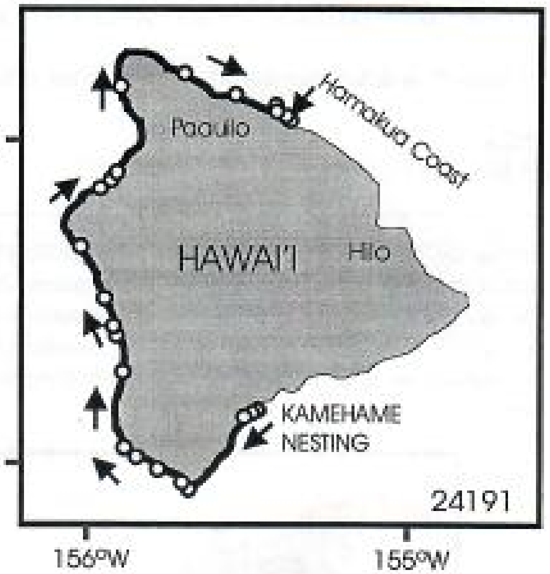

Figure 3. 1996 post-nesting migration of Hawksbill 24191 from Kamehame Beach 255 km in a clockwise direction to Paauilo on the Hamakua Coast.

Upon completion of the post-nesting movements to a coastal area, satellite transmissions continued to confirm each turtle's presence for periods of 71-204 days prior to transmitter signal deterioration. VHF coastal monitoring of the turtle that traveled to Kahului Bay (Figure 5) confirmed its presence there for at least 184 days. Sufficient data were therefore obtained to reasonably presume that foraging areas had been reached where extended residency occurs, possibly until the turtle embarks upon its next reproductive migration.

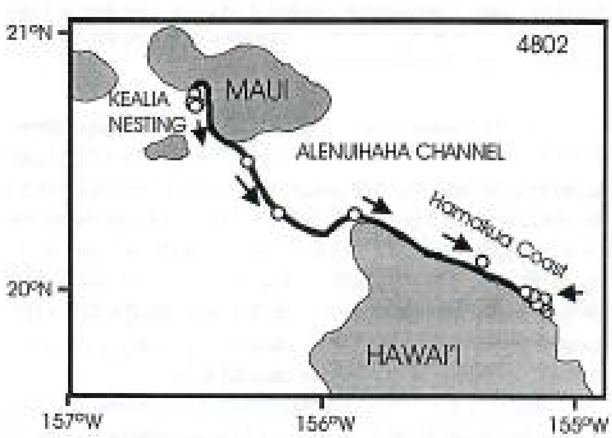

Figure 4. 1997 post-nesting migration of Hawksbill 4802 from Kealia Beach, Maui 240 km to Kuku Point on the Hamakua Coast of the Island of Hawai'i.

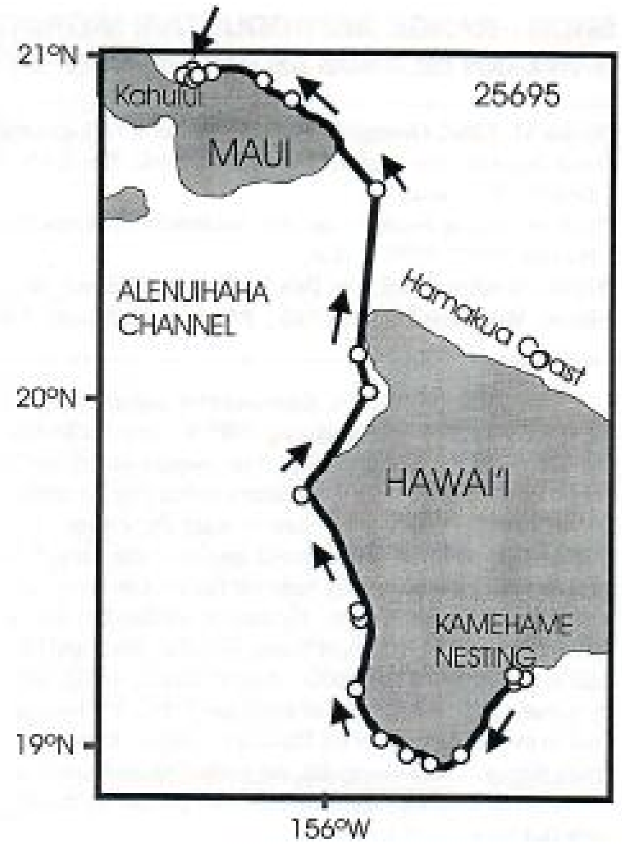

Figure 5. 1996 post-nesting migration of Hawksbill 25695 from Kamehame Beach 315 km Kahului Bay on the Island of Maui.

Results presented in this paper constitute the most successful satellite tracking of hawksbills reported to date. Future research in the Hawaiian Islands will be directed at underwater habitat assessments and censusing of hawksbills in the areas identified by satellite tracking.

NOAA Technical Memorandum NMFS-SEFSC-436

PROCEEDINGS OF THE EIGHTEENTH INTERNATIONAL SEA TURTLE SYMPOSIUM

3-7 March 1998
Mazatlán, Sinaloa MEXICO

Compilers:

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William M. Daley, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
D. James Baker, Administrator

NATIONAL MARINE FISHERIES SERVICE
Penelope D. Dalton, Assistant Administrator for Fisheries

June 2000

Technical Memoranda are used for documentation and timely communication of preliminary results, interim reports, or special-purpose information, and have not received complete formal review, editorial control, or detailed editing.

In Press. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation, March 2-6, 1999, South Padre Island, Texas.

SATELLITE TRACKING OF AN ADULT MALE AND FEMALE GREEN TURTLE FROM YUCATAN IN THE GULF OF MEXICO

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[4]National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822-2396 USA

Marine turtle migrations are principally studied by tagging, usually with metal or plastic tags. This technique provides information on the locations where turtles were tagged and recaptured, but does not reveal the routes and speed of travel. Satellite telemetry is a technologically advanced method that establishes the turtle's pathway during the actual migration. The use of satellite transmitters began in the late 1970's, and has permitted migration tracking for both terrestrial and marine animals. Over the years there has been a reduction in the size and weight of the transmitters with improved design and battery reserve. In addition, the method of attachment to the carapace of marine turtles has been perfected so as to be safe and secure (Balazs et al., 1996).

The migrations for two green turtles (*Chelonia mydas*), a male and a female, were satellite tracked after a breeding season at Isla Mujeres, Quintana Roo, Mexico (Lat. 21.2N, Long. 86.7W). Two Telonics, Inc. (Mesa, Arizona USA) ST14 satellite transmitters linked to the Argos global tracking system, were attached to an adult male (ID 22132) and adult female (ID 4804), using Silicone Elastomer and fiberglass cloth with polyester laminating resin. The turtles were obtained from the Isla Mujeres Marine Turtle Research Station of the National Fisheries Institute (Instituto Nacional de la Pesca; SEMARNAP). This facility had 70 green turtles (about one-third males and two-thirds females) in an 800 m^2 enclosure with access to a beach where females nested at various times during the season. The turtles were captured near Isla Holbox and Isla Mujeres during April - May 1998, and kept in the enclosure until being set free in early October 1998. A transmitter was attached to the female on 2 October 1998. Data were first received from the transmitter on 4 October at which time the turtle was in front of Cabo Catoche, Yucatán (Lat. 22.1N, Long. 86.9W) traveling northwest from Isla Mujeres. During the next 10-12 days she migrated northeast across the lower Gulf of Mexico and arrived off the coast of extreme southwest Florida, north of the Florida Keys, in mid-October. The turtle remained in this vicinity (centered around Lat. 25N, Long. 81W) for the duration of transmissions during the following five months. This area is a known resident foraging habitat for adult green turtles that nest in Florida (Schroeder et al., 1996).

The male, also tagged with a satellite transmitter on 2 October 1998, went to the northeast, staying along the Quintana Roo littoral between Isla Holbox and the shore (Lat. 21.5, Long. 86.9), where it was originally captured, keeping within an approximately 90 km^2 area. Females nesting in the Yucatán Peninsula show a high two year inter-nesting interval. Green turtle nesting beaches in Yucatán, such as Isla Aguada, Campeche and Las Coloradas, show high nesting abundance during even years (1990, 1992, 1994, etc.) and low numbers during odd years (1991, 1993, 1995, etc.), for 18 years of monitoring data. Flipper tagging has shown little interchange between these two groups (even and odd years). However, adult males studied in the Isla Mujeres project have been captured in the same nearby zone during various consecutive years (Rolando Chan, pers. comm.). This could indicate significant differences between males and females in their reproductive behavior and then migration routes and feeding grounds.

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Schroeder, B. A., L. M. Ehrhart, and G. H. Balazs. 1996. Post-nesting movements of Florida green turtles: Preliminary results from satellite telemetry. *In* J. A. Keinath, D. E. Barnard, J. A. Musick, and B. A. Bell (comps.), Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation, February 20-25, 1995, Hilton Head, South Carolina, p. 289. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-387.

In Press. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation, March 2-6, 1999, South Padre Island, Texas.

Post-Nesting Migrations of Hawksbill Turtles in the Granitic Seychelles and Implications for Conservation

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BACKGROUND

Significant populations of hawksbill turtles *(Eretmochelys imbricata)* nest in the Republic of Seychelles (western Indian Ocean), but in numbers much reduced from historic levels (Meylan and Donnelly, 1999). Hawksbill nesting in Seychelles is most concentrated at the granitic islands of the Seychelles Bank, in the Amirantes Islands group, and on Platte and Coetivy islands (Mortimer, 1984) (Fig. 1). Since 1973, more than 750 nesting hawksbills have been tagged at these sites. The tagging programme began in 1973 at Cousin Island (Mortimer and Bresson, 1999), and was expanded in 1980 to Curieuse, in 1981 to St. Anne Marine Park and Aride Island, in 1994 to Cousine Island, and in 1995 to Bird Island. Nesting hawksbills also have been tagged opportunistically at other islands within the Seychelles Bank and on many of the outer islands of the Seychelles since 1981 (Mortimer, 1998). Although inter-island movements of nesting hawksbills have been recorded on the granitic islands of the Seychelles Bank (Mortimer, Hitchins, Bresson, Collie and Roberts, unpubl. data), no tagged hawksbills have been recovered outside the country. Nor have tags been recovered from females captured at points distant to the nesting beaches.

Our lack of knowledge about the resident foraging grounds, where the adult females live during the several-year intervals between nesting seasons, has compromised efforts to effectively manage and conserve both the turtle populations and their foraging habitats. Data obtained from 25 years of tagging nesting hawksbills had not solved this mystery. So, we employed satellite telemetry in an effort to identify the resident foraging grounds and to track the routes taken to reach them.

THE TRACKING STUDY

In January 1998, we attached five ST14 satellite transmitters (built by Telonics of Mesa, Arizona) to post-nesting hawksbill turtles at Cousin Island (4°20'S; 55°40'E), using methods patterned after Balazs et al. (1996), and tracked them using the Argos system. Mapping of results was accomplished as described by Ellis and Balazs (1998). Our study has been very successful. Figure 2 maps the movements of the five turtles. As of early March 1999, after 13.5 months, transmitters (#4806, #4807, and #4809) were still sending good position data for three of the turtles. Two of the transmitters (#4805 and #4808) had stopped transmitting after 2.3 and 1.5 months, respectively, but not before the turtles are believed to have completed their migration back to the foraging grounds. None of the five turtles traveled beyond the edges of the Seychelles Bank, and none moved farther than 175 km from the nesting beach.

All five turtles displayed similar patterns of movement. After laying their last egg clutch of the season, the five turtles traveled for three to five days in a directed fashion to discrete and different locations on the Seychelles Bank that ranged from 20 to 175 km from the nesting beach. Upon reaching their destinations none of the turtles traveled beyond a radius of about 15 km in any direction. In fact, their travel appeared more restricted as the months passed (Fig. 2). Detailed results of this study will be published separately (Mortimer, Balazs, Hitchins, Constance and Nolin, in prep.). The tracking data confirmed in a few months what 25 years of flipper tagging had inconclusively suggested: that hawksbills nesting in Seychelles are likely to spend their adult lives within the territorial waters of Seychelles. Satellite tracking in the Hawaiian Islands has shown similar short-range post-nesting migrations (Ellis et al., in press).

IMPLICATIONS FOR CONSERVATION

The conclusions of our study enhance efforts to conserve sea turtles in Seychelles. A source of frustration when trying to manage sea turtle populations--in Seychelles, as elsewhere--is the disregard turtles have for international boundaries. Some Seychellois complain that it is unfair and futile to expect the people of Seychelles to protect turtles that will only be slaughtered when they migrate from Seychelles to the national waters of another country in the region. The present study provides evidence that hawksbills, which nest in the granitic Seychelles, remain within the territorial waters of Seychelles even after leaving the nesting habitat. As such, they are a resource that belongs to the people of Seychelles, whose responsibility it is to ensure their long-term survival.

Our data provide an incentive to the people of Seychelles to protect their hawksbills. But this only complements the extraordinary action already taken by the Government of Seychelles during the past eight years. In 1993, as a first step towards banning all domestic trade in hawksbill products, the Government devised and implemented the "Artisan Training and Compensation" programme which provided financial assistance to hawksbill artisans to help them find alternate livelihoods. A component of that programme was Government purchase of the remaining stocks of the raw hawksbill shell still in the possession of the artisans. In 1994, a law was passed providing complete legal protection for sea turtles and banning all commercial trade in turtle products. During the past four years the Government has actively promoted enforcement of this legislation, has sponsored public awareness campaigns (Mortimer, in press), and encouraged sea turtle research and population monitoring (Mortimer and Collie, 1998).

Seychelles is the site of some remarkable sea turtle conservation success stories. Green turtle *(Chelonia mydas)* nesting activity has significantly increased at Aldabra since 1968 when the atoll was made a nature reserve (Mortimer, 1988). Likewise, hawksbill nesting activity at Cousin Island has almost tripled -- increasing from some 30 animals in the early 1970's to 70-100 individual turtles nesting annually in recent years (Mortimer and Bresson, 1994). Nearby Cousine Island, protected since 1993, has already documented significant increases in hawksbill nesting activity (P. Hitchins, unpubl. data). The situation at Cousin/Cousine demonstrates that effective protection of nesting beaches can result in the recovery of nesting populations. The turtles nesting at Cousin/Cousine represented about 7% of the total estimated hawksbill nesting population of Seychelles in the early 1980's (Mortimer, 1984). Although hawksbill nesting populations have declined at many other islands in Seychelles (Mortimer, 1998), new conservation initiatives are underway at some sites. Among them, Bird, Denis, and Aride Islands, and the Marine Parks at St. Anne and Curieuse are taking strong action to protect their nesting hawksbills--in many cases very effectively.

Despite progress made, the long-term survival of hawksbills in Seychelles is not yet assured. Nesting females are particularly vulnerable. They nest in the daytime, returning repeatedly to the same stretch of beach at predictable two-week intervals to lay their eggs. The average female deposits some three to five egg clutches per season, and each clutch laid is usually associated with one or more trial nesting emergences (Mortimer and Bresson, 1999). Thus, an individual female may emerge onto the same stretch of nesting beach some 4 to 10 times during a single nesting season. Where constant surveillance is lacking, a small number of determined and energetic turtle poachers can still slaughter dozens of adult turtles at a single island during a nesting season. Foraging hawksbills--especially the immature animals that reside in relatively shallow water--are also easy prey for poachers; for they are slow swimmers with little fear of humans.

Fortunately, the Government of Seychelles takes this matter seriously. It has reassessed its national priorities and put environmental protection at the head of the list. It appreciates the fact that its pristine environment is a prime attraction for tourists, and that tourism is a major source of foreign exchange for the country. Live turtles have become increasingly popular attractions for visiting tourists who enjoy watching them on the nesting beach and in the water while they snorkel (Mortimer, in press). On 23 November 1998, in conjunction with the Miss World Pageant hosted in Seychelles, the Government of Seychelles publicly burned the stockpile of raw hawksbill shell that it had procured from the tortoise shell artisans in 1993 (Mortimer, 1999). The stockpile had been kept in a sealed container on Mahe since 1993 and could not legally be sold to a buyer outside the country because of CITES restrictions. Conservationists were concerned that by holding on to the stockpile, the Government was inadvertently sending a message to turtle poachers that eventually the trade in tortoiseshell would re-open. There was concern that this might encourage poachers to amass their own private stockpiles of raw hawksbill shell. Thus, the decision was made to destroy the stockpile in order to send a message to the world that Seychelles is serious about environmental conservation, and to send a message to potential poachers inside the country that slaughter of hawksbills would not be sanctioned or tolerated.

We hope other nations that host hawksbill populations will follow the lead of the Government of Seychelles and take whatever strong action is necessary to protect their own populations of this Critically Endangered species. *(Resolution 1999-6* of this Symposium expands on this theme).

ACKNOWLEDGMENTS

Among the collaborators on the satellite tracking study, we are especially grateful to A. "Mazarin" Constance, Roland Nolin, Robert Morris, Peter Hitchins, and Kevin Hoareau, during deployment of the satellite transmitters; John Collie (Marine Park Authority), John Nevill (Division of Conservation, Ministry of Environment), Nirmal Shah (BirdLife Seychelles), and George Troian (Director General, Ministry of Environment) for enabling logistical support by the organizations they direct; Kerstin Henri (Ministry of Foreign Affairs), for project administration; Denise M. Ellis (National Marine Fisheries Service), for data management assistance and mapping; and Caribbean Conservation Corporation for office support. The support of Peter Hitchins (Cousine Is. Co.) was instrumental to realization of the study. Cousine Is. Co. and BirdLife Seychelles provided accommodation in the field. Special thanks go to Mr. Fred Keeley (Cousine Is. Co.) who provided most of the funding for the satellite tracking study. Substantial funding also came from *EMPS Project J1: Turtle & Tortoise Conservation,* which was financed jointly by the Global Environment Facility (GEF), administered by the World Bank, and by the Government of Seychelles. Assistance and support from the Seychelles Ministry of Environment has been invaluable. JAM is grateful to the organizers of the 19th Annual Symp. on Sea Turtle Biology and Conservation and to the Packard Foundation for assistance with transportation to attend this symposium.

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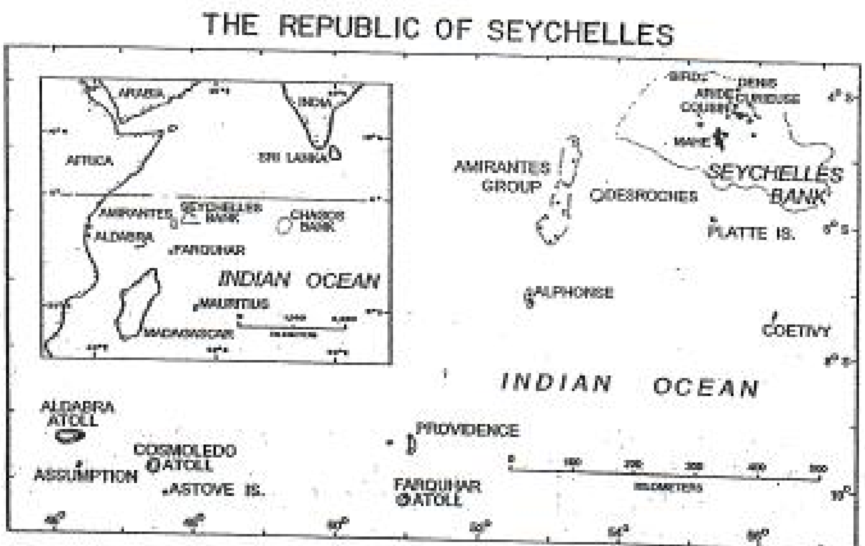

Figure 1. Map of the Republic of Seychelles.

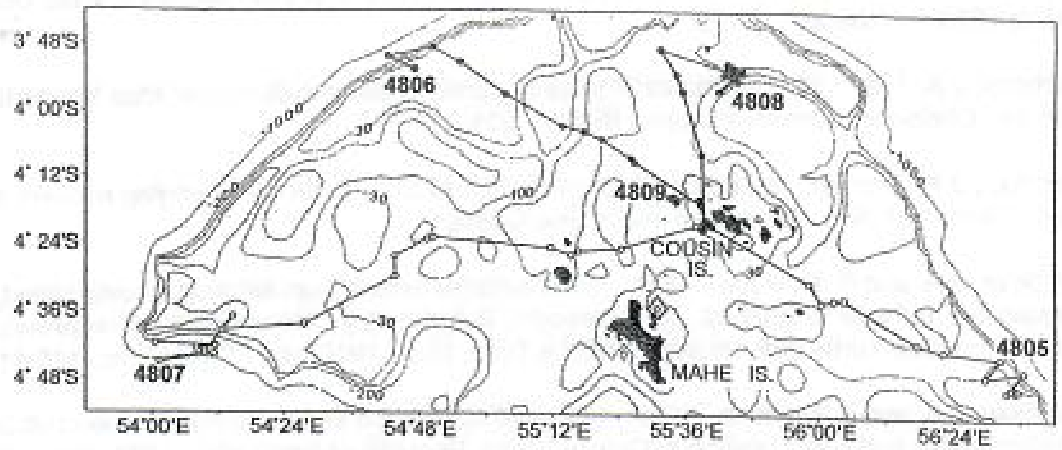

Figure 2. Movements of five satellite tracked post-nesting hawksbills on the Seychelles Bank. Depths are in meters.