Sea Turtle Conservancy's Caribbean Leatherback Tracking and Conservation Project, Bocas del Toro region, Panama

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The Sea Turtle Conservancy (STC) has been conducting sea turtle research and conservation efforts at Tortuguero, located on the northern Caribbean coast of Costa Rica, since 1959, when the organization was founded to support the pioneering work Dr Archie Carr began in the mid-1950s. STC's work in Panama began in 2003, when STC started monitoring a hawksbill nesting beach on the Caribbean coast of Panama, just south of Bocas del Toro, called Chiriquí Beach. While STC's work at Chiriquí began as an initiative to recover hawksbills, it was exciting to discover that this same beach hosts the fourth largest nesting colony of leatherbacks in the world, with between 1,000 and 7,000 nests being recorded each season. In 2013, STC began the monitoring and protection of another critical leatherback nesting beach, Soropta Beach, north of Boca del Toro, Panama. The Soropta Beach project complements STC's leatherback work being done at Chiriquí Beach. In 2003, the STC began to study the migration patterns of endangered leatherback sea turtles (*Dermochelys coriacea*) nesting along the Caribbean coast of Costa Rica and Panama. During 2003 and 2004, the leatherback tracking project focussed on leatherbacks nesting at Tortuguero, Costa Rica. In 2005, STC's leatherback satellite tracking efforts shifted from Tortuguero, Costa Rica to the Bocas del Toro region of Panama. The study has revealed important information about leatherback turtle migratory behavior that will help both conservationists and natural resource managers improve protection efforts for this endangered species.

Sea turtles fall into one of two taxonomic families, Cheloniidae or Dermochelyidae. Cheloniidae includes all sea turtles with a carapace covered in hard plates (scutes), while Dermochelyidae includes a single species, the leatherback, with a carapace without scutes, and instead having a tough, leathery, skin. While all sea turtles migrate between nesting beaches and foraging areas, adult sea turtle foraging behaviour is, for the most part, different between the two families of sea turtles. Cheloniidae are often characterized as having a single foraging area with little to no movement among multiple foraging areas (Broderick *et al.* 2007). In contrast, Dermochelyidae are often characterized as wandering foragers, not staying long in any one area (Eckert *et al*. 2012), with leatherbacks having the widest ranging and longest distance migrations of all marine turtle species (Gremillet *et al*. 2004; Seminoff *et al*. 2008).

As part of STC's nesting beach monitoring and research, metal ID tags are attached to the flippers of nesting sea turtles. These flipper tags help identify individual turtles and provided the first insights into the movement of turtles from nesting beaches to foraging grounds (Carr *et al*. 1978). If a turtle with a STC's flipper tag is found, either alive or stranded dead, the information about the turtle, including the location, is provided to STC, and used to create a 'tag return' map. Based on these flipper tag returns, STC was able to identify that leatherbacks were primarily migrating from STC's monitored nesting beaches into the North Atlantic Ocean basin, with a few leatherback turtles being found in the Gulf of Mexico.

While flipper tag returns provided data on a turtle's ending location, it was unknown if the returned tag represented a location along a migration pathway or if it was a foraging destination. The development of satellite telemetry for use in the marine environment and safe attachment methods for sea turtles have helped fill in many of the missing gaps in information about sea turtle migration. Previous leatherback satellite telemetry research has shown variation in both migration routes and distances, with a large spatial distribution of foraging areas in the North Atlantic (Eckert 2006; Witt *et al*. 2007; Fossette *et al*. 2010; Dodge *et al*. 2014). Using mathematical models, the behaviours associated with different types of movement (foraging vs migration) can be estimated from satellite tracking location data. The models use the rate of travel, turning frequency and turning angle to differentiate between behaviours. Lower rates of travel combined with high turning angles and high turning frequency suggest foraging behaviour, while high rates of travel combined with low turn angles and low turning frequency suggest migration behaviour.

In late May 2017, Argos platform transmitter terminals (SPOT6-352B from Wildlife Computers: Redmond, WA, USA) were attached dorsally to five leatherback turtles nesting in Chiriquí Beach (n = 3) and Soropta Beach (n = 2), Panama, as part of the Sea Turtle Conservancy's Tour de Turtles Education Program. Transmitter duty cycles were set to maximize battery life (on between 19:00-02:59 & 07:00-14:59 UTC with a maximum of 50 transmissions per day) and were attached during the nesting process using a direct attachment method (Dodge *et al*. 2014) that involves cable ties securing the transmitter through the dorsal ridge of the carapace (Fig. 1). The cable ties used incorporated a corrodible link to release the transmitter after two years. Each turtle was checked for flipper tags, and if no tags were present a Monel tag was applied to each rear flipper.

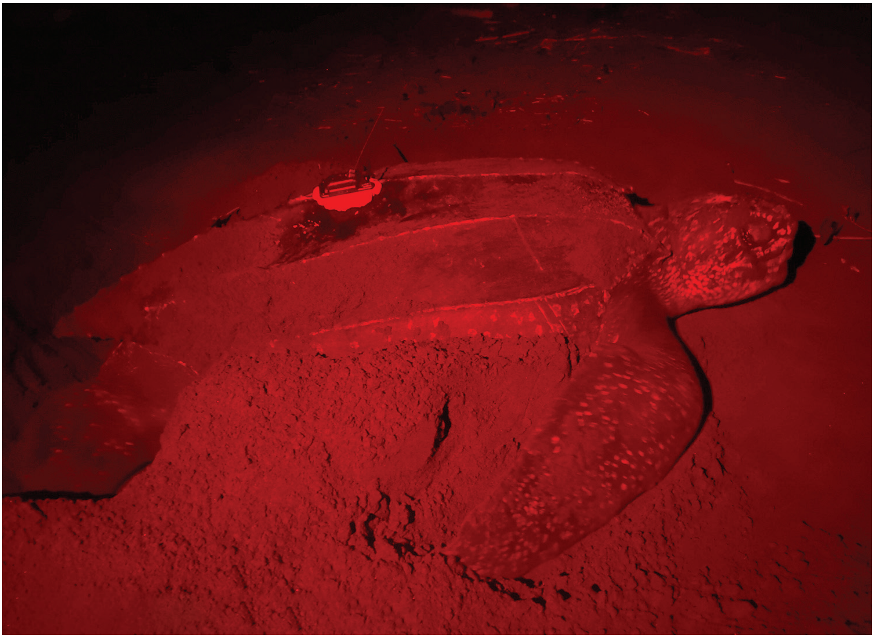

Fig. 1. Leatherback turtle finishes nesting with a satellite transmitter directly attached to the dorsal ridge. Red filtered flash used to reduce disturbance to turtle. Photo by David Godfrey, Sea Turtle Conservancy.

The raw Argos satellite data were filtered to exclude very poor and improbable locations (z-location quality, speeds greater than 10kph between successive locations, or locations on land after leaving the nesting beach) using STAT (Coyne & Godley 2005); then a Bayesian switching state-space model (SSSM) was used to estimate the behavioural state, either transit (indicative of migration) or area restricted search (ARS; indicative of foraging when observed away from mating/nesting locations), of all non-nesting leatherback locations (Jonsen *et al*. 2005).

Leatherbacks were tracked for between 158 and 349 days. Turtles migrated into the Gulf of Mexico (GoM), with turtles travelling between the western tip of Cuba and the Yucatan Peninsula, Mexico, and into the North Atlantic Ocean (NAO), departing the Caribbean through the passage between Dominican Republic and Puerto Rico or between Cuba and Haiti (Fig. 2). This was consistent with the migration destinations of post-nesting leatherback turtles previously tracked by STC (publication currently in review). For all the non-nesting locations, 57.5% were estimated as transit and 42.5% as ARS, suggesting overall that these leatherbacks are spending slightly more time in transit rather than in ARS. Leatherback turtles are migrating into the GoM and NAO to find foraging areas with high concentrations of jellyfish. It is

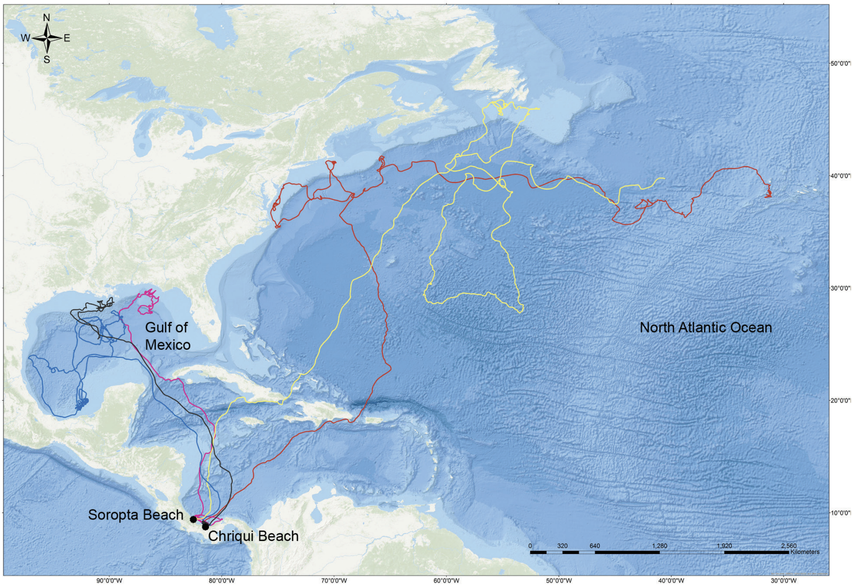

Fig. 2. Reconstructed satellite tracks (n = 7) of leatherback sea turtles tracked in 2017 from nesting beaches in Panama with a migratory route out of the Caribbean Sea. Each coloured track represents an individual leatherback turtle.

important to know the location of foraging areas in both the GoM and NAO to help guide management and conservation strategies for leatherback sea turtles. Management plans for the North Atlantic leatherback population will require continued research into leatherback foraging hot spots and areas of potential interactions with human activities, such as oil and natural gas exploration and commercial fisheries.

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