PILOT STUDY OF LOGGERHEAD TURTLES IN THE SHARK BAY WORLD HERITAGE AREA: MOVEMENTS AND COMMUNITY BASED CONSERVATION

Final Report to the Department of the Environment and Heritage

A collaborative project involving the Western Australian Department of Conservation and Land Management (CALM), Shark Bay Yadgalah Aboriginal Corporation (Inc.), Shark Bay School, Simon Fraser University, and Florida International University

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1 INTRODUCTION

Loggerhead turtles (*Caretta caretta*) are important components of marine ecosystems, where they act both as invertebrate predators and prey for large sharks (Bjorndal 2003). Loggerheads are characterized by a circumglobal distribution, which includes continental shelves, bays, estuaries, and lagoons in temperate, subtropical, and tropical waters (Bjorndal 2003). However, throughout much of their range, these turtles are in decline; indeed, the loggerhead turtle is listed (i) internationally by the IUCN as "Endangered", (ii) nationally in Australia under the *Environment Protection and Biodiversity Conservation Act 1999* as "Endangered", and (iii) in Western Australia under the *Wildlife Conservation Act 1950* as "rare and likely to become extinct".

The imperiled status of the loggerhead turtle stems largely from the complex nature of its life history characteristics relative to other reptiles and most terrestrial vertebrates. In particular, the following attributes contribute to the loggerhead's susceptibility to detrimental anthropogenic activities (Limpus 2002):

- Delayed maturity with initial breeding occurring only after several decades
- Non-annual breeding, with individuals skipping years between breeding seasons
- Given the above characteristics, a need for correspondingly high annual survival for maintenance of population stability
- Temperature dependent sex determination (female hatchlings produced on warm beaches; male hatchlings produced on cool beaches)
- Oceanic dispersal of post-hatchlings
- Recruitment of immature turtles back to coastal foraging areas separated by tens, hundreds, or thousands of kilometers from nesting beaches
- High levels of foraging site fidelity, with immature and adult animals using specific coastal feeding areas over many decades
- Migration from foraging areas to traditional nesting beaches
- Imprinting of hatchlings to their birth sites using the earth's magnetic field (presumed to be the factor enabling adults to reliably return to the region of their birth to breed)

The Shark Bay World Heritage Property (SBWHP; Figure 1) contains the largest breeding population of loggerhead turtles in Australia, and the third largest in the world. However, Limpus (2002) advises that, due to a wide and increasing range of anthropogenic activities in the region, the capacity of the SBWHP to sustain this population at its current levels should

be investigated, particularly because the maintenance of Shark Bay's loggerhead population is a critical requirement for the continued viability of the species globally.

Effective conservation of the SBWHP loggerhead turtle population requires both sound biological information and a transparent and functional community consultative process to facilitate management. The biological requirements to achieve this outcome are outlined in the *Shark Bay Marine Reserves Management Plan 1996-2006* (CALM 1996), and include research on migratory and foraging patterns.

To date, research efforts have focused primarily on the identification and assessment of nesting populations in Shark Bay. Prior to 1994, little was known about nesting animals in the SBWHP; subsequently, the Western Australian Department of Conservation and Land Management (CALM) has undertaken an annual monitoring and tagging program on the nesting beaches on Dirk Hartog Island (Figure 1). Since the inception of this initiative, CALM has determined that ~ 2,500 female loggerhead turtles nest annually in the Shark Bay region, and that this figure is subject to substantial inter-annual variation.

In 1999, researchers from Simon Fraser University, Canada (SFU; under the auspices of the Shark Bay Ecosystem Research Project, ShaBERP) initiated a complimentary tagging program involving loggerhead turtles using a large feeding ground in the Eastern Gulf of Shark Bay. Thus far, ~ 280 individual loggerheads have been captured and tagged at sea as part of this effort, which has revealed that many of the females nesting on Dirk Hartog Island migrate to the Eastern Gulf to feed (Heithaus et al. *in press*). However, many questions remain, in particular those pertaining to typical home range size, foraging areas, key habitat areas, mating areas, and the migratory paths traversed by animals between breeding and feeding zones. These questions must be answered if the threats facing loggerhead turtles in the SBWHP are to be identified and ameliorated.

The present effort builds on a previous program that commenced in 1999 to identify the movements of Shark Bay's dugongs (Holley and Gales 2003). This program was run collaboratively with the Yadgalah Aboriginal Corporation, which represents indigenous interests in the SBWHP. Following its completion, the groups involved proposed the loggerhead turtle as a species of international conservation significance that could serve as the focus of additional work designed to strengthen the relationship between the Western Australian Government and the local indigenous community.

This project is a collaborative effort between the Western Australia Department of Conservation and Land Management, the Shark Bay Yadgalah Aboriginal Corporation (Inc.), the Shark Bay School, Simon Fraser University, and Florida International University. The involvement of the Yadgalah Aboriginal Corporation is crucial to the project's success, given that the future of Shark Bay's loggerhead turtles requires genuine indigenous participation in the development of effective and broadly inclusive strategies to protect the SBWHP and its diverse fauna.

2 PURPOSE

This is the final report to the Department of Environment and Heritage detailing work carried out as part of the project, "*Pilot study of loggerhead turtles in the Shark Bay World Heritage Area: Movements and community based conservation*". The objectives of the study were:

1. **To assess the use of satellite tags to track the movements of loggerhead turtles in Shark Bay**

2. **To determine appropriate methods for the deployment of satellite tags**

3. **To collect baseline data on the movements of Shark Bay's loggerhead turtles, which ultimately should allow for an assessment of home ranges and critical habitats**

4. **To produce maps that quantify habitat types important to loggerhead turtles in the SBWHP and the depths at which they occur**

5. **To make recommendations for the conservation and management of loggerhead turtles and turtle habitat in the SBWHP, based upon project findings**

6. **To foster continued collaboration with, and participation of, the projects' consortium members (i.e., the indigenous community, the Shark Bay school, and international scientists)**

7. **To make progress toward the incorporation of baseline information into existing and future management plans relevant to turtle conservation in the SBWHP**

3 METHODS

3.1 Study Area

Shark Bay is a large (13,000 km^2), shallow (generally < 15 m) basin characterized by restricted oceanic exchange and high rates of evaporation (Logan et al. 1970; Figure 1). Containing the westernmost point along the Australian coast, the bay is located near the northern limit of a latitudinal transition region incorporating both temperate and tropical marine flora and fauna (CALM 1996). Expansive seagrass meadows cover more than 4000 km^2 of Shark Bay, and are reported to be the largest in the world (Walker 1989). Shark Bay's loggerhead turtle population falls along the southern periphery of the species' breeding range along the Western Australian coastline.

3.2 Remote Tracking

Satellite transmitter deployment occurred in Shark Bay's Eastern Gulf (ca. 25º 45'S, 113º 44' E) between 27-28 April, 2004. Three animals were instrumented with Wildlife Computers SPOT4 satellite tags (Redmond, WA USA; Figure 2) over the Cape Rose Flats, and two additional animals were equipped with similar tags near Guichenault Point (Figure 1). Both females (n = 3) and males (n = 2) were fitted with transmitters so that sex-based differences in observed movement patterns could be evaluated. Importantly, only adult animals (> 90 cm curved-carapace length) were selected for instrumentation.

Loggerhead turtles were located in shallow water (< 5 m) with the assistance of members of the Yadgalah Aboriginal Corporation, who possessed an intimate knowledge of the two capture areas. Once sighted, turtles were captured by hand following boat chases using a small vessel (4.5 m runabout, *Blowfish*). The chases, which were both brief (~ 1 min) and of low velocity (typically < 10 km h^{-1}), culminated with a designated catcher diving from the bow of the boat into the water to grab and restrain the turtle. Designated catchers included Kim Pollard (Yadgalah Aboriginal Corporation), Aaron Wirsing (Simon Fraser University), and Mike Heithaus (Florida International University); collectively, these individuals had been involved in several hundred prior turtle captures, none of which resulted in injury to the diver or the turtle. Once captured, turtles were swiftly transferred to a larger processing vessel (*Sirenia II*) for tag application.

Once aboard the processing vessel, each turtle's shell was cleaned of encrusting algae and barnacles using a hand-held paint scraper, allowed to dry for approximately 15 min, and then lightly sanded to facilitate tag adhesion. Next, a satellite tag was affixed to the shell, just behind the head near the shell's highest point (anterior to the shell's saddle; see Figure 2), with several layers of cool-setting epoxy. The epoxy was then allowed to dry fully, a process spanning approximately 20 minutes. Finally, a layer of anti-fouling paint was added to minimize the extent to which fouling agents (e.g., algae) might dampen the signals emitted by the transmitters, and the turtle was released.

Accurate communication between SPOT4 tags and overhead satellites is not possible while the tag is submerged. Consequently, the tags used in this study were equipped with saltwater switches, which ensured that each tag produced a signal only when above the ocean's surface (i.e., when the turtles breathed or rested at the surface). Moreover, the tags were programmed to establish a direct link with satellites passing overhead every second day, allowing for position fixes at two-day intervals, thereby conserving battery life.

3.3 Education

In conjunction with the Western Australia Department of Conservation and Land Management (CALM), the Shark Bay School undertook a research project involving loggerhead turtles in Term 2 of 2004. As part of this project, students (years 5-7) were required to gather information from various sources on the biology, ecology, and threats facing sea turtles. Furthermore, this project was interactive. The students were asked to name the five instrumented turtles (Buyunguarra Yajarla, Larissa, Princess Nymph, Titan, Wirriya Warda) and then to track their movements over the course of the term on a website established through a partnership between CALM and the Argos Program – http://www.monkeymia.org/Turtles/turtle_monitoring_positions.htm (also available at www.sharkbay.org). At the end of the term, the students generated a series of PowerPoint presentations, based upon their findings, which were presented to the local community in Denham.

4 RESULTS

4.1 Remote Tracking

All 5 turtles equipped with satellite tags, all had previously been marked with identification tags (titanium 'turtle' tags, attached to fore-flippers) as part of a long-term population monitoring program run jointly by CALM and researchers from Simon Fraser University. Two of the females and both males were tagged initially between 2000-2002 on their feeding grounds in the Eastern Gulf of Shark Bay (either the Cape Rose Flats or Guichenault Point). Interestingly, however, Female 2 was tagged initially on the main nesting beach on Dirk Hartog Island in 1994. Life history attributes and capture histories for each instrumented turtle are summarized in Table 1.

Since the inception of this tagging program in April, we have received a total of 521 position fixes for the turtles. At this rate, we anticipate a life of 400-600 days per tag. However, only 143 (average of 29 per animal; Table 2) of these fixes have been of sufficient quality to furnish locations accurate enough (< 3 km) for spatial analysis. Moreover, we have documented large variation in signal frequency and quality among the 5 tags. Specifically, (i) two of the tags (49542, 49546) have produced frequent, high-quality position fixes, allowing for detailed spatial analyses, (ii) two of the tags (49543, 49545) have furnished high-quality position fixes only intermittently, and (iii) one tag (49544) has rarely yielded high-quality fixes (Table 2). In fact, two tags effectively ceased transmitting just a few months after deployment (Table 2).

Since they stopped functioning within several weeks of deployment, tags 49544 and 49545 have not furnished us with data allowing for spatial analysis. In contrast, the remaining tags have yielded useful spatial information that, on a very preliminary basis, suggests sex-biased movement patterns. Specifically, since being tagged, Females 1 and 2 (tags 49542 and 49543) generally have remained within a few kilometers of their respective capture locations, and no long-distance movements have been documented to date (Figure 3). In contrast, although it showed a high degree of site fidelity (over ~ 4 months) following instrumentation, Male 5 (tag 49546) subsequently traveled > 100 km, ending up along a stretch of coastline north of Carnarvon (Figure 4). Following this large-scale movement, Male 5 has again shown strong site fidelity (Figure 4).

4.2 Education

The educational component of this project has been highly successful. Using information they gathered on loggerhead turtle biology and ecology through a search of the literature, and by monitoring the movements of the five instrumented turtles, students of the Shark Bay School entered a national competition titled "*Hands on for habitat*". For this competition, contestants selected a threatened species and then submitted (i) an illustration of the animal, (ii) a rationale for choosing the animal, (iii) an explanation of the threats facing the animal, and (iv) a proposal to help protect the animal through local action. The Shark Bay Primary

School's submission was awarded first prize for Western Australia in the senior primary school section.

A number of conservation-oriented projects have subsequently been implemented by the students of the Shark Bay School. These initiatives include:

- A beach clean-up program aimed at removing potentially harmful objects from the shoreline before they become a threat to Shark Bay's marine turtles

- An effort to encourage local businesses to sell calico rather than plastic bags, which are harmful to turtles if swallowed

- The development of a range of hand-painted greeting cards, which are being sold at the Monkey Mia visitor centre, with the proceeds going toward the protection of sea turtles

Recently, the students of the Shark Bay School won a local arts festival award for their poetry on sea turtles, which features an environmental message. Finally, a boat trip is planned for later this year, during which CALM employees will show the students how the tags were applied to the turtles and discuss the importance of the areas inhabited by these imperilled animals.

5 DISCUSSION

The results of this pilot investigation are encouraging. We needed just two days to capture and equip five loggerhead turtles with satellite tags. During the capture expedition, all participating parties (CALM, Yadgalah Aboriginal Corporation, university researchers) worked effectively and harmoniously, ensuring that no injuries occurred during the captures and, just as importantly, that all turtles were processed swiftly (< 30 minutes) and safely. Moreover, all of the instrumented animals had previously been affixed with flipper tags as part of our long-term monitoring effort in the region, providing us with life- and capture histories for the entire satellite-tagged cohort (see Table 1), and suggesting that such information will be available for many of the turtles we hope to tag in the future. Thus far, three of the five tags have supplied enough high-quality position fixes to allow for fine-scale spatial analysis, suggesting that additional tag deployments ultimately will allow for the estimation of habitat use patterns, home range sizes, and migratory paths.

Our tracking data show that two females have moved little since capture (Figure 3), but that one of the males has travelled a considerable distance after an initial period of stasis (Figure 4). Although the implications of these sexually divergent movement patterns cannot be addressed at this point given our small sample size, we are confident that future deployments will enable us to discern sex-specific movement patterns.

Though preliminary, these interesting tracking data suggest that a larger satellite tagging effort is likely to yield unprecedented and highly valuable information concerning the habitat use patterns and long-distance movements of both male and female loggerhead turtles in Shark Bay. For example, tags deployed on females nesting on Dirk Hartog Island should help to illuminate the feeding grounds from which individuals using the island as a reproductive site travel. This information will in turn help government agencies like CALM (i) measure the importance of Dirk Hartog Island as a reproductive site in relation to other nesting areas worldwide, and (ii) identify and protect feeding areas outside the confines of Shark Bay. Tags equipped to females in the Eastern Gulf, on the other hand, will allow us to ask whether some female turtles using this feeding ground nest on beaches other than those provided by Dirk Hartog Island. Finally, by attaching tags to both sexes in the Eastern Gulf, we hope to both test for sex-specific movement patterns and identify potential breeding areas in Shark Bay and elsewhere.

Aside from its many ecological applications, this effort also has resulted in the generation of an impressive, interactive website. At this site, the spatial data yielded by the tags are presented in an approachable format, allowing individuals not familiar with the project's mechanics to track the movements of the five loggerheads. Notably, access to this website has allowed students of the Shark Bay School to generate an award winning conservation project and, more importantly, prompted them to engage in a campaign to advance the cause of turtle preservation in Shark Bay. Needless to say, we are enthusiastic about continuing the educational component of this project.

The lone note of discouragement so far has been that two of the satellite tags ceased transmitting high-quality signals shortly after deployment. We believe the poor performance of these tags to be a function of algal fouling, i.e., algal build-up on the tags' saltwater switches is likely preventing the tags from turning on and/or transmitting strongly enough while the turtles surface. We have collected two pieces of evidence in support of this hypothesis: (i) after a turtle equipped with one of the moribund tags was recaptured several months following initial deployment, and the transmitter was cleaned, high-quality signals were produced for a short time; and (ii) the tag on Male 4 (49545) continues to transmit periodically, but none of its signals have been of high quality for many months. We would argue that two steps must be taken during all deployments if the likelihood of this scenario is to be minimized in the future. First, upon being attached, the saltwater switches on all tags should be given a wide buffer (~ 2 cm) that is clear of epoxy, allowing for unimpeded signal transmission. Second, turtles carrying problem tags should be recaptured periodically for a cleaning. Loggerhead turtles are generally easy to recapture (Heithaus et al. *in press*), given their pattern of site fidelity, so we do not consider this latter recommendation to be logistically difficult. In cases where tags are found to no longer be functioning, we suggest that they be removed and sent in for refurbishing (price ~ $200 US).

In summary, the outcome of this preliminary investigation suggests that an expansion of the Shark Bay loggerhead turtle tracking project is warranted. The five satellite tags deployed already have yielded interesting and useable spatial data, which have in turn galvanized a local educational and conservation effort, led by the students of the Shark Bay School. Since Shark Bay is relatively free from human disturbance, it can serve as a model system where reference data can be collected and then used to evaluate the extent of anthropogenic impacts on turtles in more exploited regions. We are confident that additional satellite tag deployments on loggerheads in Shark Bay will provide this kind of invaluable reference information, while simultaneously yielding novel insights regarding the behavior of this poorly understood species and encouraging continued community-based conservation efforts.

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Table 1. Life-history characteristics and capture histories for five loggerhead turtles equipped with satellite tags in Shark Bay, Western Australia. Note, curved carapace lengths (CCL) were measured in cm, and represent the size of the turtle on the date of its most recent capture. The general locations for each turtle's initial capture have been designated as Cape Rose Flats (CRF), Dirk Hartog Island (DHI), and Guichenault Point (GP); all fall within Shark Bay.

Turtle	Sex	Size (CCL)	Flipper Tags		Capture History		
			Left	Right	First Capture	General Location	Recaptures
1	Female	98	47347	42658	May 2000	CRF	3
2	Female	99.5	24133	24135/34592	Jan 1994	DHI	3
3	Female	95		42473	Jun 2000	GP	1
4	Male	102.5	47371	37887	Mar 2002	CRF	2
5	Male	91	47316		Mar 2002	CRF	2

Table 2. Number of high-quality position fixes (rating 0-3, Argos) furnished by SPOT4 satellite tags attached to five loggerhead turtles in Shark Bay, Western Australia. Tags were deployed on April 27-28, 2004; the last date on which a high-quality signal (< 3 km accuracy) was received from each tag has been noted (tags still functioning properly have been designated 'current').

Turtle	Tag	Fixes	Last Fix
1	49542	66	Current
2	49543	10	Current
3	49544	1	26/05/2004
4	49545	9	07/06/2004
5	49546	58	Current

Figure 1. Shark Bay, located ~ 900 km north of Perth (*a*). Loggerhead turtles (*n* = 5) were equipped with SPOT4 satellite tags in the Eastern Gulf (*b*) between April 27-28, 2004. Two shallow capture zones were utilized: the Cape Rose Flats (*CR*) and Guichenault Point (*G*). The Monkey Mia Dolphin Resort (*M*) served as a base of operations. Figure adapted from Heithaus et al. (*in press*).

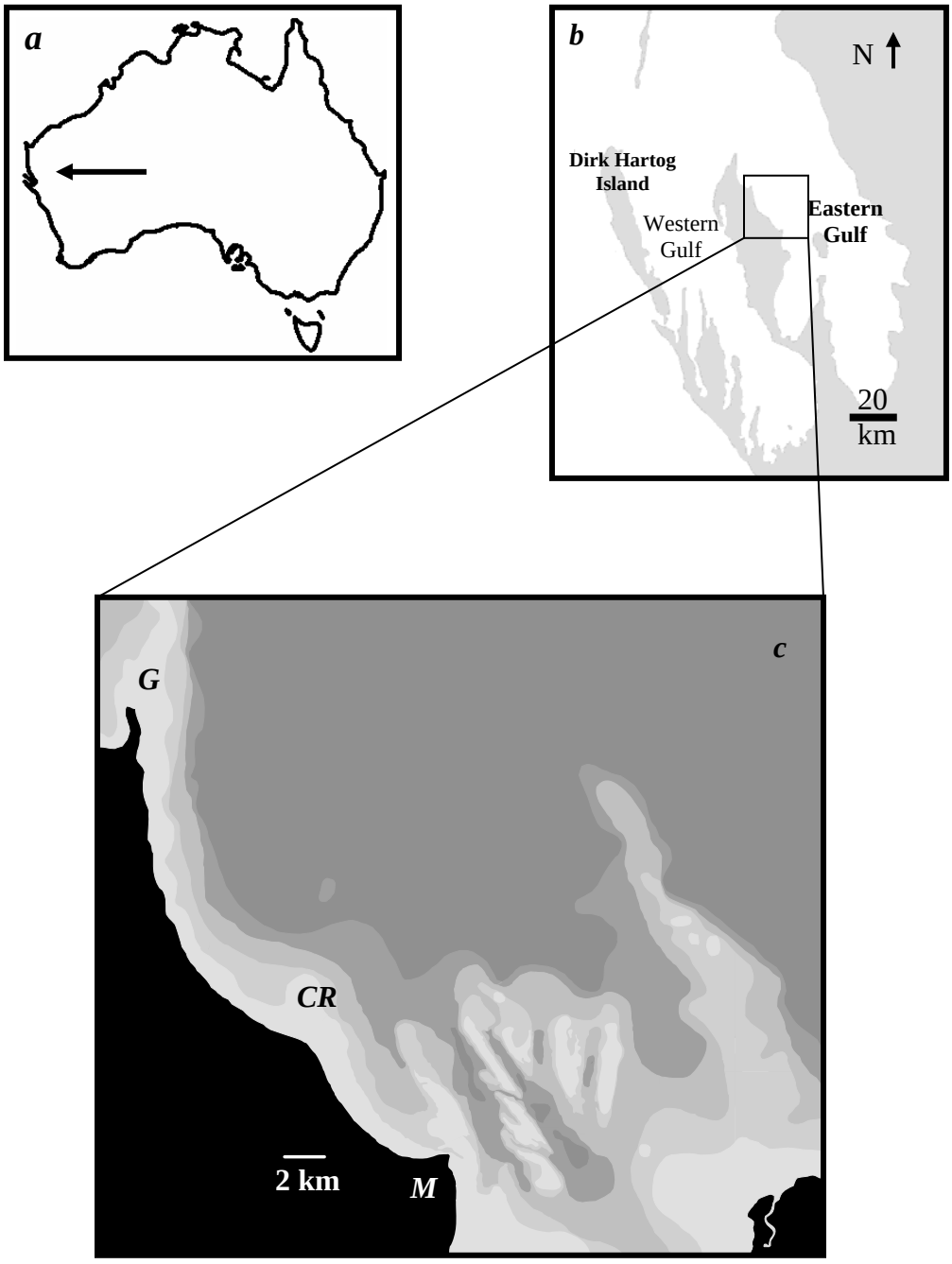

Figure 2. Loggerhead turtle equipped with a SPOT4 satellite tag from Wildlife Computers (Redmond, WA USA). The tags were mounted just behind the head using cool-setting epoxy (grey), and then coated with antifouling paint (red). Communication with overhead satellites was programmed to occur every second day post-deployment.

Figure 3. Tracks from two female loggerhead turtles equipped with SPOT4 satellite tags in the Eastern Gulf of Shark Bay (starting points denoted by an arrow). Thus far, Female 1 (circles; tag 49542) has shown a remarkable degree of site fidelity, remaining within 5 km of her initial capture location, the Cape Rose Flats. The transmitter carried by this turtle continues to link successfully with overhead satellites, yielding positions every other day. Female 2 (stars; tag 49543) also has remained relatively stationary; to date, she has traveled no farther than 10 km from her initial place of capture, Guichenault Point. Note: only high-quality position fixes (< 3 km accuracy) have been used to generate this figure; the tag on Female 1 has furnished many more such points.

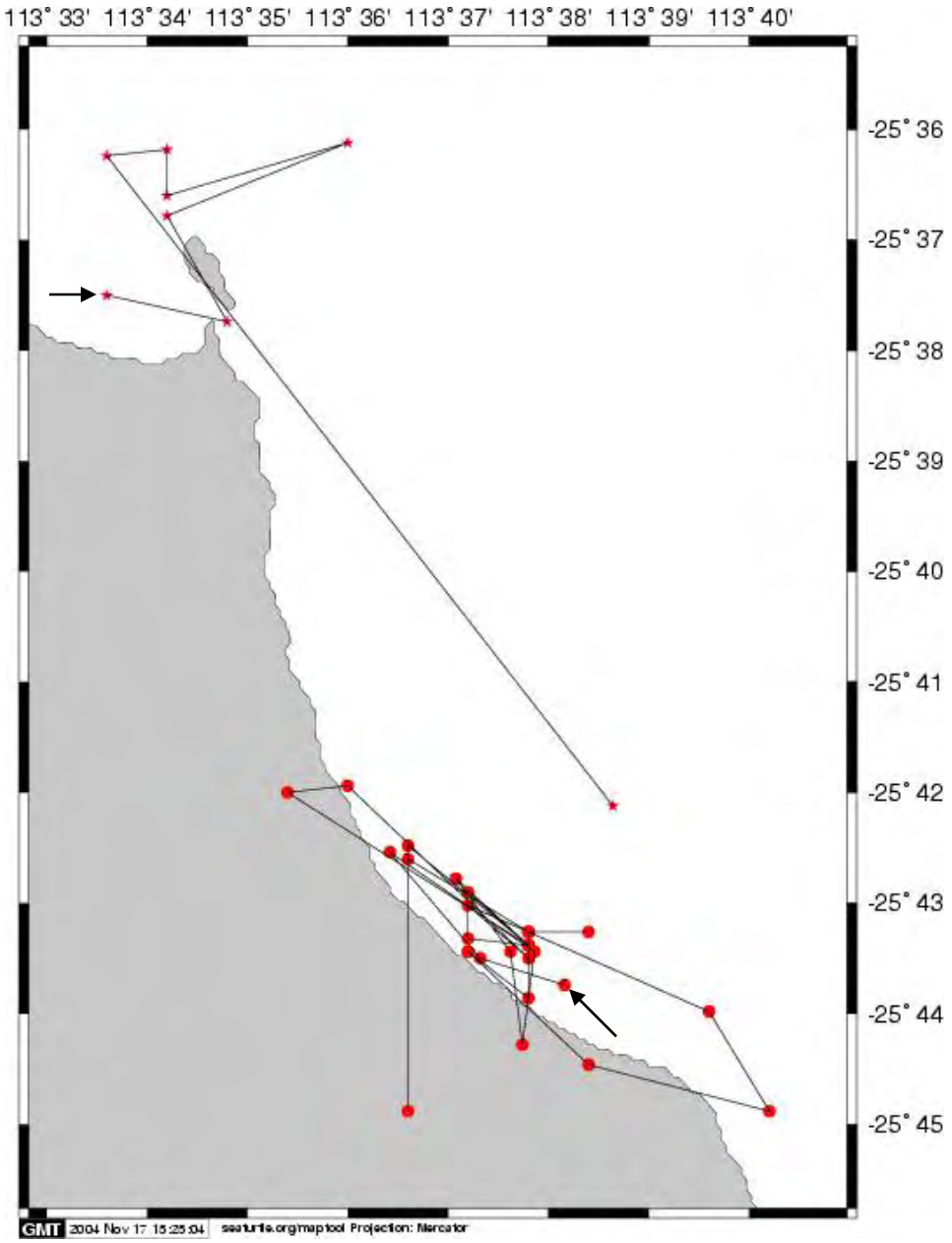

Figure 4. Tracks from a male loggerhead turtle equipped with a SPOT4 satellite tag in the Eastern Gulf of Shark Bay (starting point denoted by an arrow). This male (tag 49546) initially stayed close (< 10 km) to its place of capture (the Cape Rose Flats). However, after being monitored for four months (May-August), it traveled a distance of approximately 100 km, ending up in a coastal area near Carnarvon, where it has remained. The transmitter carried by this turtle continues to link successfully with overhead satellites, yielding positions every other day. Note: only high-quality position fixes (< 3 km accuracy) have been used to generate this figure.