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SEA TURTLE CONSERVATION

# Gnaraloo Turtle Conservation Program

## Gnaraloo Bay Rookery
## Gnaraloo Cape Farquhar Rookery

## Satellite tracking of 10 post-nesting loggerheads: Where did they go?

## Report 2015/17

www.gnaraloo.org

Gnaraloo Turtle Conservation Program - Gnaraloo Wilderness Foundation

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# 1 EXECUTIVE SUMMARY

The Gnaraloo Turtle Conservation Program (**GTCP**) of the Gnaraloo Wilderness Foundation (**GWF**) is a scientific research and public outreach program that identifies, monitors and protects sea turtle rookeries along a 65 km stretch of beach at the southern end of the Ningaloo Reef at Gnaraloo, Western Australia (**WA**). Gnaraloo is now, along with Dirk Hartog Island, recognised as one of the two index beaches for the monitoring of loggerhead turtles in WA (Hamann 2013).

In this document, we report on the first ever satellite tracking of loggerhead females that nest on the Gnaraloo coastline, a project that was undertaken by the GTCP during the sea turtle nesting season 2015/16. In total, sixteen females (average curved carapace length (**CCL**) = 96.32 cm; SD = 3.97; range = 88.5 – 100.5) from the Gnaraloo Bay Rookery (**GBR**) and the Gnaraloo Cape Farquhar Rookery (**GCFR**) were fitted with satellite trackers during December 2015 and January 2016. Six of the trackers failed to function correctly due to a software malfunction later identified by the manufacturer. The longest tracked turtle 'Caretta' broadcasted her geolocation for 404 days until 15 February 2017. The ten successful trackers averaged 237.4 days (n=10; SD = 95.63; range 103 - 404; median = 265.5).

Seven individuals re-nested after the initial tagging event, with an average of 19.14 days after the first recorded nesting (SD = 2.41; range = 17 - 22). Six turtles were recorded nesting a third time and re-nesting periods were found to be shorter for every successive clutch (mean days = 16.17; SD = 2.32; range = 14 – 20). This was found to correlate with an increase in sea surface temperature during the inter-nesting period in each case. Fidelity to rookery was found to be not fixed, as one turtle used both the GBR and GCFR for nesting.

The post-nesting migrations were completed to the turtles' respective foraging grounds in a mean of 35.4 days (SD = 56.9; range = 5 – 183). The straight line distance covered was a mean of 725 km (SD = 706.9; range = 157 – 2,281). Two main migratory directions were taken. Five tracked turtles moved south to foraging grounds around Shark Bay, migrating a distance between 157 – 289 km (mean 231.8 km; SD = 57). The other five turtles travelled northwards and then east, and ended their journey between Onslow and Darwin on the Australian coast. The northerly turtles migrated a straight line distance of between 300 – 2,281 km (mean = 1,218.4; SD = 716.11) to reach their foraging grounds. It is to be noted however that the final foraging destination for the turtle 'Marloo' is in doubt. Although she began to settle into the typical small foraging pattern of movements in her last two weeks of life in Beagle Bay near Darwin, where she was located posthumously on Melville Island after her tracker indicated she had been on the beach for over

24 hours, the subsequent necropsy found no food in her crop or upper intestines, and those movements may reflect a listless partial drifting.

Nine out of the ten tracked turtles migrated along coastal waters, however, the turtle 'Marloo' generated a unique migratory track, particularly when compared to the other four turtles that went north, who all travelled within 2 - 8 km off the Ningaloo coast for nearly 200 km. After heading northwards, Marloo stopped and went into Coral Bay for two days, and then she changed direction and headed west 200 km out into the Indian Ocean, then north and finally east across the Timor Sea. She was found dead and the subsequent necropsy indicated that she had sustained an amputation to the front left flipper which could explain the divergent and perhaps weaker swimming behaviour.

The GWF collaborated with Brains during 2015/16 to develop and use a near real-time satellite tracking app for mobile phone and computer tablets to increase community engagement and public outreach. This app tapped directly into the ARGOS PTT Tracking Database in France. The GWF established a fundraising initiative ('Name an endangered loggerhead turtle') for the public and schools to name the turtles tagged at Gnaraloo during 2015/16.

At the conclusion of the field season 2015/16, the GTCP developed and used a variety of communication and educational tools to engage the public in the findings of the satellite tracking project. This included presentations to 44 primary and high schools, 2 post-secondary institutions and 1 science fair in WA (including Carnarvon, Geraldton, Dongara, Bullsbrook, Harvey, Australind, Bunbury, Dardanup and Perth). The GTCP established a profile on *Skype in the Classroom* (Microsoft) to reach out to 5 schools located elsewhere in Australia and around the world. The GTCP researchers helped these audiences to set up and explore the Turtle Tracker App on their phone and computer devices (**Figure 6**). The GWF also promoted the satellite tracking project and the Turtle Tracker App on its website (www.gnaraloo.org) and the GTCP's Facebook page.

In conjunction with the CSIRO, the GWF developed a poster about the project for display at seminars, conferences and wide distribution to schools.

This document complements the report: Hattingh, K., Thomson, J., Goldsmith, N., Nielsen, K., Green, A. & Do, M. (2016). Gnaraloo Turtle Conservation Program (GTCP). Gnaraloo Bay Rookery and Gnaraloo Cape Farquhar Rookery, Report 2015/16. Gnaraloo Wilderness Foundation, Western Australia, www.gnaraloo.org

The data generated from this project is available to other researchers and programs, upon request to Karen Hattingh (GWF), for further collaborative analysis and research.

# 2 BACKGROUND

## 2.1 Organisation and program overview

The Gnaraloo Station Trust operates the Gnaraloo pastoral lease, which is located adjacent to the *Ningaloo Marine Park*, *Ningaloo Coast World Heritage Area* and *Ningaloo Coast National Heritage Listed Area*, approximately 1,100 km north of Perth, WA. It commenced the GTCP on-ground in 2008. While nesting occurs in lower densities along much of the Gnaraloo coastline that has sandy beaches, the GTCP currently focuses on two high density turtle rookeries: namely, the GBR (6.7 km) and GCFR (7.1 km) where loggerhead turtles (*Caretta caretta*) are the primary nesting species, with green turtles (*Chelonia mydas)* also nesting, but infrequently.

The Gnaraloo Station Trust also commenced the Gnaraloo Feral Animal Control Program (**GFACP**) in 2008 to control feral predators on turtle nests and hatchlings such as the European red fox (*Vulpes vulpes*), feral cats (*Felis catus*) and wild dogs (*Canis dingo x Canis familiaris*).

The Gnaraloo Station Trust established the GWF on 12 January 2016 as the terrestrial and marine landscapes at Gnaraloo are also habitat to many flora and fauna other than endangered and threatened sea turtles. The area is a unique and rare remaining remnant of Australian wilderness. The aim of the GWF is to protect the native terrestrial and marine flora and fauna in, on and under the landscape at Gnaraloo for present and future generations. The Foundation is a separate legal entity to the Gnaraloo Station Trust. Its Charter can be viewed at www.gnaraloo.org.

## 2.2 Loggerhead nesting in WA

All known nesting by loggerhead turtles in the southeast Indian Ocean occurs in WA (Dodd 1988; Baldwin *et al.* 2003; Wallace *et al.* 2010). Primary nesting sites are located at Dirk Hartog Island, which is situated at the southern mouth of Shark Bay; the Muiron Islands offshore of Exmouth and on mainland beaches along the Ningaloo coast from Carnarvon to Exmouth. Dirk Hartog Island hosts approximately 70% of all nesting in WA, with an estimated 1,000 – 3,000 females nesting at this site annually (Baldwin *et al.* 2003; Limpus 2009; Reinhold and Whiting 2014). In terms of mainland rookeries, the GBR and GCFR at Gnaraloo represent one of the larger known and concentrated nesting aggregations on the Ningaloo coast.

## 2.3 Value of satellite telemetry

Sea turtles are highly migratory and undertake complex movements throughout their entire life cycle (Wallace 2000). After commencing breeding, loggerhead females at Mon Repos (Queensland) return to and remain in their home foraging ground, for a mean period of 3.84 years (range = 1 - 10) (Limpus 2009), before returning to their chosen nesting site close to their natal beach. The foraging grounds can be nearby to the coastal nesting beaches or up to thousands of kilometres away. This can pose significant problems regarding their conservation due to the animal's ability to transgress multiple jurisdictions where variations in environmental conditions and lack of protection from anthropogenic threats (e.g. bycatch, pollution, harvesting) can impact their longevity. Government conservation should be viewed as a shared international responsibility as law and policies adopted by one country will be insufficient for conservation if no protection is given in countries where sea turtles migrate (Wilson 1999). Currently the foraging habitats of the Southeast Indian Ocean Management Unit are largely unstudied, except for the Eastern Gulf of Shark Bay (Heithaus *et al.* 2005) (Thomson *et al.* 2012). Although the other foraging habitats and the routes of travel to foraging habitats are largely unknown, flipper tag recoveries from loggerhead turtles tagged at Dirk Hartog Island and the Muiron Islands have identified a broad dispersal, ranging from the southwest through to Shark Bay in WA and all across Northern Australia to the Gulf of Carpentaria and to north of Java (Indonesia) (Hamann 2013). Loggerhead sea turtles are known to exhibit high levels of fidelity to migratory routes and foraging areas, after successive breeding migrations (Broderick *et al.* 2007).

The use of satellite telemetry enhances the understanding of sea turtle spatial ecology and provides insight into critical aggregation areas (Godley *et al.* 2008). Establishing significant migratory routes and destinations will enable targeted conservation management.

## 2.4 Loggerhead tracking in WA

*Foraging studies*

Five trackers were deployed in Shark Bay, 200 km to the south of Gnaraloo, on three adult females and two adult male foraging loggerheads in 2003 (Wirsing *et al.* 2004). Fourteen trackers were deployed on both sexes of adult loggerheads of the resident foraging population in the Eastern Gulf of Shark Bay, where they are found in a 1:1 male to female ratio (Heithaus *et al.* 2005). Nine trackers were deployed in Shark Bay on adult male foraging loggerheads in 2009 (Olson 2012).

*Nesting studies*

During the nesting season 2006/07, 9 trackers were deployed by the Department of Parks and Wildlife (WA) (**DPaW**) on post-nesting female loggerheads at Cape Range in the Ningaloo Marine Park. A preliminary report was published (Mau 2008) and these track maps can be seen on http://www.seaturtle.org/tracking/?project_id=265

During the nesting season 2015/16, as well as the 10 trackers deployed and posted by Gnaraloo on http://www.seaturtle.org/tracking/?project_id=1149, 5 trackers were deployed at each of Dirk Hartog Island (see http://www.seaturtle.org/tracking/?project_id=1189) and South Muiron Island (http://www.seaturtle.org/tracking/?project_id=1188) in a collaborative project between Aubrey Strydom and DPaW, to give a whole of nesting range insight into the WA loggerheads.

## 2.5 Project objectives

The objectives of the GTCP's satellite tracking project in 2015/16 of female loggerheads in the GBR and the GCFR were to:

- assess clutch frequency of re-nesting turtles;
- assess with-in season site-fidelity of re-nesting turtles;
- record inter-nesting habitat and behaviour of re-nesting turtles;
- after completion of their nesting activities, determine where the female loggerheads migrated;
- map the migratory pathway(s) between the tagged female loggerheads' nesting and home foraging sites;
- identify the tagged female loggerheads' home foraging sites;
- widely communicate and share the project findings with Government agencies, turtle scientists, interested parties and the public.

## 2.6 Outreach

Education and community engagement lie at the heart of the GTCP. Positive and lasting conservation outcomes are intrinsically linked to public education and community involvement. An increase in community engagement and awareness benefit species through informing and changing views and the values placed on them. Therefore, education and community involvement is vital to protect sea turtles at a local, regional, national and international level.

# 3 METHODOLOGY

## 3.1 Approvals

The satellite tracking project by the GTCP during 2015/16 was conducted under a Regulation 17 licence issued by DPaW under the *Wildlife Conservation Act 1950* (WA).

## 3.2 Study sites

The GBR Survey Area (-23.76708° S; 113.54584° E to -23.72195° S; 113.57750° E) is a 6.7 km long. The topography of the Gnaraloo Bay shoreline ranges from wide and flat, low-energy beaches at the southern end to narrow and steep, high-energy beaches backed by large, dynamic dune systems at the northern end. Vegetation is sparse, primarily comprising low-lying shrubs on or behind the dunes. The benthic habitat supports a coral reef system intermixed with sand-bottomed channels (Thomson *et al.* 2016).

The GCFR Survey Area (-23.61336º S; 113.64379º E to -23.57697º S; 113.69828º E) is 7.1 km long and lies 22 km north of the GBR Survey Area. The coastline here ranges from shallow protected bays with fringing coral reef to dynamic beaches with rolling waves and steep rocky outcrops.

## 3.3 Tagging

During December 2015 and January 2016, sixteen female loggerhead sea turtles were randomly selected to be satellite tagged at Gnaraloo, ten individuals at GBR and six at GCFR (**Table 1**). When encountered, turtles were approached on foot and the nesting phase was determined using the standard approach techniques described in the Ningaloo 'Turtle Watchers Code of Conduct' (DPaW 2015), to not disturb their nesting behaviour, and the Standard Operating Procedure (**SOP**) No. 12.5. (DEC 2009).

As a turtle finished nest covering and began moving toward the ocean, she was restrained and measured for two curved-carapace lengths (notch and extent) and curved carapace width. Skin biopsy samples were taken and two 'Stockbrands' titanium flipper tags in the DPaW series were applied immediately adjacent to the first scutes on the trailing edges of the front left and right flippers to allow re-identification of the animals if found stranded or if recaptured in later studies. These procedures were conducted according to SOP No. 12.5.

**Table 1: Metadata for the female loggerhead turtles satellite tagged at Gnaraloo during 2015/16**

| NO. | NAME | TAGGING DATE | GNARALOO ROOKERY | PTT | TRACKER BRAND AND MODEL | FLIPPER TAG | BIOPSY | CCL (cm) |
|---|---|---|---|---|---|---|---|---|
| 1 | Hannah | 01/12/2015 | GBR | 148590 Failed 1 | Sirtrack 'K2G' Kiwisat 202 | L) WB3652 R) WB3696 | AA55372 | 99.5 |
| 2 | Mrs Monster | 02/12/2015 | GBR | 148591 Failed 2 | Sirtrack 'K2G' Kiwisat 202 | L) WB1284 R) WB1281 | AA55655 | 98.0 |
| 3 | Tione | 02/12/2015 | GBR | 148592 Failed 3 | Sirtrack 'K2G' Kiwisat 202 | L) WB1282 R) WB1283 | AA55398 | 94.3 |
| 4 | Tanith | 03/12/2015 | GBR | 148593 Failed 4 | Sirtrack 'K2G' Kiwisat 202 | L) WB1285 R) WB1286 | AA55927 | 99.5 |
| 5 | Nerine | 03/12/2015 | GBR | 148594 Failed 5 | Sirtrack 'K2G' Kiwisat 202 | L) WB1287 R) WB1288 | AA55697 | 88.5 |
| 6 | Michelle | 04/12/2015 | GBR | 148595 Failed 6 | Sirtrack 'K2G' Kiwisat 202 | L) WB4958 R) WB4959 | AA55976 | 91.3 |
| 7 | NormAlex | 05/12/2015 | GCFR | 148582 | Sirtrack 'F4G' Fastloc GPS | L) WB4960 R) WB4961 | F6851 | 98.5 |
| 8 | Gnarly | 06/12/2015 | GBR | 148583 | Sirtrack 'F4G' ARGOS only | L) WB4962 R) WB4963 | AA55963 | 90.7 |
| 9 | Caretta | 08/01/2016 | GCFR | 148597 | Sirtrack 'F4G' Fastloc GPS | L) WB4970 R) WB4971 | F6968 | 98.3 |
| 10 | Marloo | 09/12/2015 | GBR | 157673 | Wildlife Computers 'Spot' | L) WB4964 R) WB4965 | AA55056 | 93.9 |
| 11 | Gwoonwardu | 09/12/2015 | GBR | 157674 | Wildlife Computers 'Spot' | L) WB4966 R) WB4967 | AA55392 | 100.5 |
| 12 | Oceaneve | 09/12/2015 | GBR | 157675 | Wildlife Computers 'Spot' | L) WB4968 R) WB4969 | AA55955 | 97.5 |
| 13 | Eugenie | 09/01/2016 | GCFR | 148589 | Sirtrack 'F4G' ARGOS only | L) WB4972 R) WB4973 | AA55564 | 91.5 |
| 14 | Tildy | 09/01/2016 | GCFR | 148599 | Sirtrack 'F4G' ARGOS only | L) WB4974 R) WB4975 | AA55944 | 99.5 |
| 15 | Pulsy | 10/01/2016 | GCFR | 148596 | Sirtrack 'F4G' Fastloc GPS | L) WB4976 R) WB4977 | F6835 | 99.3 |
| 16 | Constance-Winifred | 10/01/2016 | GCFR | 148598 | Sirtrack 'F4G' Fastloc GPS | L) WB4978 R) WB4979 | F6897 | 100.3 |

New techniques for restraining the turtles had to be developed to meet the constraints of

scattered nesting over the 2 x 7 km long beaches which, due to GTCP protocols to protect nesting turtles from disturbance, and hatchlings' passage to the water, is only accessible on foot. The traditional plywood restraining box is heavy and awkward to carry a long distance. The use of lightweight poles (namely broom and shovel handles) driven into the sand around the turtles had been successfully trialled during October 2014 and 2015 with green turtles on Fraser Island (Queensland). However, the difference in the sand texture, the pitch of the beach and the greater agility of the loggerheads meant that we had to constantly hold the poles in place which was onerous for the 4 - 5 hours needed to fit the tag and wait for the epoxy to set.

For the last 10 turtles, we adapted the technique used for restraining flatback turtles *(Natator depressus)* to fit their harnesses by elevating them off the beach on a box. The thought was to lift the loggerheads too, so that they could not get traction with their flippers on the sand. We designed a restraining board and placed the turtle up on a large plastic box. We trialled a few models to harness the turtle onto the board and hold her steady with cam straps.

The final model of the board was shaped from 10 ply structural pine board to provide a chin rest at the front and be as far under the plastron as possible at the front and back, to give no purchase to the flippers, and with two or four extensions: front, back and optionally centrally both sides with a hole at each end to accommodate a wooden pole driven through and into the sand to stabilize her. Slots were cut into the board at the front and rear to accommodate the 25 mm wide cam straps to harness her securely to the board, and by connecting the front and back straps on both sides with rope, she was not able to wriggle out of the cam straps. We found that we did need to restrain the flippers so that they did not rub against the edge of the board and cut her skin if she flapped her flippers about.

The turtles quickly settled down into a tonic state and later when it was time for the release, after the straps were removed, they often needed to be patted on the flippers to wake them up. (**Appendix: Photos 9 and 10**).

A mounting area of 400 mm x 400 mm on the upper carapace was cleaned and sanded by hand using scrapers and sandpaper to remove any barnacles and algal growth. The carapace was then washed with fresh water, then acetone and dried with cloths. The cool-curing 2-part epoxy glue 'Powers Pure150' was applied to the cleaned area and the satellite tracker which was then pressed into the glue. This epoxy glue (formerly branded as 'Powerfast Plus', then coloured grey) was also used in the Cape Range deployment (WA) (Mau 2008). It is used to prevent temperature-related injury to the animal, but the pay-off for its cool-curing means a longer time before it sets and turtle has to be held for a further four hours. On those occasions when a further hour was available before release (dictated by the GTCP protocol of a 8am release deadline to

avoid the sun heating up the turtles), a coat of 'Velox Plus' grey antifouling was applied on the epoxy and given an hour to dry. A few days prior to application, the transmitter itself was coated with the antifouling paint 'PropSpeed' to help reduce epibiont encrustation. Both antifouling types were found to have been ineffective when the tracker was recovered after the turtle Marloo's death in August 2016 (**Appendix: Photos 17 and 18**). In the photo, the grey Velox antifouling on the epoxy can just be discerned behind the tracker and in places the transparent PropSpeed can be seen on the tracker where there are no growths.

The satellite tags were programmed to transmit at a repetition rate of either 40 or 45 seconds when on the surface. The subsequent telemetry data was generated utilizing the Argos satellite Doppler GPS position calculations for all 10 trackers, as well as taking advantage of the higher resolution data collection capability for GPS co-ordinates from the four Sirtrack (New Zealand) Fastloc GPS enabled trackers and collecting the temperature and wet/dry data from the three WC 'Spot' trackers.

The Sirtrack GPS trackers were programmed to sample Fastloc GPS location co-ordinates every time they surfaced and every 30 minutes when hauled-out (= continuously dry for more than 5 minutes), which allows confirmation of the GPS co-ordinates on the beach as haul-out for nesting activity.

The Wildlife Computers (United States of America) 'Spot' tags transmitted the current temperature as sea surface temperature (**SST**) with every ARGOS transmission. They created and transmitted % wet/dry histograms for each hour (which enables haul-out = nesting activity for these turtles). They also transmitted % Time at Temperature histograms over 2C degree increments from 12C to 32C for 4 x 6 hourly blocks each 24-hour, starting at midnight local time. If a turtle hauls-out two or more times a night, or nights in nights-in-a-row, the earlier haul-outs are taken as Unsuccessful Nesting Attempts and the final one as nesting.

## 3.4 Outreach

The GWF ran a public turtle naming initiative prior to development and launch of the new GTCP Turtle Tracker App for smartphones ('Name an endangered loggerhead turtle', www.youcaring.com). The purpose was for the public and schools to participate and be directly engaged with the tagging project.

An advertising company (Brains, based in Sydney), in partnership with the GWF, developed an app for mobile phones and computer tablets called the GTCP Turtle Tracker App (**Figure 6**) to share the results of the project. The app was designed to use the ARGOS PTT satellite data to

track and display the movements of the 10 female loggerheads in near real-time throughout their journeys. This was made public and free for anyone to download using Apple Store or android downloads.

The GTCP encouraged schools in person and via online forums to participate with its loggerhead tracking project via enquiry-based learning projects in the curriculum areas of environmental science and geography by students and teachers downloading the app, following the results of the turtles' migration and including the turtles' migratory journeys into class syllabi.

The GTCP's education and community engagement program also included a diverse suite of onsite and offsite activities such as:

- presentations at Gnaraloo, primary and high schools, a science fair and other institutions in WA (in person) and around the world (via *Skype in the Classroom*, Microsoft);
- community and school group participation in field surveys (both day and night) of turtle track and nesting activities;
- media articles and social media.

In partnership with CSIRO, the GWF developed an educational poster highlighting the journeys of the four northern-most turtles, including the circumstances of the deceased turtle 'Marloo'. It was displayed at the 'Natural World of the Kimberley' Seminar (Western Australian Marine Science Institution and the Kimberley Society) in Perth on 15 October 2016 (**Figure 1**).

The Bardi Jawa traditional owners were kept informed of the progress of the turtle Eugenie in their traditional sea country at Pender Bay.

Knowledge sharing was undertaken with the scientific community and with various Government agencies. The GTCP sought technical advice from DPaW on establishing the Gnaraloo data on seaturtle.org. On behalf of DPaW, we inserted two flipper tags into each of the 16 turtles, and collected skin biopsy samples from each, for DPaW's use in other ongoing research projects for DNA studies and stable isotope analysis. We presented the project's findings to the Third Australian Sea Turtle Symposium in Darwin during 22 – 24 August 2016.

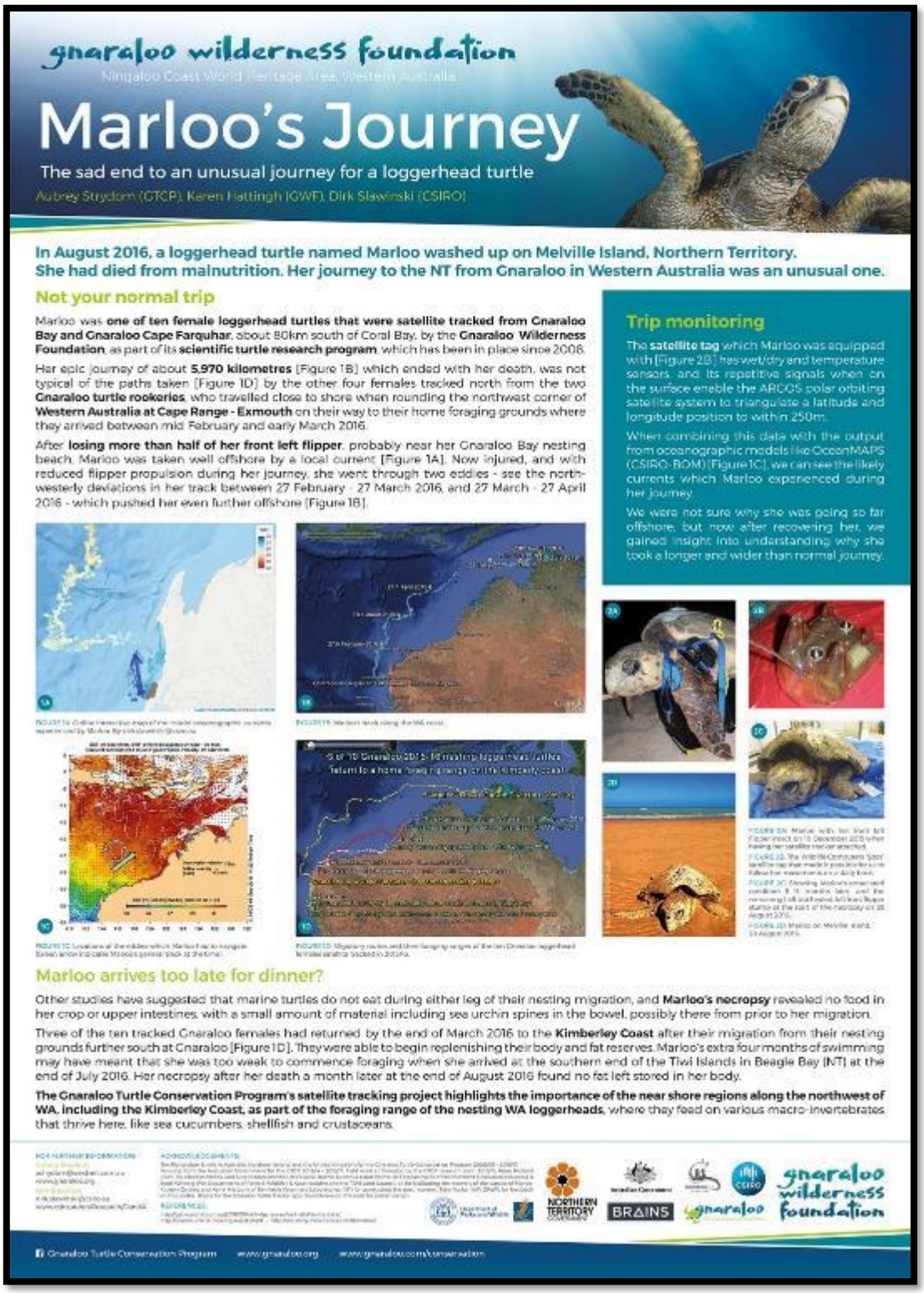



**Figure 1: GWF Poster about Marloo's journey, GTCP 2016/17**

# 4 RESULTS

## 4.1 Functionality of satellite tag units

In total, 16 female loggerheads were tagged and released over the course of this study at Gnaraloo (mean CCL = 96.32 cm; SD = 3.97; range = 88.5 – 100.5). Ten Sirtrack 'K2G' Kiwisat 202 trackers had been purchased for the project, but the first 6 deployed did not work correctly, with 2 failing completely on entry into the sea. The intermittent tracking data collected from the other 4 trackers has been excluded from this analysis, and deployment of the rest of this model tracker was discontinued on 5 December 2016. The 4 trackers were returned to the manufacturer who later identified the issue as faulty software associated with the saltwater switch. Two Sirtrack 'F4G' model and 3 Wildlife Computers 'Spot' trackers were borrowed from another project and deployed between 5 - 9 December 2015.

Three weeks later, Sirtrack sent replacement 'F4G' trackers, 5 of which were allocated to complete the Gnaraloo project. They were deployed during 8 - 11 January 2016. Upon deployment, 3 of the Sirtrack 'F4G' trackers were found initially to be operating on ARGOS only (one of them commenced sending GPS data three months later) and 2 operated correctly, both on the 45-second repetition rate for successful ARGOS fixes as well as collecting and transmitting Fastloc GPS fixes.

These events and the associated month delay resulted in data loss of two or more re-nesting events, and associated inter-nesting intervals per tracker, and of information about habitat use and possible within-season changes of rookery for the second 5 turtles. Of the 5 later tagged Gnaraloo turtles, 3 were captured on their final nest for the season. However, an advantage was that 7 of the 10 replacement trackers were models that provided higher quality additional data (4 of the 7 Sirtrack trackers provided accurate GPS fixes and haul-out indication and the 3 Wildlife Computers 'Spot' trackers provided temperature and wet/dry histograms).

The final 10 successful trackers continued to transmit data consistently from release to their last known transmission. The longest tracked turtle 'Caretta' with a Sirtrack 'F4G' Fastloc GPS broadcasted her geolocation for 404 days until 15 February 2017. The 10 successful trackers averaged 237.4 days (n=10; SD = 95.63; range = 103 - 404; median = 265.5).

## 4.2 Clutch frequency and fidelity to rookery

Seven of the 10 tagged Gnaraloo turtles re-nested after the initial nesting when they were

tagged. Of these, 5 were tagged between 5 - 9 December 2015 and 2 during 8 - 11 January 2016. Three of the females tagged in early January 2016 were on their final nesting and did not nest again.

Six females were recorded nesting 3 times over the season. The average days between nesting for the first interval was 19.14 days (SD = 2.41; range = 17 – 22). Re-nesting periods were shorter for every successive clutch laid (mean = 16.17 days; SD = 2.32; range = 14 – 20) (**Figure 2**). One female 'Caretta' re-nested once.

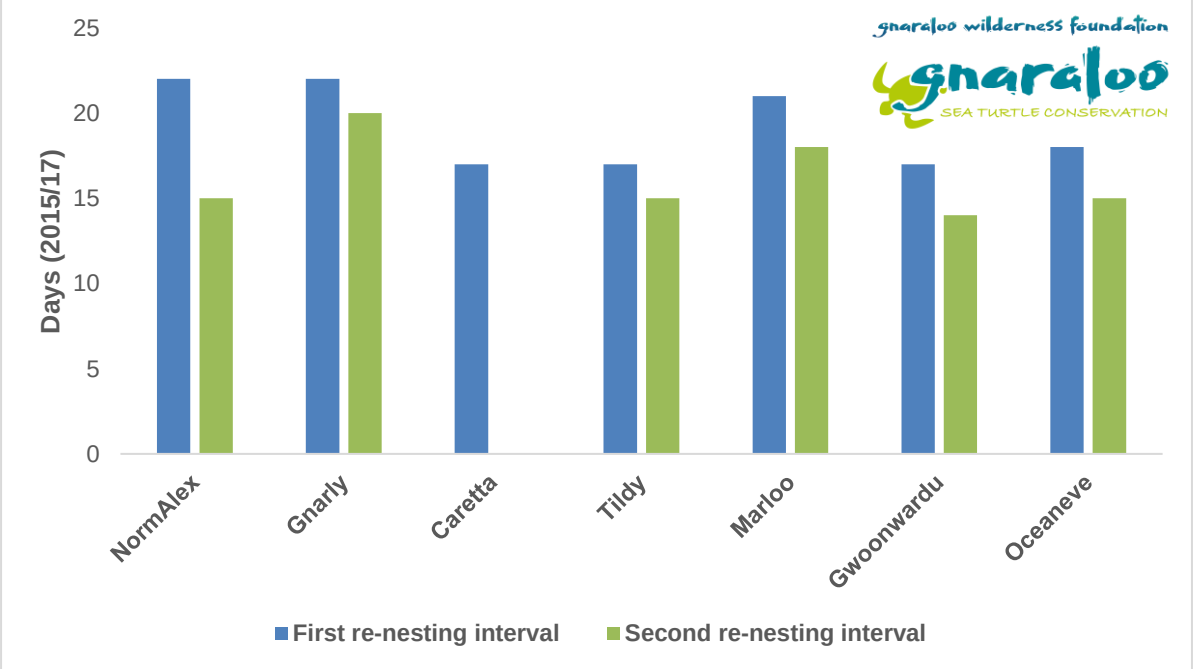



**Figure 2: Inter-nesting periods of 7 tagged Gnaraloo loggerhead turtles, GTCP 2015/16**

During the inter-nesting periods, all 7 re-nesting turtles remained in the near-shore region, either in the sheltered bays or within the fringing reefs. This contrasts with some other studies, where some turtles remained close in and others in the same rookery swam small oceanic loops during the inter-nesting periods (Rees 2010). While 6 turtles maintained fidelity to the initial rookery in which they were tagged, the turtle 'Gwoonwardu' after being tagged at the GBR, laid both her subsequent clutches at the GCFR, indicating there is some population overlap between the two rookeries at Gnaraloo.

The SST increase recorded by 3 trackers at the time of ARGOS transmissions during the December 2015 inter-nesting period in the near-shore habitat was +0.69 C, +0.21 C and -0.33 C (n = 3, Mean = 0.19 C, SD = 0.51, range = -0.33 to +0.69), and +0.49 C 12 km offshore in the

SST data sourced from the Integrated Marine Observing System (**IMOS**[1]).

## 4.3 Inter-nesting habitat and behaviour

All 10 tagged Gnaraloo females remained close to or within the fringing reef after nesting and during the inter-nesting periods. The 7 tagged turtles who re-nested were reasonably sedentary. For example, refer to the turtle 'Oceaneve' fitted with the ARGOS-only tracker with temperature and wet/dry sensors (**Map 1**) and to the turtle 'Normalex' fitted with a Fastloc GPS tracker (**Map 2**).

Superficially it would appear that 'Oceaneve' nested at both the GBR and the GCFR, but with an ARGOS-only tracker, we would have to filter or examine the fixes for the large cluster of high quality Class 3, 2 or 1 fixes usually obtained when the tracker is out of the water for the hour or two when nesting occurs. However, with this tracker's wet/dry sensor, we can tell that she did all her nesting at the GBR and spent her inter-nesting time in the water just off the GCFR. The actual area covered is much tighter than the inaccurate ARGOS 0, A and B fixes are indicating here (demonstrated by also spiking out over the land). A Fastlock GPS tracker on 'OceanEve' would have given a precision of loci similar to that of 'Normalex'.

After nesting, 'Normalex' did 3 quick loops in 2 days (15 km, 13.5 km and then 6 km to the north) and then settled into 2 very small patches 400 m and 870 m off the beach in front of her first nest. She attempted 3 nights in a row before successfully nesting twice more along this 450 m stretch of beach, over the next month. 'Normalex's inter-nesting habitat was just offshore from her 3 known clutches.

## 4.4 Post-nesting migrations and home foraging sites

Foraging destination was ascertained for all the tagged Gnaraloo turtles, except the female 'Marloo', defined as >10 days at a fixed locale, which for these animals was found to be a single small area 3 - 10 km in diameter, except for 'Normalex' who had two such locations just over 50 km apart in the western gulf of Shark Bay. After her return to foraging, she moved between these two sites four times over the seven months of the tracker's life during 24 January 2016 to 29 August 2016. See the green lines (**Map 4**).

Five turtles migrated north and five migrated south. There was no remarkable difference in size between the five turtles that went south and the five that went north from the Gnaraloo nesting

[1] http://imos.org.au/sstdata0.html

beaches. The five indivuduals who went south all went to the subtropical Shark Bay region and had a median CCL of 98.3 cm (mean CCL = 97.26 cm, SD = 3.82, range = 90.7 - 100.3). The five who went north into the tropics had a median CCL of 98.5 cm (mean CCL = 96.74 cm, SD = 3.85, range = 91.5 – 100.5).

The tracked turtles initiated their post nesting migration between 1- 10 days after their final clutch, during January and February 2016, and 9 of the 10 tagged turtles reached their neritic foraging grounds (**Map 3**)[2]. They migrated for a mean of 35.4 days (SD = 56.9; range = 5 – 183, **Figure 3**) to foraging grounds: 9 located within WA and 1 probably in the Northern Territory (**NT**).

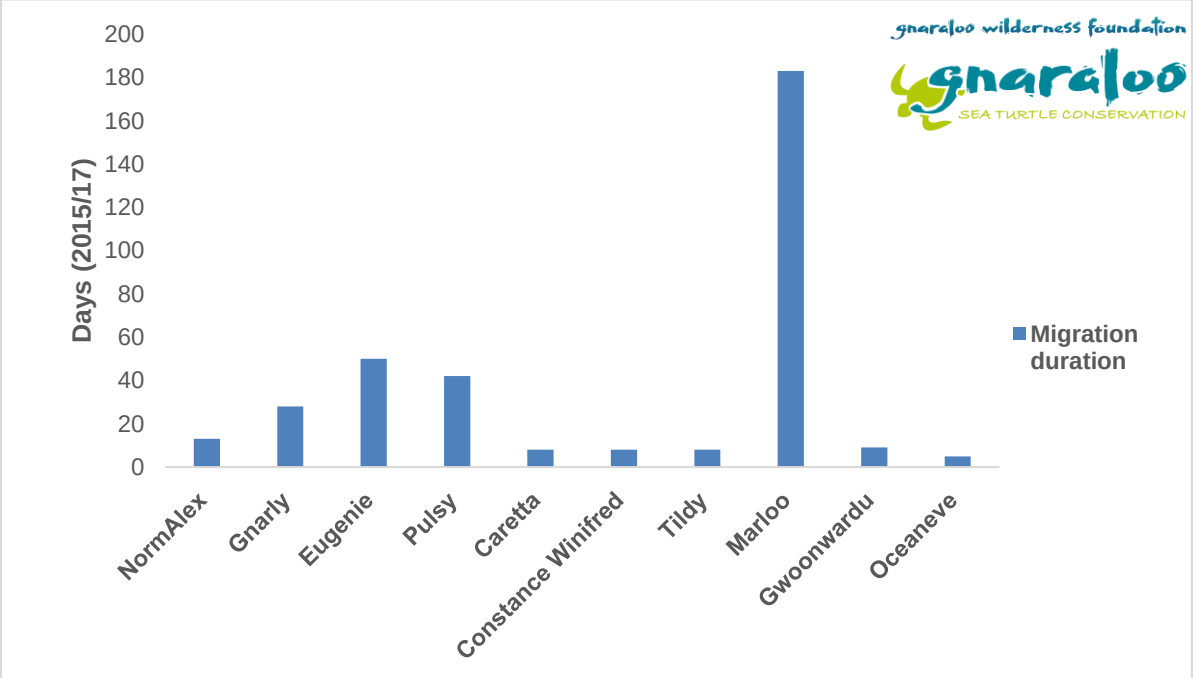



**Figure 3: Duration of the migration to their foraging grounds of the Gnaraloo female loggerhead turtles, GTCP 2015/17**

The displacement varied between individuals with all the northerly migrations greater, and 4 of them significantly greater than the rest. The five individuals that had a southerly migration travelled a mean of 231.8 km (SD = 57.0; range = 186 – 289, **Figure 4**) compared to the northerly migrating turtles with a mean of 1,218.4 km (SD = 716.1; range = 300 – 2281, **Figure 5**).

[2] As seen on the web www.seaturtle.org/tracking/?project_id=1149

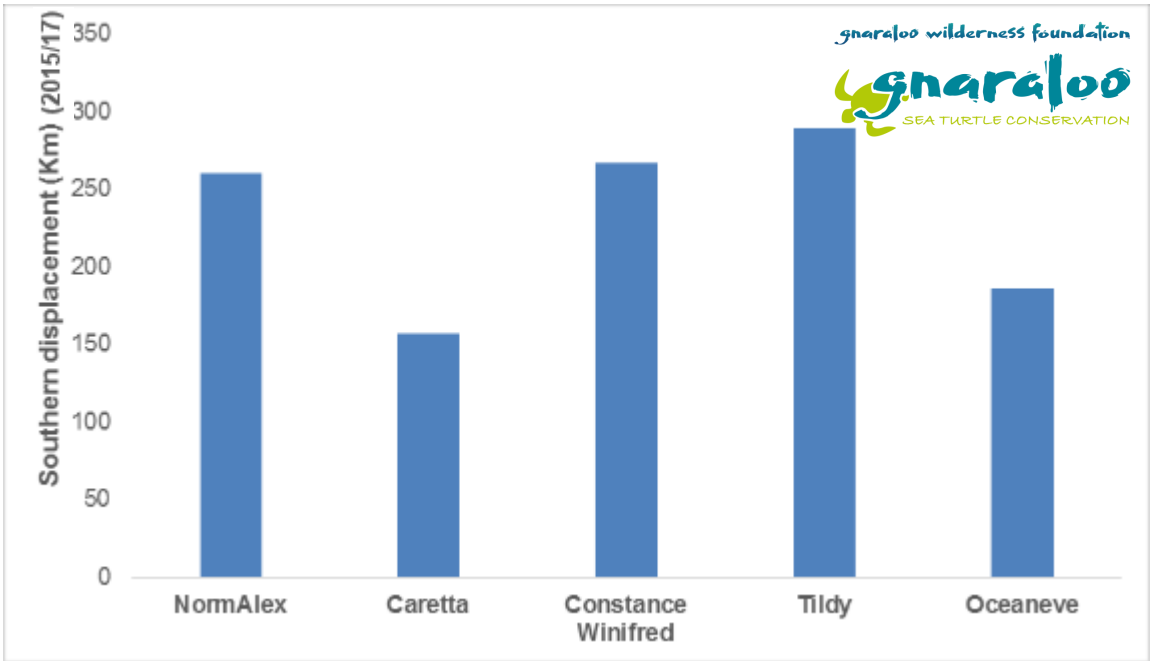



**Figure 4: Distances of the southward migrations of Gnaraloo female loggerhead turtles, GTCP 2015/17**

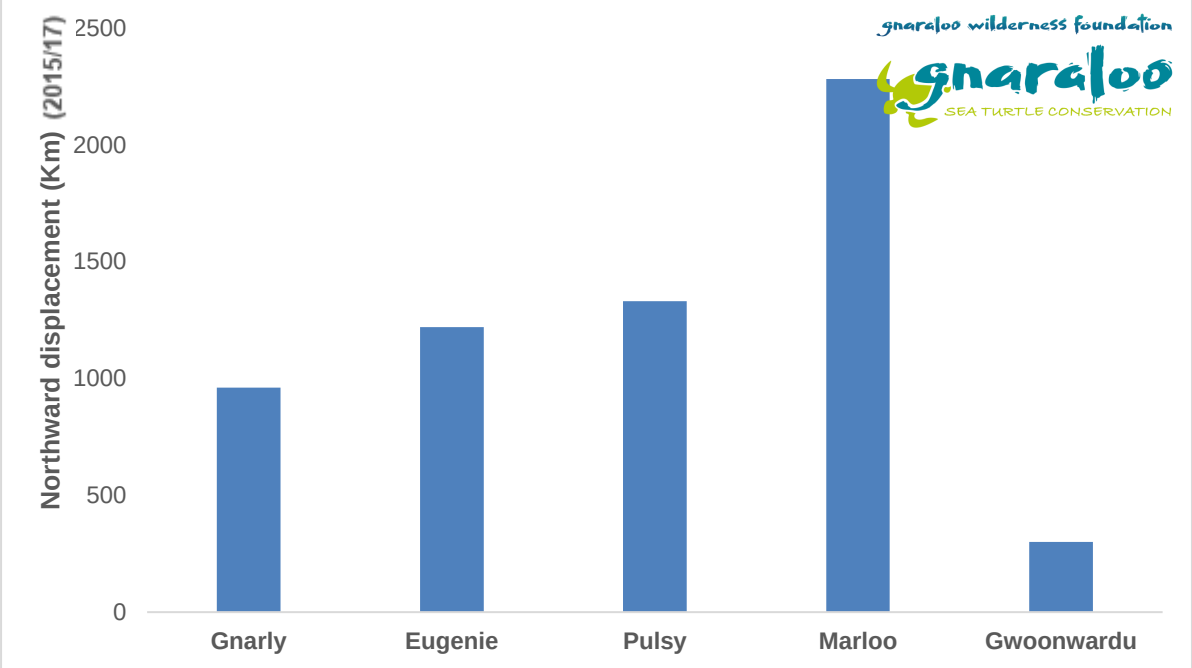



**Figure 5: Distances of the northward migrations of Gnaraloo female loggerhead turtles, GTCP 2015/17**

The minimum average speed was calculated for each turtle by elucidating the distance of the total route taken with the 'path' function on Google Earth (rather than the straight line distance traveled or the recorded distances between each of the ARGOS fixes) divided by the number of days spent migrating to get km/h (mean = 1.38 km/h, SD = 0.32, range = 0.83 -1.75).

## 4.5 A notable migration: the turtle 'Marloo'

The turtle 'Marloo', who was tagged after nesting on 9 December 2015, re-nested twice before starting her migration northwards towards Coral Bay on 29 January 2016. She then made an unusual detour and headed into the pelagic zone of the Indian Ocean on 2 February 2016 (**Map 10**). Once she left the continental shelf, she performed one clockwise loop, travelling out into the Indian Ocean and across the Timor Sea, and arrived in Beagle Bay (NT) on 28 July 2016.

She appeared superficially to move into the foraging stage, spending 7 days from 15 - 22 August 2016 along an 8 km area of coast on the southerly tip of Melville Island, but then moved 15 km northeast from there, and on 27 August 2016, we noticed that she had been 12 hours on the beach on Melville Island, about 75 km from Darwin harbor.

We contacted the Marine Ecosystems, Flora and Fauna Division of the NT Department of Land Resource Management and its Marine Threatened Species Scientist. Together with a Parks and Wildlife Commission NT officer, and with the permission of the Tiwi Island traditional landowners, they flew out in a helicopter chartered by the Marine Sciences Division of DPaW (WA), and located 'Marloo' emaciated and freshly dead on the beach. She was collected and returned to Darwin where a necropsy was performed by the NT Government's Berrimah Veterinary Laboratory a couple of days later.

Examination of 'Marloo's ovaries showed 2 – 3 mm diameter healed corpus luteum, indicating that she also nested in a prior season more than 2 years ago, and pre-vitellogenic follicles, showing that she would have bred again in a future season. Marloo also had atretic follicles – indicating the resorption of some of the current season's mature egg follicles - used to fuel longer migration to nesting by sea turtles.

'Marloo' had lost half of her front left flipper sometime after being tagged at Gnaraloo. The necropsy found the injury well healed. The necropsy indicated that she had not commenced foraging as her crop was empty and her intestines devoid of recent food.

See **Appendix C** for 'Marloo's necropsy report by Berrimah Veterinary Laboratory, provided courtesy of the Department of Environment and Natural Resources (NT).

## 4.6 Communication activities

### 4.6.1 Name an endangered loggerhead turtle initiative

The GWF invited 65 schools in WA and 30 schools on the East coast of Australia to submit proposed names for the turtles to be tagged and tracked. The Gnaraloo turtle naming initiative was very successful with 48 schools participating. The wining turtle names were: NormAlex; Gnarly; Caretta; Marloo; Gwoonwardu; Oceaneve; Eugenie; Tildy; Pulsy and Constance-Winifred.

### 4.6.2 GTCP Turtle Tracker App

The GTCP Turtle Tracker App was launched during mid-December 2015 (**Figure 6**) and recorded 1,784 downloads.

### 4.6.3 Seaturtle.org

The GTCP also set up the Gnaraloo tagging project on seaturtle.org. Seaturtle.org automatically downloaded the ARGOS Doppler data fixes from each Gnaraloo tracker every few hours. The aim of participating with seaturtle.org was to freely share the project information with the scientific world and the public. To 30 June 2016, over 5,000 views were recorded of this project.

The migratory movements of the 10 tagged Gnaraloo loggerhead turtles can be viewed on both the GTCP Turtle Tracker App on smartphones and on www.seaturtle.org[3].

[3] http://www.wildlifetracking.org/?project_id=1149

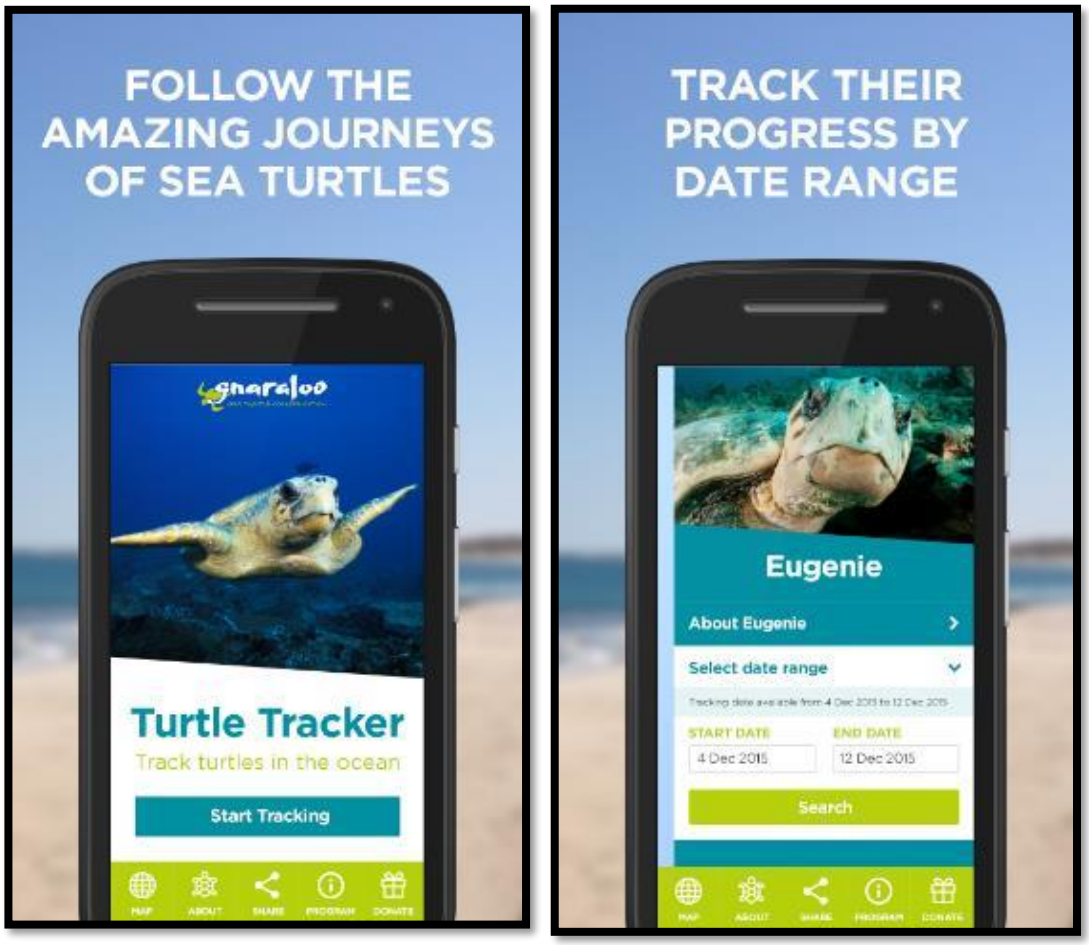



**Figure 6: New Turtle Tracker App, GTCP 2015/16**

### 4.6.4 Presentations in WA and worldwide

To 31 May 2016, the GTCP Field Research Team directly engaged with 3,846 persons in total in WA, United Kingdom, United States of America, Spain, India and Egypt. This was done partially onsite and offsite, including with the communities of Carnarvon, Geraldton, Dongara, Bullsbrook, Harvey, Australind, Bunbury, Dardanup and Perth.

The GTCP Field Research Team gave onsite presentations at Gnaraloo, including about the tagging project, to 67 people during 2015/16. This included a group of students (ages 11 – 13) and staff from the Gwoonwardu Bush Rangers in Carnarvon, who later submitted the name 'Gwoonwardu' for 1 of the 10 tagged Gnaraloo turtles. The others were guests from Gnaraloo, biologists and Government land managers such as DPaW.

Individuals came from 10 different countries[4], the majority (44) being Australian, aged between 11 – 57 years.

The GTCP Field Research Team gave offsite presentations during March – May 2016 at 44 primary and high schools. These presentations directly reached 3,104 students and 174 teachers.

The GTCP Field Research Team also gave offsite presentations to post-secondary institutions (Murdoch University and Edith Cowan University) and to the Batavia Coast Maritime Institute / Durack Institute of Technology (total of 63 persons). The team participated with a SciTech Science Festival in WA. The festival was attended by an estimated 981 local students; 157 of which participated via the GTCP stall with the tagging project.

The GTCP established a profile on *Skype in the Classroom* (Microsoft) and used YouTube to reach out to schools (5) located elsewhere in Australia and around the world, including United States of America, Spain, India and Egypt (total of 274 persons). It used YouTube to reach out to schools in the United Kingdom (7 persons).

### 4.6.5 Media and social coverage

The tagging project was featured in various media streams (including TV, print, online and radio) in WA, Australia and internationally during 2015/16. For example, ABC television and radio news crews attended Gnaraloo for interviews and filming during the tagging activities. For each media outlet and educational event, the GTCP developed and delivered specific scientific content for the target audiences. Through these activities, the schools in particular became personally invested in the well-being and progress made throughout the sea turtles' journeys.

Media coverage ranged from local and online newspapers; turtle, scientific, environmental and general interest websites; online science and news blogs; online encyclopedia; magazines; newsletters and journals.

The GTCP also shared information about the project via its Facebook page[5] and has over 3,000 followers. The GTCP also shared project information via Instagram, Twitter

[4] Namely, Australia, Canada, England, France, Germany, Ireland, Japan, Switzerland, United Kingdom, United States of America.

[5] https://www.facebook.com/gnaralooturtleconservationprogram

and YouTube.

### 4.6.6 Poster for a nature conservation seminar

The 'Natural World of the Kimberley' Seminar (Western Australian Marine Science Institution and the Kimberley Society) in Perth on 15 October 2016, where the GTCP displayed the project's educational poster, was reached 130 people.

The GTCP widely distributed the Gnaraloo tagging project poster to schools and other institutions during 2016/17.

### 4.6.7 Presentation at a turtle symposium

The Third Australian Sea Turtle Symposium in Darwin during August 2016, where the GTCP gave a presentation about the Gnaraloo tagging project, reached 100 people. The presentation summarized the migratory routes and foraging home ranges of 20 nesting loggerheads which were satellite tracked in WA during 2015/16: 10 females from Gnaraloo, 5 females from Dirk Hartog Island to the south and 5 females from South Muiron Island to the north of Gnaraloo (the latter two projects in further collaborative work between Aub Strydom and DPaW).

# 5 DISCUSSION

The PTT lifespan for the scope of this project was sufficient to see 9 female turtles established back in their home ranges for some months, and the 10th to the end of her life. Of the 16 PPT deployed, only 10 were functional for the duration of the project. The defective trackers failed due to a software malfunction later identified by Sirtrack. Fortunately, the replacement trackers provide a unique insight into elucidating the turtles' nesting behavior, migratory patterns and foraging grounds of a previously understudied population (Hamann 2013).

Inter-nesting habitat was identified for 7 of the 10 tagged individuals, with 6 re-nesting twice post tag deployment and 1 re-nesting once. Between nesting, they all used near shore waters, mostly inside the fringing reefs close to their nesting beach, and did not go more than 2 km offshore. An interesting finding in this study is that 1 of the 7 re-nesting loggerheads was shown to use both rookeries (GBR and GCFR), with the others maintaining fidelity to their rookery, namely the GBR. Inter-nesting intervals were shorter for every successive clutch, coinciding with a small seasonal increase in sea temperature, and consistent with other findings (Hays *et al*. 2002; Sato *et al*. 1998). Climate change is believed to be increasing sea surface temperatures world-wide. As the clutches laid per season is limited by the number of the follicles developed by a female loggerhead prior to the season beginning, and the number of follicles resorbed to fuel her migration, there will be an overall shortening of the total nesting season if temperatures continue to increase (Sato *et al.* 1998; Owen 1980).

The majority of loggerhead turtle nesting in WA occurs on Dirk Hartog Island, located at the southern mouth of Shark Bay, approximately 200 km southwest of Gnaraloo Bay (Baldwin *et al.* 2003). An estimated minimum of 1,000 – 3,000 females nest here annually. However, the Gnaraloo rookeries may play an important role in the dynamics of the Southeast Indian Ocean Management Unit by acting as important population buffers in response to extreme events resulting in major nest loss at the primary nesting location (Thomson *et al.* 2016).

There were two distinct post nesting movements to foraging grounds: half of the 10 tagged Gnaraloo turtles migrated south towards Shark Bay and the other half migrated north. Shark Bay is considered to be a significant foraging ground for loggerheads in WA. It provides relatively pristine habitat with minimal human influence, where turtles face greater shark related injuries than anthropogenic impacts (Heithaus *et al.* 2005).

The spatial variation and scale of the post-nesting movements from Gnaraloo generated through satellite telemetry is consistent with other loggerhead nesting populations: sea turtles are known to travel up to thousands of km to reach their foraging grounds (Zbinden *et al.* 2007; Godley *et al.* 2003). Sea turtles demonstrate high fidelity to migratory corridors (Broderick 2007). Human induced mortality

has had major impacts on sea turtle populations around the world. A reduction of anthropogenic impacts throughout the pathways during migration periods may lead to improved sea turtle population numbers, and this can only start to be achieved if these pathways are identified.

The migratory speeds of the tagged Gnaraloo turtles (average 1.38 km/h) are similar to those that have been recorded in other studies (Walllace *et al*. 2000; Zbinden *et al.* 2007). Although loggerheads can reach speeds in excess of 10km/h, it is highly unlikely that it can be sustained for long periods of time.

Adult loggerhead turtles are mostly benthic invertebrate feeders (Bjorndal 1997) and do not forage during their nesting migrations. The loss of the front left flipper of the turtle 'Marloo' sometime after being tagged at Gnaraloo could explain the unusually circuitous and long migration towards her home foraging range - which she may not have yet reached when she was found dead on Melville Island (NT) during August 2016. With more skin biopsy sampling from other turtles over the next few years, the stable isotope analysis will help to identify the location of that home range - her intended destination.

Phenotypically linked dichotomy in foraging strategies has been reported for adult loggerheads from Japan (Hatase *et al.* 2002) and the Cape Verde Islands (Hawkes *et al.* 2006). This was not the case with 'Marloo' as her crop was empty and her intestines devoid of recent food. It is suspected that she encountered a vessel or shark to sustain the injury resulting in the front left flipper amputation, and rather than choosing her atypical route, we believe that she partly drifted with the current and, with a lower propulsion efficiency, it meant that she travelled further into the pelagic ocean and took longer to get towards her home foraging ground. To further support this supposition, 'Marloo' demonstrated a lower than average speed of 0.84 $kmh^{-1}$ when compared to the other turtles in this study.

Of sampled clutches from the GBR, 86 % were found to contain multiple paternity, compared to 25 % at Bungelup Beach (Cape Range National Park) and 36 % at Dirk Hartog Island (Shark Bay) (Tedeschi 2014). At Mon Repos (Queensland), it was found to be 33 % (Harry 1988), similar to the sampled southern and northern WA rookeries. However, the Queensland male to female ratio in the foraging population is about 2:1, compared to the Shark Bay foragers at 1:1. The high figure for the GBR could point to a nearby undiscovered courting area. Annual opportunistic flipper and satellite tracking of, and skin biopsy samples from the mating loggerhead turtles which have been occasionally observed within the fringing reefs at Gnaraloo, will be valuable to gain insight into the home ranges of the male loggerhead turtles who are courting and to see if the courting females are at Gnaraloo also for nesting or just passing through.

While loggerheads are known to *not* congregate in great numbers adjacent to nesting beaches (Harry 1988), we propose to infer similar behaviour for occasional loggerheads to the greens described by Dethmers as we did not find comparable research for loggerheads. Green males return to near their natal beach for courting, and some females migrating through from distant foraging grounds on their way to their natal nesting beaches mate with these males, providing a flow of genes across into their own natal beaches (Dethmers 2006). Gnaraloo is about halfway or 200 km from the 2 major loggerhead rookeries in WA (being Dirk Hartog Island to the south and the Muiron Islands group to the north), and so is in a position for the local males to service passing females heading to both of these rookeries, and provide some of the gene flow between the southern and northern populations.

# 6 CONCLUSION

This document reports the first satellite telemetry study on the interesting habitat, re-nesting intervals, rookery fidelity, migratory pathways and foraging destinations of loggerhead turtles nesting within the GBR and the GCFR survey areas, a part of the Southeastern Indian Ocean population. This use of satellite telemetry on the GBR and GCFR sea turtles has elucidated key insights into nesting and foraging behaviour within WA's loggerhead population.

Satellite telemetry was used to assess the connectivity between the two rookeries at Gnaraloo and determined that there was an overlap between them, with one of the seven tagged female which re-nested, nesting at both sites. The successively shorter inter-nesting periods between clutches as the SST increased is consistent with other loggerhead studies.

The migratory corridors were mostly neritic and half of the 10 tagged loggerhead females went south to the well described foraging grounds at Shark Bay, and the other half to lesser known sites across the western and central tropics of northern Australia. These results suggest that these two regions represent the main foraging areas for this part of the Southeastern Indian Ocean population, but more satellite telemetry in future seasons are recommended to consolidate this and to clarify the more remote and distant outlying foraging areas used by these turtles, only some of which have been identified by flipper tag recoveries, mostly in areas where traditional and commercial harvesting, and fishery by catch has taken them.

*Further analysis of the available Gnaraloo data*

The annual population estimates for Gnaraloo since the inception of the GTCP in 2008 have been based on re-nesting interval data from other studies, which will be biased by local SST conditions, and local clutch frequency, which if using only nocturnal recapture data, may be significantly underestimated (Tucker 2010). There is the opportunity to refine these estimates for Gnaraloo by developing a better model for predicted re-nesting intervals specific to Gnaraloo's rookeries progressively during each of the past and for the future seasons as the SST changes during the season. By analyzing the temperature histogram data obtained from the 3 temperature sensor enabled trackers used during 2015/16, a better estimate of the temperature of the inshore inter-nesting habitat used by the turtles will be made. By correlating this to the closest offshore SST pixel available from IMOS, and then using this pixel as the baseline from the historical IMOS SST data over the previous seasons, it will be possible to estimate the progressive re-nesting intervals for each season at Gnaraloo. This refined estimate will still be dependent on total clutch frequency data from other studies until a larger sample of early nesting Gnaraloo turtles are satellite tracked during future seasons, to clarify the mean number of clutches by turtles using the Gnaraloo rookeries.

*Recommendation for repeat satellite tracking in a future season*

Follow-up satellite tracking studies in future are strongly recommended on the nesting Gnaraloo turtles at the very start of the season in early to mid-November, to capture animals coming in for their first nest for the season.

Use of high quality trackers that are Fastloc GPS enabled and have temperature and depth sensors will enable an expansion of the initial insights gained into rookery fidelity, inter-nesting habitat, re-nesting intervals, migratory routes and the foraging home ranges of the Gnaraloo loggerheads.

Combined with the more accurate estimates of clutch frequency gained, a refinement of the proposed model of SST driven re-nesting intervals with the larger sample thus obtained will enable more robust estimates of the population size of the two Gnaraloo rookeries.

# 7 GLOSSARY

| | |
|---|---|
| Clutch | All of the eggs deposited in a single Nest. |
| Clutch frequency | Number of clutches laid per year by an individual female. |
| GBR Survey Area | The present designated area for surveys within the GBR by the GTCP. Specifically between GBN and BP9 (inclusive of sub-sections BP7 and BP8). |
| GCFR Survey Area | The present designated area for surveys within the GCFR by the GTCP. Specifically between GRS and GLN (inclusive of sub-section GFR). |
| Inter-nesting | The period of time between a successful Nest and the next nesting attempt. Sea turtles of all species lay several clutches of eggs during a nesting season. |
| Rookery | A breeding area for a large number of animals. |
| Unsuccessful Nesting Attempt | A nesting attempt during which the turtle does not deposit any eggs, but there is evidence of digging. |

# 8 ABBREVIATIONS

| | |
|---|---|
| BP7 | Beach Point 7 (-23.75001º S; 113.56871º E). |
| BP8 | Beach Point 8 (-23.73631º S; 113.57448º E). |
| BP9 | Beach Point 9 (-23.72195º S; 113.57750º E). |
| CALM | Department of Conservation and Land Management – now DPaW. |
| CCL | Curved carapace length. |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation. |
| DEC | Department of Environment and Conservation – now DPaW. |
| DPaW | Department of Parks and Wildlife, Western Australia. |
| GBN | Gnaraloo Bay North (-23.76708º S, 113.54584º E). |
| GBR | Gnaraloo Bay Rookery, Western Australia. |
| GCFR | Gnaraloo Cape Farquhar Rookery, Western Australia. |
| GFACP | Gnaraloo Feral Animal Control Program (2008 – 2015). |
| GFR | Gnaraloo Farquhar Runway (-23.59641º S; 113.66083º E). |
| GLN | Gnaraloo Lagoon North (-23.57697º S; 113.69828º E). |
| GPS | Global Positioning System. |
| GRS | Gnaraloo Runway South (-23.61336º S; 113.64379º E). |
| GTCP | Gnaraloo Turtle Conservation Program, Western Australia. |
| GTCP Field Research Team | The seasonal GTCP Program Assistant and scientific Interns. |
| GTCP season | The standard GTCP monitoring period from 1st November each year to 28th February the following year. |
| GWF | Gnaraloo Wilderness Foundation, Western Australia. |

| | |
|---|---|
| IMOS | Integrated Marine Observing System (an Australian Commonwealth-funded body initiating and co-ordinating marine studies and data sharing). |
| Km | Kilometre. |
| $kmh^{-1}$ | Kilometre per hour |
| M | Metre. |
| Mm | Millimetre. |
| NMP | Ningaloo Marine Park, Western Australia. |
| NTP | Ningaloo Turtle Program, Exmouth, Western Australia. |
| PTT | Platform Transmitter Terminal. |
| SOP | Standard Operating Procedure. |
| SST | Sea surface temperature. |
| WA | Western Australia. |

# 9 REFERENCES

Baldwin, R., Hughes, G., Prince, R. (2003). Loggerhead turtles in the Indian Ocean. *Loggerhead sea turtles*. Smithsonian Books. pp 218-232.

Bjorndal, K.A. (1997). Foraging ecology and nutrition of sea turtles. *The biology of sea turtles*. pp 199-231.

Broderick, A.C., Coyne, M.S., Fuller, W.J., Glen, F., and Godley, B.J. (2007). Fidelity and over-wintering of sea turtles. *The Royal Society Biology*. Volume 274.

Bugoni, L., Krause, L., and Petry, M. (2001). Marine Debris and Human Impacts on Sea Turtles in Southern Brazil. *Marine Pollution Bulletin*. Volume 42, issue 12: pp 1330-1334.

DEC Animal Ethics Committee. (2009). Marking of marine turtles using flipper and PIT tags. *DEC Nature Conservation Service, Biodiversity, Standard Operating Procedure*. Perth. WA: Western Australian Governement.

Dethmers, K.E.M., Broderick, D., Moritz, C., Fitzsimmons, N.N., Limpus, C.J., Lavery, S., Whiting, S., Guinea, M., Prince, R.I.T., and Kennett, R. (2006). The genetic structure of Australasian green turtles (Chelonia mydas); exploring the geographical scale of genetic exchange. *Molecular Ecology.* Blackwell Publishing.

Dodd, C K. (1988). Synopsis of the biological data on the loggerhead sea turtle Caretta caretta (Linnaeus 1758). *Fish and Wildlife Service Biological Report.* Volume 88, issue 14: pp 1-110.

DPaW (2015). Ningaloo Turtle Program - http://www.ningalooturtles.org.au (accessed 11/01/2015).

Godley, B.J., Broderick, A.C., Glen, F. and Hays, G.C. (2003). Post-nesting movements and submergence patterns of loggerhead marine turtles in the Mediterranean assessed by satellite tracking. *Journal of Experimental Marine Biological Ecology*. pp 119-134.

Godley, B.J., Richardson, S., Broderick, A.C., Coyne, M.S., Glen, F., Hays, G.C. (2002). Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. *Ecography*. Volume 25: pp 352–362.

Godley, B.J., Blumenthal, J.M., Broderick, A.C., Coyne, M.S., Godfrey, M.H., Hawkes, L.A., Witt, M.J. (2008). Satellite tracking of sea turtles: Where have we been and where do we go next? *Endangered Species Research.* Volume 4: pp 3-22.

Hamann, M., Kamrowsk, I.R.L., and Bodine, T. (2013). Assessment of the conservaton status of the loggerhead turtle in the Indian Ocean and South-East Asia. *IOSEA Marine Turtle MoU Secretaria.*: Bankok. pp 40-45.

Harry, J.L., and Briscoe, D.A. (1988). Multiple paternitiy in the loggerhead turtle (Caretta caretta).*Journal of Heredity.* Volume 79, Issue 2: 96-99.

Hatase, H,, Takai, N., Matsuzawa, Y., Sakamoto, W., Omuta, K., Goto, K., Arai, N., Fujiwara, T. (2002). Size-related differences in the feeding habitat use of adult female loggerhead turtles Caretta caretta around Japan determined by stable isotope analyses and satellite telemetry. *Marine Ecology Progress Series.* Volume 233: pp 273 – 281.

Hattingh, K., Thomson, J., Goldsmith, N., Nielsen, K., Green, A. & Do, M. (2016). Gnaraloo Turtle Conservation Program (GTCP). Gnaraloo Bay Rookery and Gnaraloo Cape Farquhar Rookery, Report 2015/16. *Gnaraloo Wilderness Foundation*, Western Australia, www.gnaraloo.org, pp 1–86.

Hays, G.C., Broderick, A.C., Glen, F., Godley, B.J., Houghton, J.D.R. and Metcalfe J.D. (2002). Water temperature and internesting intervals for loggerhead (*Caretta caretta*) and green (*chelonia mydas*) sea turtles. *Jounal of Thermal Biology*: Volume 27: pp 429-432.

Hawkes, L.A., Broderick, A.C., Coyne, M.S., Godfrey, M.H., Lopez-Jurado, L.F., Lopez-Suarez, P., Merino, S.E., Varo-Cruz, N., Godley, B.J. (2006). Phenotypically Linked Dichotomy in Sea Turtle Foraging Requires Multiple Conservation Approaches. *Current Biology*. Volume 16, issue 10: pp 990-995.

Heithaus, M.R., Frid, A., Wirsing, A.J., Bejder, L., and Dill, L.M. (2005). Biology of sea turtles under risk from tiger sharks at a foraging ground. M*arine Ecology Progress Series.* Volume 288: pp 285-294.

Lasala, J.A., Harrison, S.J., Williams, K.L., and Rostal, D.C. (2013). Strong male-biased operational sex ratio in a breeding population of loggerhead turtles (Caretta caretta) inferred by paternal genotype reconstruction analysis. *Ecology and Evolution.* Volume 3, issue 14: pp 4736-4747.

Lewison R.L., Crowder L.B. (2006). Putting Longline Bycatch of Sea Turtles into Perspective. *Conservation Biology*. Volume 21, issue 1: pp 79 - 86.

Limpus, C J. (2009). A biological review of Australian Marine Turtles. *Queensland Enviromental Protection Agency*.

Markovina, K., and Prophet, M. (2014). Ningaloo Turtle Program Annual Report 2013 - 2014. Exmouth, Western Australia: *Department of Parks and Wildlife and the Ningaloo Turtle Program*.

Mau, R., Halkyard, B., Hughes, M. (2008). Satellite Tracking of Loggerhead Turtles (Caretta caretta) at Ningaloo Marine Park. Exmouth, Western Australia: Exmouth District, *Department of Environment and Conservation.*

Olson, E.L., Salomon, E.K., Wirsing, A.J., and Heithaus, M.R. (2012). Large-scale movement patterns of male loggerhead sea turtles (Caretta caretta) in Shark Bay, Australia. *CSIRO Publishing, Marine and Freshwater Research*. Volume 63: pp 1108-1116.

Owens, D.W.M. (1980). "The Comparative Reproductive Physiology of Sea Turtles. *American Zoologist*. Volume 20, issue. 3: pp 549-563.

Rees, A.F., Al Saady, S.A., Broderick. A.C., Coyne, M.S., Papathanasopoulou, N., and Godley, B.J. (2010). Behavioural polymorphism in one of the world's largest populations of loggerhead sea turtles *Caretta caretta*. *Marine Ecology Progress Series.* Volume 418: 201-212.

Reinhold, L., and Whiting., A. (2014). High density Loggerhead sea turtle nesting at Dirk Hartog Island, Western Australia *Marine Turtle Newsletter*. Volume 141: pp 7-10.

Sato, K., Matsuzawa, Y., Tanaka, H., Bando, T., Minamikawa, S., Sakamoto, W. and Naito, Y. (1998). Internesting intervals for loggerhead turtles, (*Caretta caretta*), and green turtles, (*Chelonia mydas*), are affected by temperature. *Canadian Journal of Zoology*. Volume 76, issue 9: pp 1651-1662.

Strydom, A., Hattingh, K., Whiting, S. and Tucker, A. (2016). Satellite Tracking 20 Post-Nesting Western Australian Loggerheads (*Caretta caretta*) in the 2015-16 Season. 3rd Austaliasian Sea Turtle Symposium, *Darwin: AusTurtle.*

Tedeschi, J.N., Mitchell, N.J., Berry, O., Whiting, S., Meekan, M. and Kennington, W.J. (2014). Reconstructed parental genotypes reveal variable rates of multiple paternity at threes rookeries of loggerhead sea turtles (*Caretta caretta*) in Western Australia: *Australian Journal of Zoology*: http://dx.doi.org/10.1071/ZO14076.

Thomson, J.A., Heithaus, M.R., Burkholder, D.A., Vaudo, J.J., Wirsing, A.J., and Dill, L.M. (2012). Site specialists, diet generalists? Isotopic variation, site fidelity, and foraging by loggerhead turtles in Shark Bay, Western Australia. *Marine Ecology Progress Series.* Volume 453: pp 213-226.

Thomson, J. A., Hajnoczky, N., and Hattingh, K. (2016). The Sea Turtle Rookery at Gnaraloo Bay, Western Australia: Using Nocturnal Observations to Validate Diurnal Track Interpretations. *Chelonian Conservation Biology*. pp 187-196.

Tucker, A D. (2010). Nest site fidelity and clutch frequency of loggerhead turtles are better elucidated by satellite telemetry than by nocturnal tagging efforts: Implications for stock estimation. *Journal of Experimental Marine Biology and Ecology*. pp 48-55.

Wallace, B. P., DiMatteo, A. D., Hurley, B. J., Finkbeiner, E. M., Bolten, A. B., Chaloupka, M. Y., Hutchinson, B. J., Abreu-Grobois, F. A., Amorocho, D., Bjorndal, K. A., Bourjea, J., Bowen, B. W., Briseño Dueñas, R., Casale, P., Choudhury, B. C., Costa, A., Dutton, P. H., Fallabrino, A., Girard, A., Girondot, M., Godfrey, M. H., Hamann, M., López-Mendilaharsu, M., Marcovaldi, M. A., Mortimer, J. A., Musick, J. A., Nel, R., Pilcher, N. J., Seminoff, J. A., Troëng, S., Witherington, B. and Mast, R. B. (2010). Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales. *PLoS ONE*. Volume 5, Issue 15465.

Wallace, N.J., Resendiz, A. and Seminoff, J., Resendiz, B. (2000). Transpacific Migration of a Loggerhead Turtle Monitored by Satellite Telemetry. *Bulletin of Marine Science*. Volume 67, issue 3: pp 937-947.

Whiting, A. (2016). Estimating abundance and detecting trends for green, loggerhead and hawksbill turtles nesting within the Ningaloo region: 2013-14 to 2015-16 seasons*. Report to the Department of Parks and Wildlife,* Exmouth, WA, August 2016: http://www.ningalooturtles.org.au/media_reports.html, Accessed February 2017.

Wilson, C. and Tisdell, C. (1999). Sea turtles as a non-consumptive tourism resource especially. *science direct (Tourism Management)*. Volume 22, issue 3: pp 279–288.

Wirsing, A.J., Crane, K., Heithaus, M.R., Charles, D. and Dill, L.M. (2004). Pilot study of Loggerhead turtles in the Shark Bay World Heritage Area: Movements and community based conservation. *Department of Conservation and Land Management: Shark Bay District*. Denham, Western Australia.

Zbinden, J.A., Aebischer, A., Margaritoulis, D. and Arlettaz, R. (2007a). Important areas at sea for adult loggerhead sea turtles in the Mediterranean Sea: satellite tracking corroborates findings from potentailly biased sources. *Marine Biology*. Volume 153: pp 899-906.

Zbinden, J. A., Aebisher, A., Margaritoulis, D. and Arlettaz, R. (2007b). Insights into the management of sea turtle internesting area through satellite telemetry. *Biology conservation*: pp 157-162.

# APPENDICES

# APPENDIX A: PHOTO PLATES

1. **Tagged turtle 'Hannah' at Gnaraloo, 01/12/2015, GTCP 2015/16**
2. **Tagged turtle 'Mrs Monster' at Gnaraloo, 02/12/2015, GTCP 2015/16**
3. **Tagged turtle 'Tione' at Gnaraloo, 02/12/2015, GTCP 2015/16**
4. **Tagged turtle 'Tanith' at Gnaraloo, 03/12/2015, GTCP 2015/16**
5. **Tagged turtle 'Nerine' at Gnaraloo, 03/12/2015, GTCP 2015/16**
6. **Tagged turtle 'Michelle' at Gnaraloo, 04/12/2015, GTCP 2015/16**
7. **Tagged turtle 'NormAlex' at Gnaraloo, 05/12/2015, GTCP 2015/16**
8. **Tagged turtle 'Gnarly' at Gnaraloo, 06/12/2015, GTCP 2015/16**
9. **Tagged turtle 'Caretta' at Gnaraloo, 08/12/2015, GTCP 2015/16**
10. **Tagged turtle 'Marloo' at Gnaraloo, 09/12/2015, GTCP 2015/16**
11. **Tagged turtle 'Gwoonwardu' at Gnaraloo, 09/12/2015, GTCP 2015/16**
12. **Tagged turtle 'OceanEve' at Gnaraloo, 09/12/2015, GTCP 2015/16**
13. **Tagged turtle 'Eugenie' at Gnaraloo, 09/12/2015, GTCP 2015/16**
14. **Tagged turtle 'Tildy' at Gnaraloo, 09/12/2015, GTCP 2015/16**
15. **Tagged turtle 'Pulsy' at Gnaraloo, 10/12/2015, GTCP 2015/16**
16. **Tagged turtle 'Constance-Winifred' at Gnaraloo, 10/12/2015, GTCP 2015/16**
17. **Marloo's PTT tracker before 8.5 months at sea, GTCP 2015/16**
18. **Marloo's PTT tracker after 8.5 months at sea, GTCP 2015/17**

**Photo 1: Tagged turtle 'Hannah' at Gnaraloo, 01/12/2015, GTCP 2015/16**

**Photo 2: Tagged turtle 'Mrs Monster' at Gnaraloo, 02/12/2015, GTCP 2015/16**

**Photo 3: Tagged turtle 'Tione' at Gnaraloo, 02/12/2015, GTCP 2015/16**

**Photo 4: Tagged turtle 'Tanith' at Gnaraloo, 03/12/2015, GTCP 2015/16**

**Photo 5: Tagged turtle 'Nerine' at Gnaraloo, 03/12/2015, GTCP 2015/16**

**Photo 6: Tagged turtle 'Michelle' at Gnaraloo, 04/12/2015, GTCP 2015/16**

**Photo 7: Tagged turtle 'NormAlex' at Gnaraloo, 05/12/2015, GTCP 2015/16**

**Photo 8: Tagged turtle 'Gnarly' at Gnaraloo, 06/12/2015, GTCP 2015/16**

**Photo 9: Tagged turtle 'Caretta' at Gnaraloo, 08/12/2015, GTCP 2015/16**

**Photo 10: Tagged turtle 'Marloo' at Gnaraloo, 09/12/2015, GTCP 2015/16**

**Photo 11: Tagged turtle 'Gwoonwardu' at Gnaraloo, 09/12/2015, GTCP 2015/16**

**Photo 12: Tagged turtle 'OceanEve' at Gnaraloo, 09/12/2015, GTCP 2015/16**

**Photo 13: Tagged turtle 'Eugenie' at Gnaraloo, 09/12/2015, GTCP 2015/16**

**Photo 14: Tagged turtle 'Tildy' at Gnaraloo, 09/12/2015, GTCP 2015/16**

**Photo 15: Tagged turtle 'Pulsy' at Gnaraloo, 10/12/2015, GTCP 2015/16**

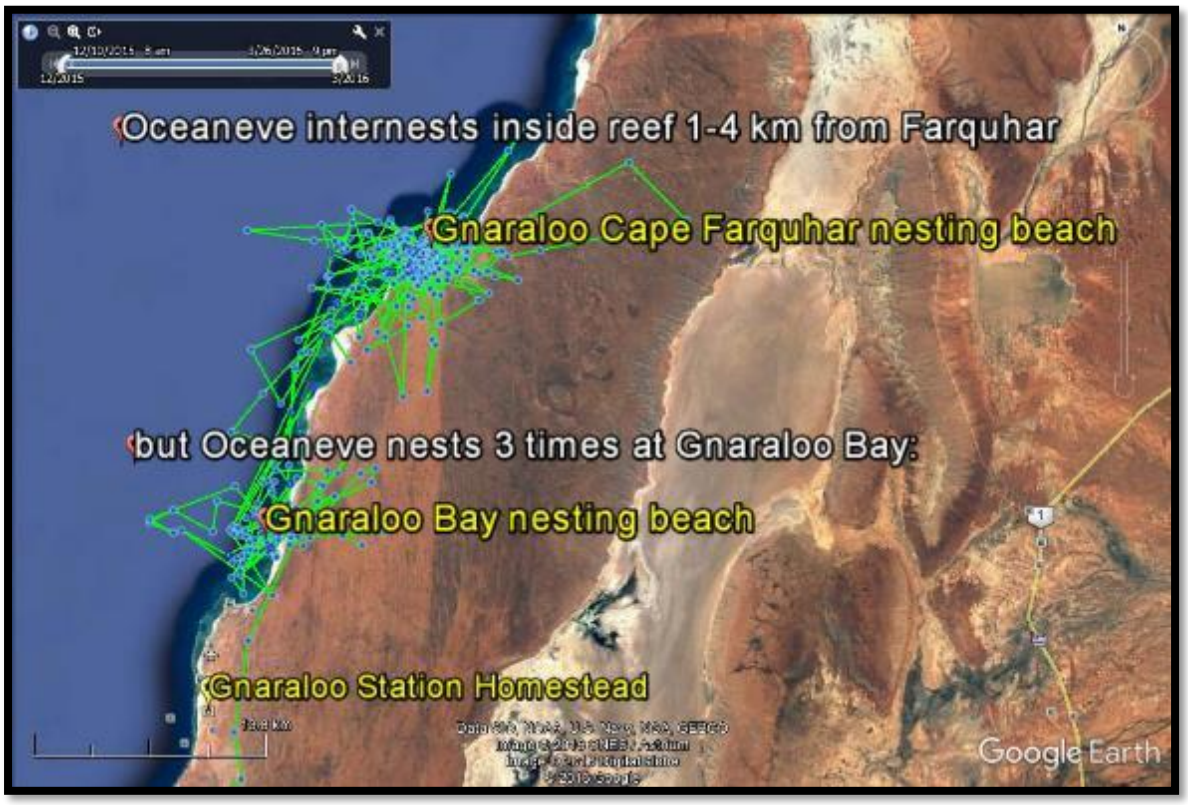
**Photo 16: Tagged turtle 'Constance-Winifred' at Gnaraloo, 10/12/2015, GTCP 2015/16**

**Photo 17: Marloo's PTT tracker before 8.5 months at sea GTCP 2015/16**

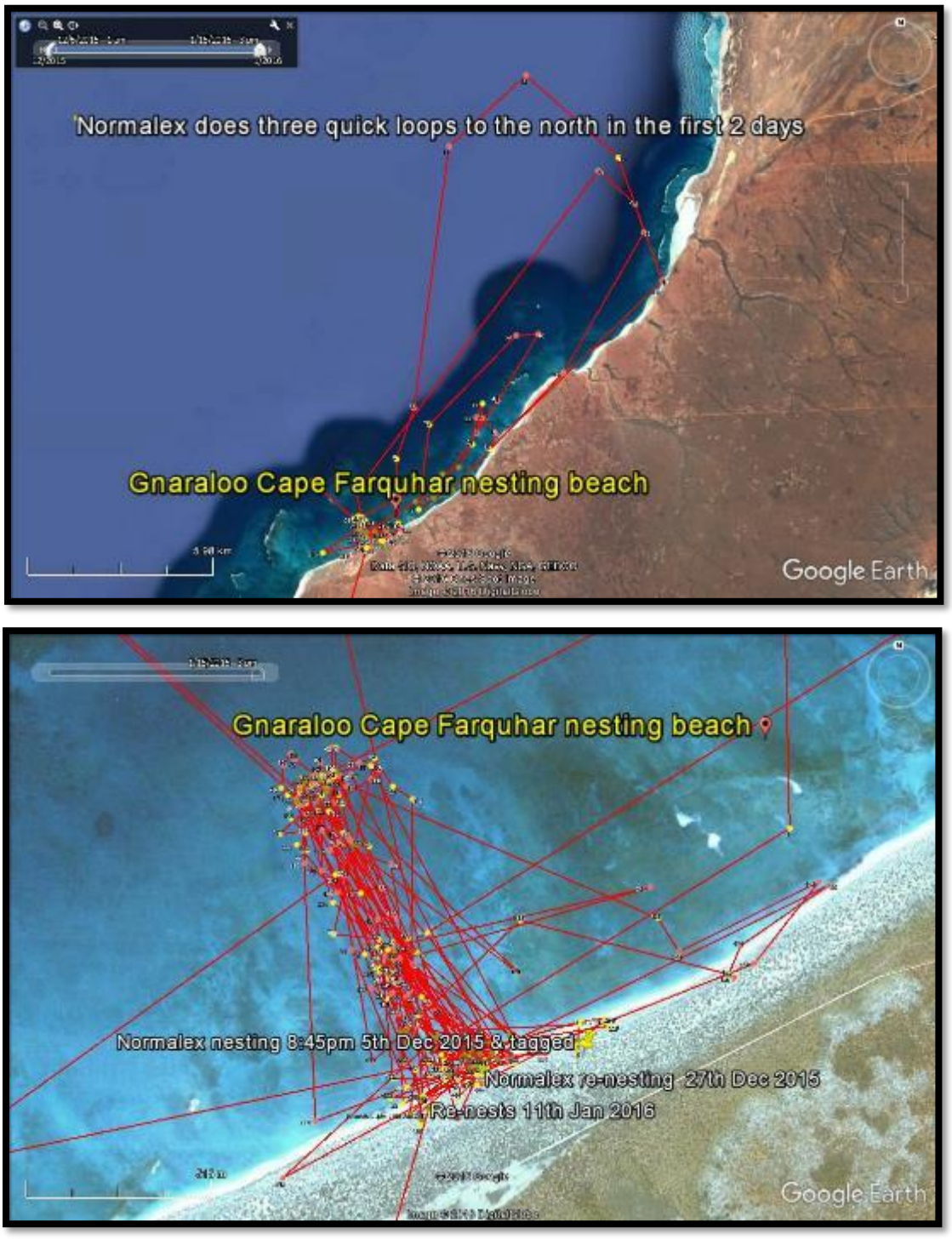
**Photo 18: Marloo's PTT tracker after 8.5 months at sea, GTCP 2015/17**

# APPENDIX B: MAPS

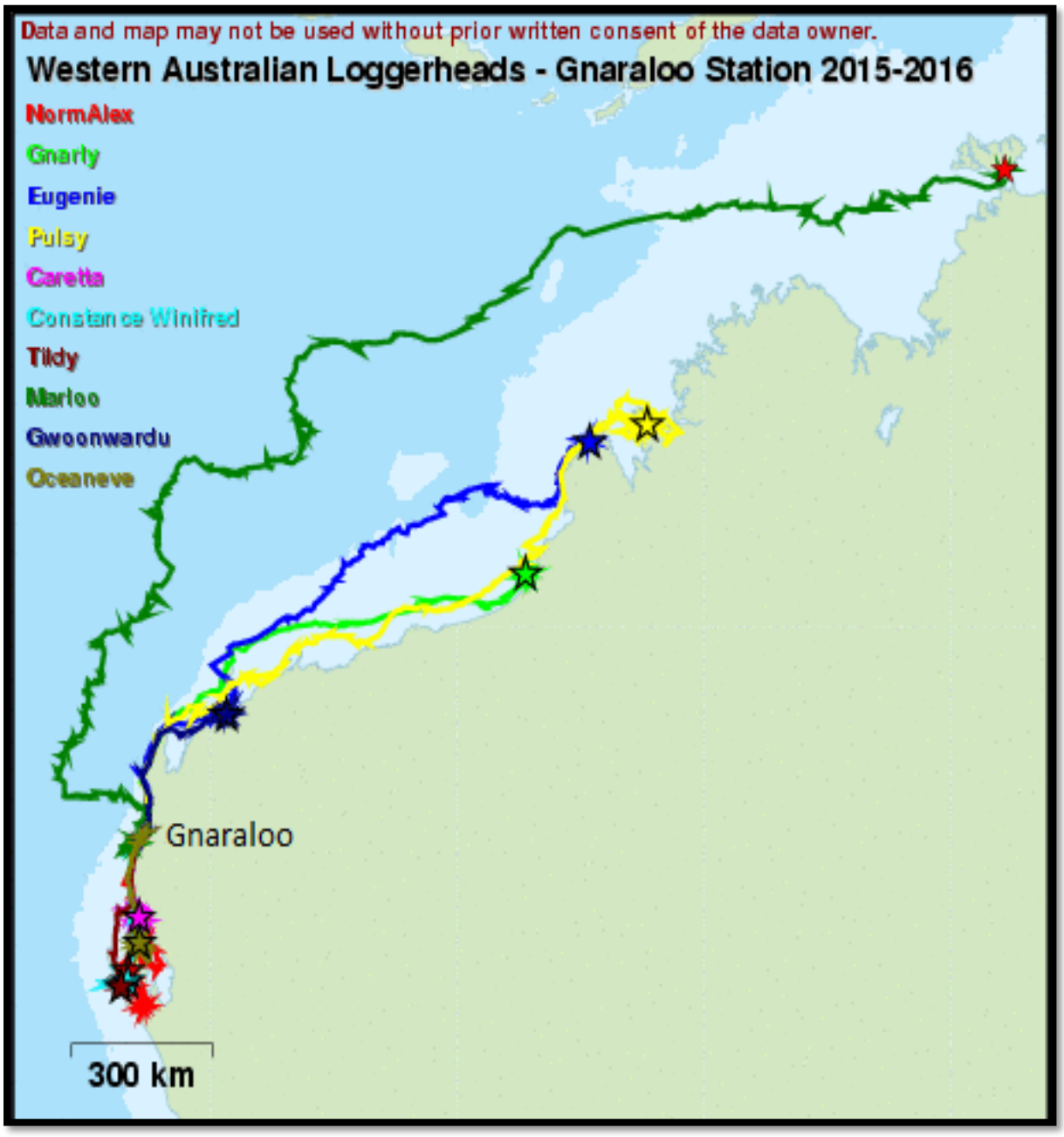
1. **Inter-nesting habitat and behaviour of the tracked turtle 'Oceaneve', GTCP 2015/16**
2. **Inter-nesting habitat and behaviour of the tracked turtle 'Normalex', GTCP 2015/16**
3. **Migration routes of the 10 female loggerheads tracked from their Gnaraloo nesting grounds, GTCP 2015/17**
4. **Foraging grounds at Shark Bay (WA) of the 5 southerly migrating female loggerheads, GTCP 2015/16**
5. **Foraging grounds along north western Australian coast of the 5 northerly migrating female loggerheads, GTCP 2015/17**
6. **Tracked turtle 'Eugenie' reaching her foraging grounds, GTCP 2015/16**
7. **Tracked turtle 'Pulsy' reaching her foraging grounds, GTCP 2015/16**
8. **Tracked turtle 'Marloo' leaving the nesting beach at Gnaraloo, GTCP 2015/16**
9. **Final position of 'Marloo' at Melville Island (Northern Territory), GTCP 2015/17**
10. **Scope of the tracked turtle 'Marloo's' journey, GTCP 2015/17**




**Map 1: Inter-nesting habitat and behaviour of the tracked turtle 'Oceaneve', GTCP 2015/16**

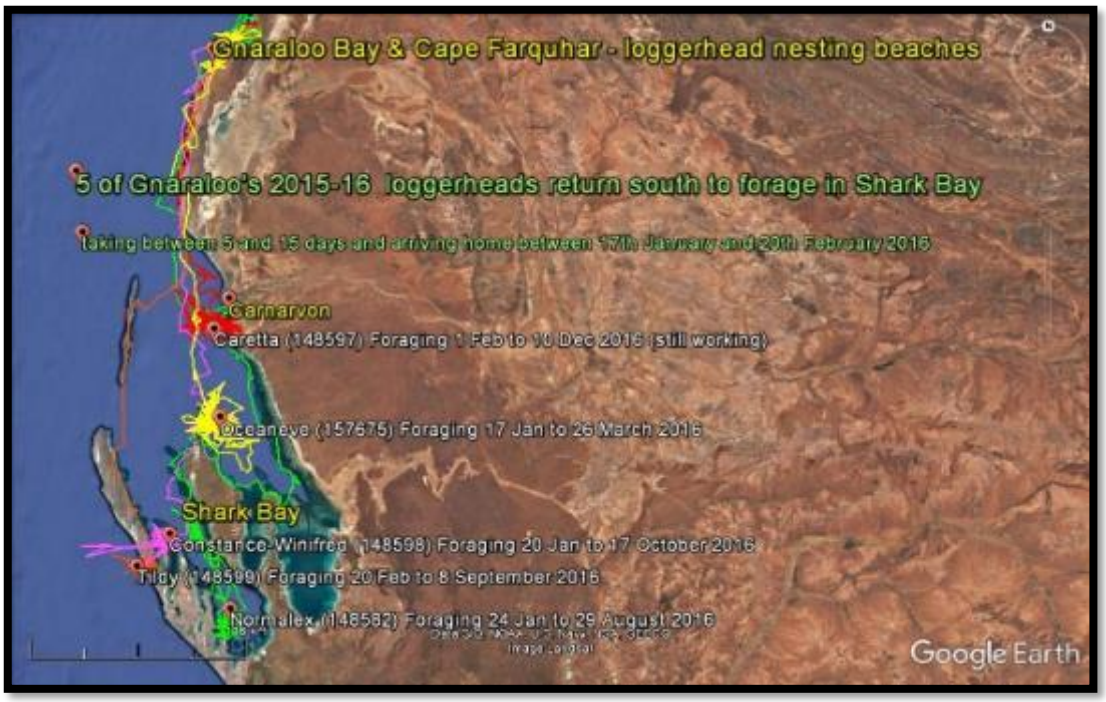


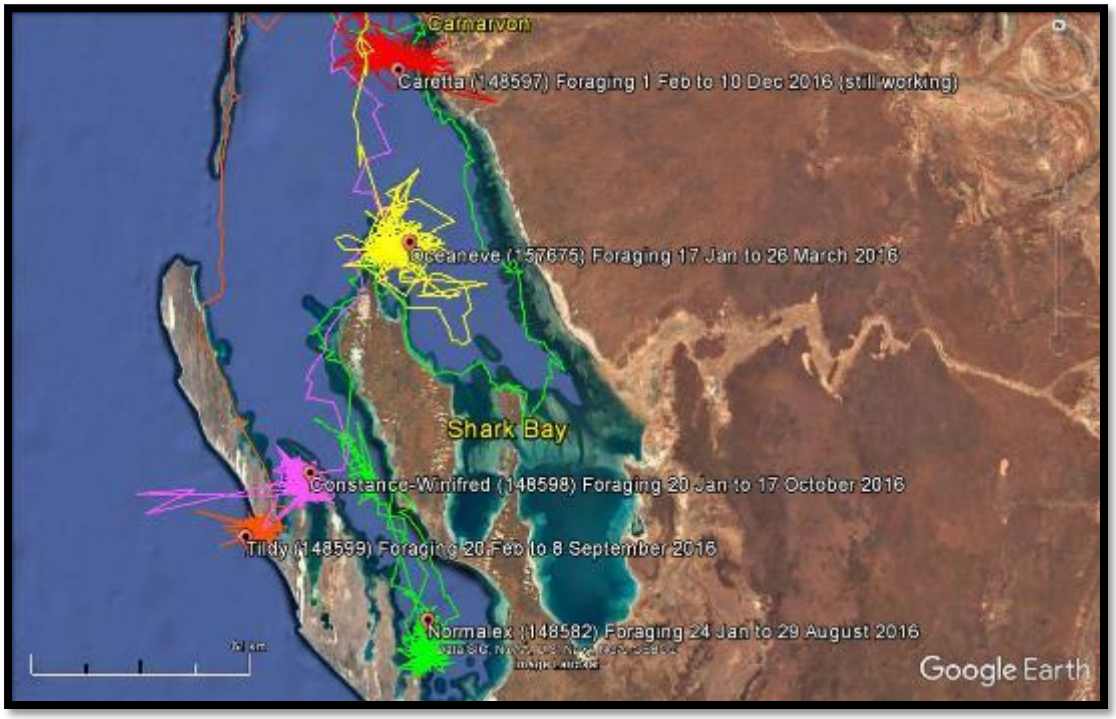

**Map 2: Inter-nesting habitat and behaviour of the tracked turtle 'Normalex', GTCP 2015/16**



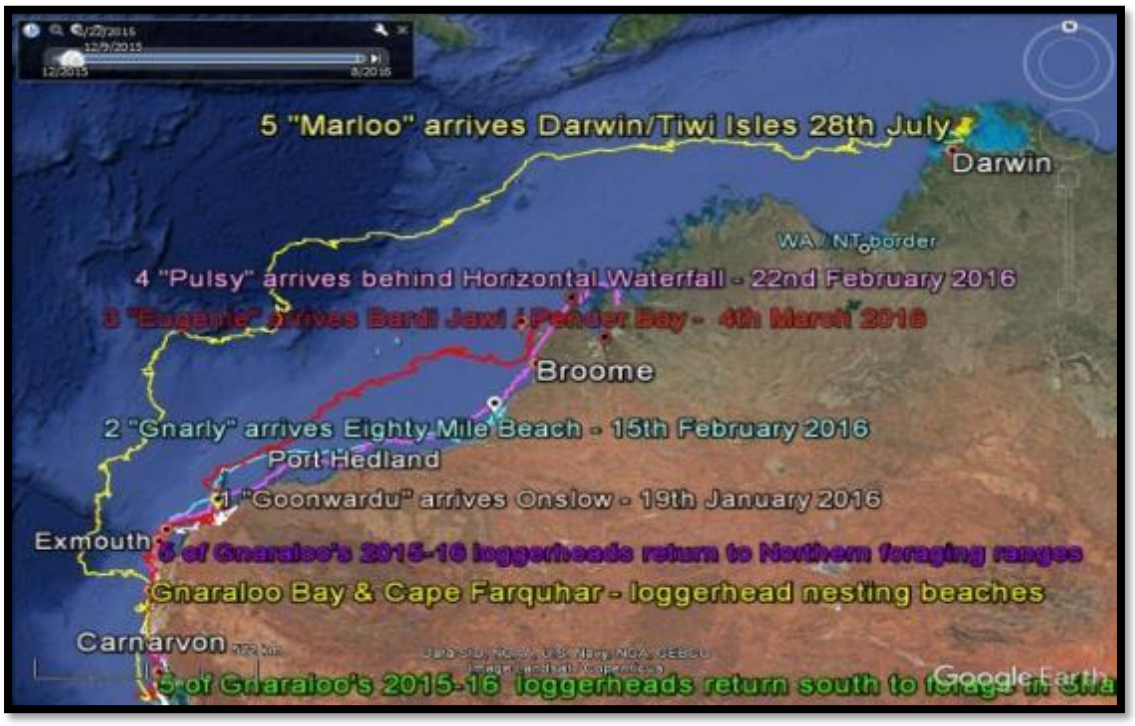

**Map 3: Migration routes of the 10 female loggerheads tracked from their Gnaraloo nesting grounds, GTCP 2015/17**

Map courtesy of www.seaturle.org




**Map 4: Foraging grounds at Shark Bay (WA) of the 5 southerly migrating female loggerheads, GTCP 2015/16**



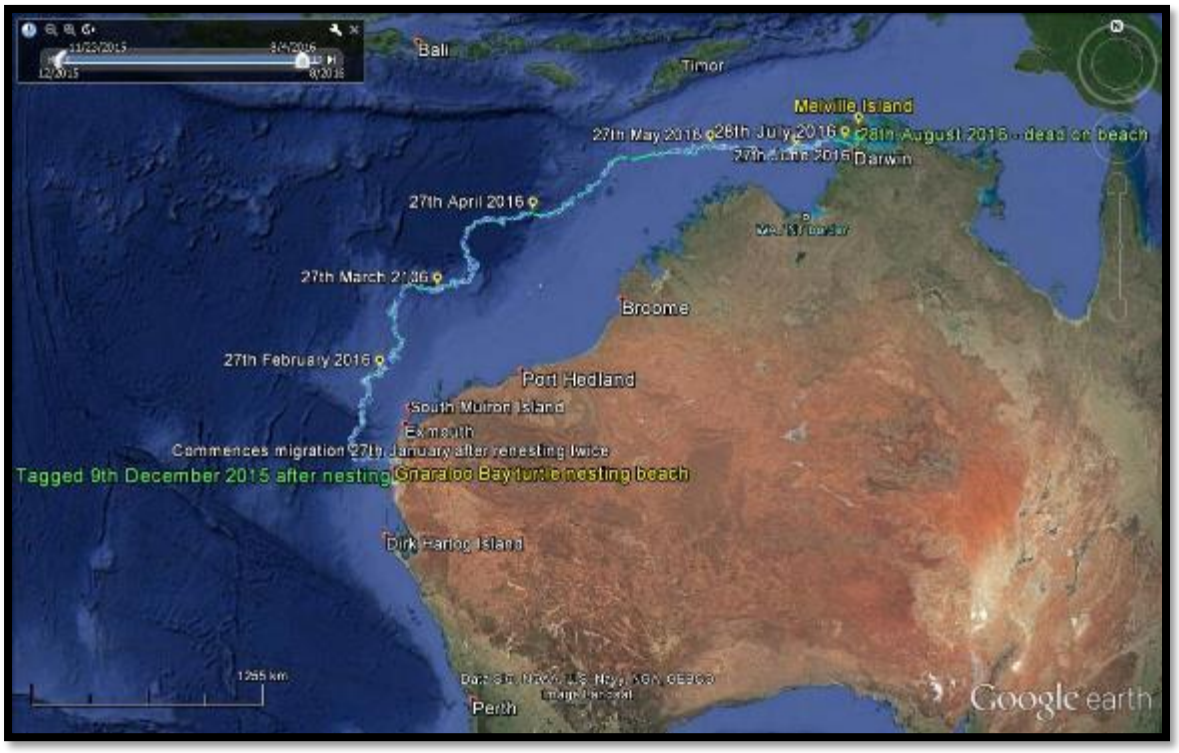

**Map 5: Foraging grounds along north western Australian coast of the 5 northerly migrating female loggerheads, GTCP 2015/17**


**Map 6: Tracked turtle 'Eugenie' reaching her foraging grounds, GTCP 2015/16**


**Map 7: Tracked turtle 'Pulsy' reaching her foraging grounds, GTCP 2015/16**


**Map 8: Tracked turtle 'Marloo' leaving the nesting beach at Gnaraloo, GTCP 2015/16**


**Map 9: Final position of 'Marloo' at Melville Island (Northern Territory), GTCP 2015/17**




**Map 10: Scope of the tracked turtle 'Marloo's journey, GTCP 2015/17**

# APPENDIX C: TURTLE 'MARLOO'S NECROPSY REPORT

Department of Primary Industry and Resources

# Berrimah Veterinary Laboratories

POSTAL ADDRESS
GPO Box 3000
Darwin NT 0801

GENERAL RECEPTION PHONE: 08 89992249
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DELIVERY ADDRESS
29 Makagon Road
Berrimah NT 0828

20160855 FINAL Report Version: 1 Print Date: 03/10/2016

| | | | |
|---|---|---|---|
| Accession number: | 20160855 | Property/Location/Clinic details: | TIWI ALT (MELVILLE ISLAND) |
| BVL SAN: | B50917 | Property Id Code (PIC): | TJDG0392 |
| Animal Owner: | Melville Island - Loc 11.8255; 131.1162 | | |
| Date collected: | 29/08/2016 | Date received: | 31/08/2016 |

Submitter: NTG
Ms. Rachel Groom
Phone: 0409813479
Fax:
Email: rachel.groom@nt.gov.au

| | | | |
|---|---|---|---|
| Animal Type: | TURTLE | Common name: | N/A |
| Breed: | N/A | Scientific name: | N/A |
| Sex: | Female | Age: | 0 Mature |

NLIS Tag

Duty Pathologist for this case: Kirran Dyrting
Department Contact Officer: Dr. Elizabeth Stedman
Reports To: Ms. Rachel Groom

## Case History: 20160855

One mature wild Loggerhead turtle, *Caretta caretta*, carcass was submitted for post mortem examination late in the afternoon of 29/08/2016. The submitter requested the tracker and a range of other samples to be saved for research purpose.

## Pathology: 20160855

Animal ID: Turtle Specimen: Body

**Gross Pathology**

This was the carcass of the mature, female, Loggerhead turtle, *Caretta caretta*, weighed approximately 56 kg ( calculated by subtracting gross weight from weights of electronic tracker, chains of hoist, the blue tarp and duct tape ). Other morphometric measurements were as listed.

- Carapace length (curved): 91 cm
- Carapace length (straight): 86.5 cm
- Carapace width (curved): 81 cm
- Carapace width (straight): 65 cm
- Plastron length: 60.4 cm
- Plastron width: 66 cm
- Plastron to tail tip (from posterior plastron): 16.5 cm

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3-Oct-2016

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**Pathology: 20160855**

- Plastron to vent (from posterior plastron): 11 cm
- Head length: 20.4 cm
- Head width: 19 cm

Identification
Attached tightly onto the midline of the carapace cranially, there was a device approximately 5 cm x 5 cm x 2 cm with an antenna about 15 cm long (electronic tracer). The tracker had been fixed in place by red-coloured epoxy glue which covered approximately 10% of the carapace surface. Removal of the tracker and dried epoxy glue revealed no apparent damage to the underlying scutes or internal bony structure of the carapace. (Submitter had removed flipper tags from forelimbs before carcass submission.)

Carcass condition
The carcass condition was fair (degree of decomposition was about 3 out of a scale of 6). There was no significant gas release on incision into the plastron and the internal organs were generally intact.

Nutritional condition
The nutritional condition of the turtle was very poor. It was emaciated with dehydration. Both eyes were markedly sunken into the eye sockets. The plastron was sunken, concave and pliable. The scutes of the plastron of the ventral midline seam did not meet tightly along the midline but held together by thick connective tissue which was more pronounced cranially. (The distance between the scutes along the midline seam ranged from 1 cm cranially to 0.4 cm caudally.) Internally in the plastron, the bony projections on the medial edges of the hyoplastron and hypoplastron could easily be palpated as sharp projections. There were small amounts of muscling and subcutaneous fat associated with the limbs and plastron. The skeletal muscles were generally pale and flabby (marked muscle atrophy). The visceral fat was dark greenish grey with a watery consistency (marked serous atrophy of fat).

External condition
The entire external surface of the carapace was covered in dried algae that had obscured all the scutes. In addition, there were generally low numbers of gooseneck barnacles and acorn barnacles attached on the carapace and plastron.

The caudolateral part of the carapace over the right hind limb was missing. This defect was half oval in shape, with the widest point at the most lateral edge of the carapace, about 22 cm long by 12 cm deep to the lateral edge. The edges of the defect were smooth and rounded (old and healed wound) and there was no penetrating wound into the coelomic cavity. On the rest of the carapace superficially, there were about half a dozen randomly scattered linear scratch marks, ranging from 2 cm to 15 cm long by about 2 mm deep. There was no disruption to the underlying bony structure of the carapace.

The left front flipper had been amputated distally at the level of the first carpal joint. It was estimated that approximately 30 cm of the distal flipper was missing. The end of this amputated limb had healed and completely covered in skin. There was no evidence of infection or inflammation in the underlying bone.

Both the left hind foot and the right hind foot had a deep, full thickness, relatively large wedge-shape defect distally, approximately 4 cm deep to the edge by 5.5 cm along the edge and 4 cm deep to the edge by 12 cm along the edge respectively. The edges of both defects were generally smooth and rounded with no evidence of inflammation or infection, but the normal rudder-shape outline of both hind feet had been destroyed. ( Both Rachel and Aud commented verbally that the right feet lesion was caused by entangled fishing line which had been removed when this turtle was seen nesting late last year.)

Internal findings
In the muscle of the left pectoral girdle, there was an approximately 1 cm circular, slightly reddened, depressed focus with a sharply demarcated central yellowish brown necrotic centre which was about 3 mm deep. This focus of necrosis was likely caused by direct bony trauma from one of the medial bony projections on the right medial hyoplastron when apposed (as a result of emaciation and lack of soft tissue cushioning there).

In the respiratory tract, the lumen of the entire trachea and lower airways in the lungs contained a large amount of stable foam, indicating severe diffuse pulmonary oedema. Both lungs were diffusely greyish brown. In the soft tissue of the mediastinum near the tracheal bifurcation, there was a mild haemorrhage.

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**Pathology: 20160855**

In the pericardial sac, there was a moderate amount, about 50 ml, of clear reddish brown fluid. In the anterior ventricle of the heart, near the base of the pulmonary trunk at the free edge of a septal endocardium (probably of cavum venosum), there was a 1 cm diameter by 2 mm area of tissue thickening which was yellowish, translucent and myxomatous with smooth outline (# see comment). Adhering loosely elsewhere on the endocardium of the ventricle and atrium, there were several trematodes, about 1 mm wide by 4 mm long, presumptive Spirorchiid flukes, however, there were no associated damages in the heart or major blood vessels.

The thyroid gland was large, about 3 cm in diameter by 6 cm long, slightly nodular, orange-brown, translucent and gelatinous on cut surface.

In the coelom cavity, there was a large amount, about 3 L, of dark brownish green fluid. The mesentery appeared to be twisted and wrapping around the colon, however, the mesenteric blood vessels or the intestinal serosal blood vessels were not engorged, there was no adhesion and the twist could easily be reduced upon removal of the gastrointestinal tract. These additional observations supported the twist in the mesentery was an post-mortem artefact. Bile imbibition was present along the length of the gastrointestinal tract, part of the liver and mesentery (post-mortem changes).

The liver was diffusely dark brownish purple, firm, smaller than normal with sharp edges (liver atrophy). The gall bladder was engorged by a large amount of dark green, slightly viscous bile.

The spleen appeared normal apart from several randomly scattered small, about 1 mm in diameter, slightly raised spots, presumptive granulomatous responses to Spirorchiid eggs. In the nearby mesentery, there were 3 accessory spleens about 0.5 cm to 1 cm in diameter. Similarly there were a few dark spots in the accessory spleens.

The tongue, oral cavity and oesophagus were unremarkable The stomach and upper intestine was empty . The large intestine was extended by a moderate amount of gas and a small amount of bile stained fluid (post-mortem changes). The lower intestine, colon and rectum, contained a small to moderate amount of crushed calcareous shells, a few sea urchin spines and some unidentified sponge-like material.

The kidney surface was mildly diffusely congested. The urinary bladder did not contain urine but the mucosa had a small amount of yellowish brown mucus, mild petechiae and a few loosely attached unidentified trematodes, approximately 2 mm wide by 3 mm long.

Both ovaries had numerous dark greenish atretic follicles, generally < 2 cm in diameter, along with numerous small yellowish-white corpus albicans, about 1 to 2 mm in diameter. The presence of corpus albicans indicated the turtle had nested previously. The oviducts were normal.

The brain and eyes were not examined.

**Gross provisional diagnosis**

- Emaciation
- Dehydration
- Severe acute diffuse pulmonary oedema
- Diffuse thyroid hyperplasia (colloid goiter)
- Multiple old injuries resulted in missing body parts including entire left front flipper, part of left and right hind feet and part of left caudolateral carapace
- Mild focal subacute muscle necrosis in the left pectoral girdle
- Mild mixed parasitic trematode infections (presumptive Spirorchiid blood flukes in heart and an unidentified fluke in urinary bladder) with presumptive granulomas in the spleen due to Spirorchiid eggs
- Focal endocardiopathy, dubious (# see comment below)

**Comment**

The turtle carcass had been stored in the cold room until post-mortem examination was conducted in the morning of 31 /08/2016. Necropsy was performed by Kitman Dyrting and Ayrial Harburn, in the presence of Racheal Groom ( Department of Land Resource Management) and Ian Bell (Queensland Department of Environment and Heritage Protection) who assisted in collecting samples and taking pictures for research purposes.

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## Pathology: 20160855

The immediate cause of death of this turtle was severe pulmonary oedema which was likely resulted from terminal heart failure from exhaustion and hypovolaemia (dehydration).

The turtle was emaciated which was evidenced by marked muscle atrophy, serous atrophy of fat, liver atrophy and perhaps ovarian atrophy, although the latter (ovary condition) could also be affected by seasonality. The focus of muscle necrosis in the left pectoral girdle was likely secondary to emaciation. The excessive fluid accumulations in the coelomic cavity and the epicardial sac could be a combination of malnutrition (hypoproteinaemia) and post-mortem autolysis. This turtle had concurrent multiple healed but significant injuries. Most importantly the missing left front flipper blade and the misshaped hind feet would have affected the normal swimming behaviour and hunting ability of this turtle, especially if all these happened before the turtle had sufficient time to adapt to each of the injuries. Apart from the injury in the right hind feet (with entanged fishing line which had been removed late last year), the causes of other old injuries were unknown. The enlarged thyroid gland in this case could be a response to hypofunction of the gland secondary to chronic debilitation or illness. The brain and eyes were not examined as the research team requested the entire head to be returned.

A range of tissue samples, including the dubious heart lesion (#), have been collected and preserved for histopathology to look for underlying microscopic disease processes, although the state of moderate to severe carcass autolysis would affect interpretation of findings. Further testing, such as microbiology, will be conducted on other stored tissue samples if indicated. Di Barton (Department of Primary Industry and Fisheries) is assisting with parasite identification.

The electronic tracker, dried epoxy glue, skin samples, one humerus, epibiont samples, intestinal contents, ovaries and the head were collected for the research team for further examination.

## Pathology: 20160855

**Animal ID:** Turtle **Specimen:** Necropsy Tissues

**Histopathology**

Tissues are in moderate to severe autolysis. Tissues examined include skeletal muscle, fat, liver, spleen, pancreas, heart, large artery, lung, thyroid gland, kidney, urinary bladder, ovary, oviduct, stomach, small intestine, large intestine and spinal cord.

Skeletal muscle (3 sections):
Diffusely the diameters of the muscle fibres are generally very small (generalised severe muscular atrophy) with no associated inflammation or peripheral neuropathy. The focus of muscle necrosis in the left pectoral girdle noted grossly was necrotic tissue surrounded by many granulocytes with lesser numbers of histiocytes and fibroblasts. Gram stain failed to reveal bacteria. (However, the number of infiltrating granulocytes appeared to be in excess of normal muscle healing response, suggestive of local granulocyte chemotactic response such as due to transient bacterial infection or bacterial toxin.)

Fat (1 section):
Diffusely the adipocytes are generally small with little fat vacuoles but prominent round nuclei. There is no inflammatory response but there are moderate to large numbers of resident melanomacrophages.

Liver (2 secrtions):
Diffusely, the hepatocytes are small (atropy) and contain low to moderate amount of fine brown cytoplasmic pigment which is Perl's stain positive (haemosiderin). In the hepatic sinusoids, there are many Kupffer 's cells containing abundant granular dark-brown cytoplasmic pigment which is also Perl's stain positive (haemosiderin). There is no inflammatory response.

Spleen (3 sections):
Multifocally there is moderate numbers of well-encapsulated granuloma containing many yellowish-brown, angular, thick-walled Spirorchid trematode eggs (Spirorchid granuloma). In the parenchyma diffusely, there are many macrophages containing abundant granular dark-brown cytoplasmic pigment which is Perl's stain positive ( haemosiderin).

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**Pathology: 20160855**

Pancreas (1 section):
Diffusely the exocrine pancreatic acinar cells are small and do not have discernible cytoplasmic zymogen granules. Randomly, there are a few well-encapsulated Spirorchiid granulomas.

Thyroid gland (2 sections):
The thyroid follicles are generally very large and distended with a large amount of homogeneous eosinophilic thyroid colloid, however, the follicular cells are low cuboidal (inactive). Apart from a few small foci of mild infiltration of macrophages containing yellowish-brown fine cytoplasmic pigment (presumptive lipofuscin or ceroid lipopigment related to advancing age), there is no inflammatory response.

Large artery (carotid or subclavian, 2 sections):
In both sections, the intimal layer is regionally oedematous with moderate increase in cellularity (intimal hyperplasia). In one section, extending from the intima to the media there is a focus of moderate to severe granulocytic inflammation with a few multinucleated giant cells and fibrin deposition.

Heart (4 sections):
In the vascular spaces in the myocardium, there are very occasional Spirorchiid trematode eggs with nil to generally mild inflammatory response. The dubious focus of "endocardiopathy" noted grossly is confirmed to be an area of normal cartilaginous structure with moderate amount of extracellular matrix.

Lung (4 sections):
There is moderate diffuse vascular congestion. As in the heart, there are a few Spirorchiid eggs associated with generally nil to mild inflammatory response.

Kidney (1 section):
There is patchy vascular congestion. As in the heart and lung, there are a few Spirorchiid eggs associated with generally mild inflammatory response.

Urinary bladder (1 section):
Multifocally there is very mild perivascular lymphohistiocytic infiltration and scattered very mild haemorrhage. (The unidentified intraluminal trematodes did not cause significant inflammatory response.) As in the kidney, there are a few Spirorchiid eggs associated with generally mild inflammatory response.

Stomach (1 section) and intestine (7 sections):
Multifocally extending from the lamina propria to the serosa, there are mild to moderate well-encapsulated Spirorchiid granulomas. The mucosa is sloughed (due to autolysis) and could not be assessed.

Ovary (1 section):
There are several atretic follicles that are infiltrated with foamy macrophages, several normal looking small follicles and a collagenous corpus albican with mild mineralization.

Oviduct (1 section):
There is no specific finding.

Spinal cord (cervical, 1 section):
There is no specific finding.

**Histological diagnosis**

- Skeletal muscle: Severe diffuse muscular atrophy; incidental focal chronic pyogranulomatous necrotising myositis
- Fat: Diffuse serous atrophy of fat
- Liver: Diffuse hepatocyte atrophy; Moderate hepatic haemosiderosis
- Spleen: Moderate splenic haemosiderosis; Multifocal moderate Spirorchiid egg granuloma
- Pancreas: Diffuse depletion of zymogen granules in exocrine pancreatic cells
- Thyroid gland: Diffuse quiescent colloid goiter
- Artery: Focal subacute moderate pyogranulomatous endarteritis

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* NATA accreditation does not cover the performance of this test.

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## Pathology: 20160855

- Heart: Multifocal mild Spirorchiid egg granuloma
- Lung: Multifocal mild Spirorchiid egg granuloma
- Kidney and urinary bladder: Multifocal mild Spirorchiid egg granuloma
- Stomach and intestines: Multifocal mild to moderate Spirorchiid egg granuloma

**Comments**

There are no underlying microscopic disease processes, such as sepsis, overwhelming inflammation or neoplasia. However, there are compelling histological evidences that the turtle in this case suffered from marked generalised tissue wasting (muscular atrophy, serous atrophy of fat, atrophy of hepatocytes and reduced zymogen granules in exocrine pancreatic cells) consistent with emaciation caused by severe malnutrition and starvation. As noted grossly, the condition was most probably resulted from severe physical debilitation from the multiple limb injuries. The thyroid gland was enlarged but quiescent indicating the gland was in hypofunction state. Splenic and hepatic haemosiderosis indicated there was iron sequestration. Both changes were likely secondary to chronic illnesses related to malnutrition and starvation.

In the lung, the lack of eosinophilic fluid in the lower airspaces indicates the pulmonary oedema noted grossly was low-protein pulmonary oedema. There is no pneumonia. There are no foamy macrophages in the airspaces to suggest chronic heart failure. The pulmonary oedema noted grossly was confirmed to be acute and was a terminal finding.

Spirorchiid egg granulomas were found in various tissues, but they were well-encapsulated and did not appear to have affected normal tissue functions. There was a focal subacute endaterritis, suspected to be inflicted by intraluminal Spirorchiid trematodes (a few of these parasites were found in the heart grossly), but there was no associated thrombosis or vascular rupture to suggest compromised cardiovascular function. The Spirorchiid trematode burden was generally considered moderate, probably with limited clinical significance.

## Case Summary: 20160855

31 Aug to 2 Sep 2016: Interim gross findings were discussed verbally and via email exchanges.
19 Sep 2016: Interim report-1. Note written Gross findings and comments. Histopathology is pending.
03 Oct 2016: Final report-1. Note Histopathology findings and comments.

Dr Kitman Dyrting - Veterinary Pathologist

03/10/2016

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