API MANAGEMENT PTY LTD

MARINE TURTLE SURVEYS ANKETELL POINT 2010/2011

Prepared by

Pendoley Environmental Pty Ltd

For

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1 INTRODUCTION

1.1 Project Location

Currently, this proposal includes the development of port facilities in Nichol Bay, Dampier, with a causeway and wharf proposed off the north-east corner of Dixon Island (**Figure 1**).

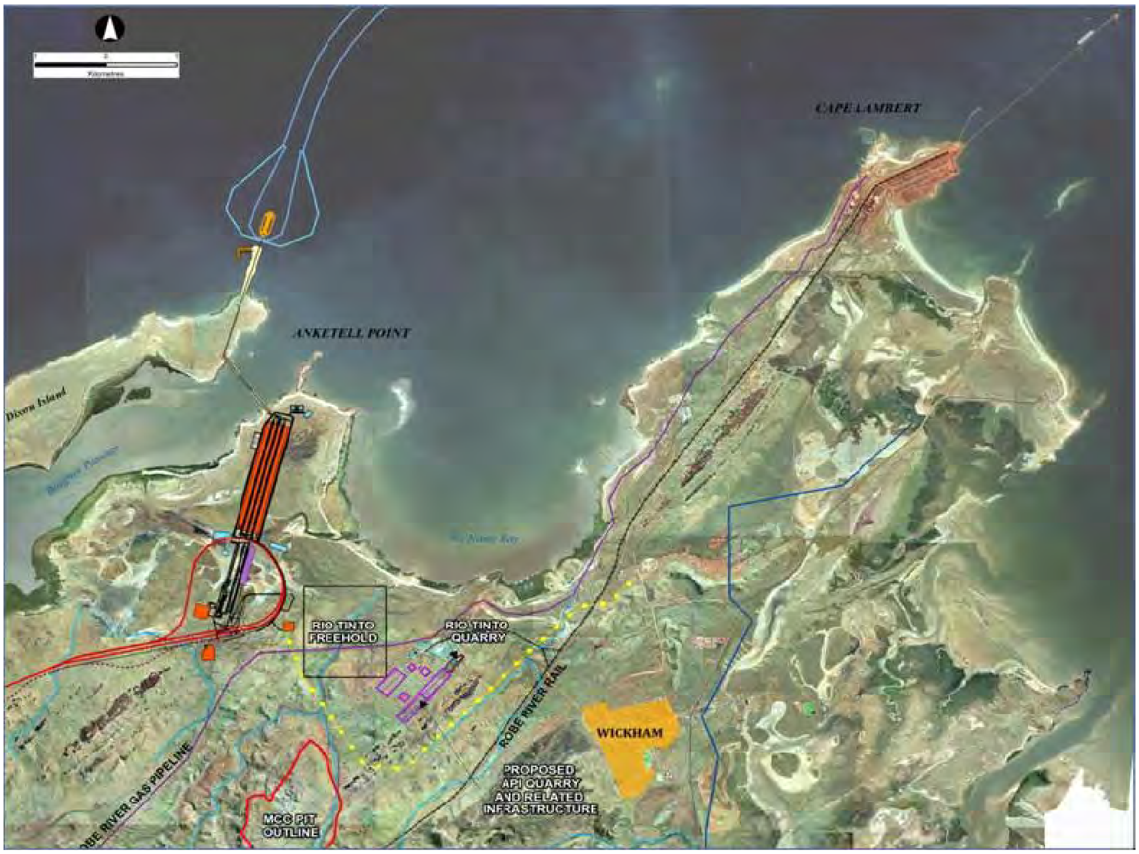

Figure 1: Proposed layout of infrastructure at Anketell Point (source: Aquila Resources press release April 2010)

1.2 Scope of Works

Marine turtle baseline surveys conducted during the 2010/2011 reproductive season consisted of three separate field surveys. Combined, these provide an overview of marine turtle activity in the Dampier Region. The three study components included:

- October 2010 monitoring surveys - Adult (**hawksbill**) turtle nesting activity and deployment of temperature loggers.
- January 2011 monitoring surveys - Adult (**flatback and green**) turtle nesting activity, hatch success and (**hawksbill turtle**) hatchling orientation.
- February 2011 monitoring surveys - **Flatback and green turtle** hatch success, hatching orientation and retrieval of temperature loggers.

Previous surveys completed for this scope of works include:

- February 2008 – initial site assessment Delambre, Dixon and Bezout Islands;
- January 2009 monitoring surveys - Adult (**flatback and green**) turtle nesting activity;
- March 2009 monitoring surveys – Adult and hatchling (**flatback and green**) turtle surveys;
- April 2009 monitoring surveys - Adult and hatchling (**flatback and green**) turtle survey; and
- October 2009 monitoring surveys - Adult (**hawksbill**) turtle nesting activity.

1.3 Objectives

The objective of this program was to monitor marine turtle nesting activity on selected regional beaches in the vicinity of the proposed Anketell Point Project. These data will add to the current store of knowledge regarding marine turtle activity in the Dampier region, and specifically in the vicinity of Anketell Point. Particular goals included documentation of:

- Spatial and temporal distribution and abundance of nesting populations of marine turtles at Anketell Point, Bell's Beach, Delambre, Dixon and Huay Islands;
- Marine turtle hatching and emergence success;
- Hatchling morphology, clutch size and clutch morphology;
- Baseline levels of hatchling sea-finding orientation;
- Sand temperatures at nest depth; and
- Opportunistic observations of in-water turtles.

2 BACKGROUND INFORMATION

2.1 Marine Turtles in the Dampier Archipelago

Surveys conducted on behalf of API in the Dampier Archipelago are the only known systematic surveys of marine turtle habitat, assessing both nesting and hatching phases of the reproductive cycle. While other surveys have been conducted in recent years on behalf of industry, these data are not publicly available. The bulk of information within this report comes from grey literature including government reports, previous surveys conducted by Pendoley Environmental and anecdotal sources.

Four species of marine turtle are likely to utilize the survey area for nesting. These are:

- Green turtle, *Chelonia mydas* (listed as Vulnerable under the Environment Protection and Biodiversity Conservation Act) (the EPBC Act);
- Hawksbill turtle, *Eretmochelys imbricata* (listed as Endangered under the EPBC Act);
- Flatback turtle, *Natator depressus* (listed as Vulnerable under the EPBC Act); and
- Loggerhead turtles, *Caretta caretta* (listed as Endangered under the EPBC Act).

The most abundant are flatback and hawksbill turtles and these are discussed in more detail below.

2.1.1 Flatback turtle breeding units

The flatback turtle is endemic to the Continental Shelf waters of northern Australia extending from the Pilbara region of Western Australia, northwards to around the Northern Territory and into Queensland waters (Limpus *et al.,* 1988; Limpus, 2009). Four genetic units/stocks are currently recognised; North West (NW) Shelf, Northern Territory, Gulf of Carpentaria and eastern Australia (see **Figure 2**; Dutton *et al.,* 2002). Long-term studies on the breeding biology of flatback turtles have largely been confined to the eastern Australia genetic stock (Limpus *et al.,* 1981, 1983, 1984; Parmenter & Limpus, 1995) and recently the Cape Domett population, considered to be part of the Northern Territory stock (Whiting *et al.,* 2008).

2.1.2 Hawksbill turtles

The Western Australian hawksbill population is the largest in the Indian Ocean (supporting 2000 or more nesting females each year) with nesting centred on the Dampier Archipelago, in particular Rosemary Island (Broderick *et al.*, 1994). Less is known regarding abundance at other nesting sites within the Archipelago; further study will provide valuable and key information to assist in the successful management of this species.

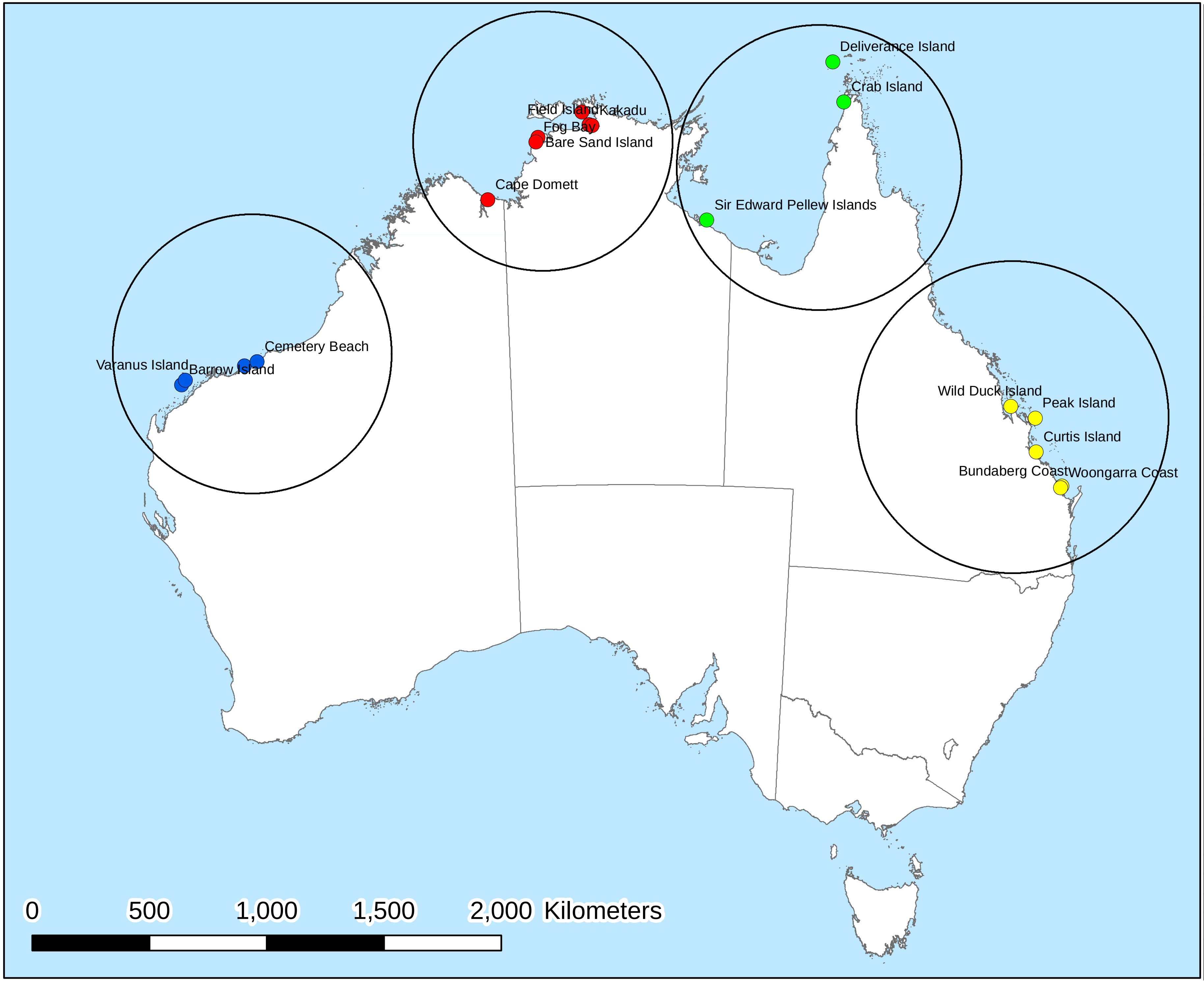

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Figure 2: Flatback genetc management units and rookeries in Australia (only those rookeries discussed in this report are shown on this map)

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2.2 Nesting Habitat

Significant rookeries for flatback turtles in the Pilbara region are centred on Barrow Island, Mundabullangana, the Lowendal Islands, Thevenard Island, the Montebello Islands and Dampier Archipelago (Prince, 1994; Pendoley, 2005; Osborne *et al.*, 2000). Smaller rookeries are also found on smaller Pilbara islands and along the mainland coast. Hawksbill turtle rookeries include the Lowendal Islands, Rosemary Island, the Dampier Archipelago and some other small Pilbara islands (Pendoley, 2005; Morris, 1990). Significant rookeries of green turtles occur on Barrow Island, the Montebello Islands and the Dampier Archipelago, with smaller rookeries on many smaller Pilbara islands (Pendoley, 2005; Morris, 1990; Osborne *et al.*, 2000). The Dampier Archipelago is the current known northern limit of nesting for the loggerhead turtle in Western Australia where it has been recorded on Rosemary and Cohen Islands (Morris, 1990). Loggerhead turtles have not been recorded nesting within the study area either during these surveys or at any other time. There have been no records of the leatherback or olive ridley turtle nesting in the Pilbara region.

2.3 Internesting Habitat

Internesting movements and habitats for marine turtles nesting in the Dampier Archipelago region are not known. However, it is likely that green and hawksbill turtles remain within the general vicinity of their nesting beaches during their internesting period. Green turtles nesting on the west coast of Barrow Island stay within approximately 5 km of shore throughout the entire internesting period (Pendoley, 2005). Flatback turtles nesting at Barrow Island have been satellite tracked and are shown to be routinely using the nearshore habitats of the mainland coast 50 to 60 km to the south-east of Barrow Island during their internesting period (Barrow Island flatback tracking 2006-2007, 2007-2008; www.seaturtle.org). Flatback turtles nesting at Mundabullangana and Cemetery Beach, Port Hedland however, remain within approximately 20 km of their mainland nesting rookeries (Cemetery Beach flatback tracking project; www.seaturtle.org). Three flatback turtles nesting at Cape Lambert were satellite tracked in 2010/2011 (www.seaturtle.org) and all three remained within the Archipelago during the internesting period prior to departure for the foraging ground.

2.4 Mating Habitat

The locations of mating aggregations for marine turtles have not been formally documented for the survey area; however, it is likely that green turtles will occur in mating aggregations off nesting beaches. Aerial survey data collected during 2009/2010 show large aggregations of turtles directly offshore from Legendre, Huay and Delambre Islands (Jenner & Jenner, 2010) where large numbers of green (Legendre Island), hawksbill (Huay and Delambre Islands) and flatback (Delambre Island) turtles are known to nest (Pendoley Environmental, 2010). Large aggregations also occur off the north-west coast of Thevenard Island and the west coast of Barrow Island (Pendoley, 2005). Mating hawksbill turtles are commonly seen just off Rosemary and Delambre Island (A. Vitenbergs, pers. obs.).

2.5 Migratory Pathways

Migratory pathways for marine turtles nesting in the Pilbara and Gascoyne regions include the coastal waters of the Dampier Archipelago region. Migratory pathways are extensive and varied among and within species. Green, hawksbill and flatback turtles nesting on Barrow Island, Varanus Island and Cemetery Beach, Port Hedland have been satellite tracked moving through the coastal waters of the Dampier Archipelago mostly outside the 60 m bathymetric contour (Barrow Island flatback tracking project; Barrow Island green tracking project; Varanus Island hawksbill tracking project; Cemetery Beach flatback tracking project; www.seaturtle.org). Three flatback turtles tracked from Cape Lambert (www.seaturtle.org) each took a different migratory route – one headed south-west along the coastline toward Thevenard Island, one headed north-east along the coastline and the other travelled directly offshore ~ 80 km before returning to take up what currently appears to be annual residence within the Archipelago not 5 km from the nesting site.

Limited satellite tracking data are available for hawksbill turtles in Western Australia however studies of post-nesting females from other regions, for example north-east Australia (Miller *et al*., 1998) and Costa Rica (Troeng *et al.,* 2005) show similar levels of displacement during post-nesting migration as other hard-shell species of marine turtle.

2.6 Foraging Habitat

Foraging habitat for green or hawksbill has not been specifically identified in the survey area; however, it is reasonable to expect green turtles to occur in the vicinity of sea grass or algal beds and hawksbill turtles on or near coral reef habitat (Pendoley, 2005). Algal and coral habitat occurs on the shallower reef platforms along the coast and surrounding the offshore islands in the region.

Flatback turtles are likely to forage over soft bottom habitat supporting sea pens or other infauna (Pendoley, 2005). Recent flatback turtle satellite tracking studies suggest foraging in a wide variety of habitats and in water depths of 10 to 50 m off the Western Australian coast (www.seaturtle.org; Pendoley, unpublished data). Foraging grounds appear more diffuse in this species and any suitable habitat should not be ruled out. One female flatback turtle has been tracked following nesting and now resides within the Dampier Archipelago (www.seaturtle.org) not 10 km from her nesting beach at Cape Lambert.

Aerial surveys conducted outside the marine turtle nesting season to focus on spatial distribution and abundance of resident turtles, indicate aggregations of turtles around the northern islands of the Dampier Archipelago (Prince *et al*., 2001), and more recent aerial surveys conducted by the Centre for Whale Research (CWR), have documented large numbers of turtles resident in the survey area during winter months (Jenner & Jenner,2010).

3 METHODOLOGY

3.1 Survey Design

Daytime track surveys are a common monitoring tool for marine turtle nesting activity and are especially useful for assessing nesting activity on beaches where resources are limited. Data are gathered during peak season to quantify species-specific nesting effort per beach (Eckert *et al.*, 1999; Whiting *et al.,* 2007; Whiting *et al.,* 2008). Defining the spatial range of preferred nesting habitat for each rookery and identifying periodicity, abundance and output during consistent annual survey periods is necessary for successful conservation management and planning.

These surveys were designed to build upon data gathered in previous marine turtle surveys (Pendoley Environmental, 2010) conducted for API during January and October 2009. Initial investigations surveyed a wide area inclusive all potentially suitable nesting habitat within the Dampier Archipelago to identify primary nesting areas for all species of marine turtle found in the region. In these subsequent surveys, having identified primary areas of study, the surveys were focused to include more in-depth analysis of marine turtle abundance, distribution and reproductive biology at selected primary sites of known activity in proximity to the proposed development at Anketell Point/Dixon Island (**Figures 1 & 3**).

In addition to track surveys to assess abundance and distribution of nesting activity during the survey period, the 2010/2011 surveys included:

- Hatchling orientation
- Hatching success; and
- Sand temperatures.

3.1.1 Survey location

Survey sites for 2010/2011 programs were selected based on proximity to the project site (**Figures 1 & 3**) and included:

- Anketell Point
- Bell's Beach
- Delambre Island
- Dixon Island (east) (**Figures 3 & 4**).

Where possible, snapshot surveys were also conducted at Huay Island (**Figure 3**).

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Figure 3: Location of all survey areas

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Proposed survey areas

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Project
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Figure 4:
Location of all survey sites

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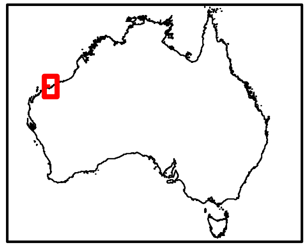
Survey lines



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3.1.2 Survey schedule

The survey schedule is detailed below. A red cell indicates a temperature logger was deployed at this location on this date. A blue cell indicates a temperature logger was removed at this location on this date.

Table 1: October Survey schedule

Survey Locations	Adult turtle nesting survey					
	15 Oct-2010	16 Oct-2010	17 Oct-2010	18 Oct-2010	19 Oct-2010	20 Oct-2010
Dixon Island (East)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (NE)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (SE)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (SW)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Anketell Point East	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Anketell Point West	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Bells Beach	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Huay Island	No survey	No survey	No survey	Line in	Day 1	Day 2
Dixon Island (west)	No survey	Snapshot	No survey	No survey	No survey	No survey

Table 2: January Survey Schedule

Survey Locations	Adult turtle nesting/hatching survey					
	06-Jan-2011	07-Jan-2011	08-Jan-2011	09-Jan-2011	10-Jan-2011	11-Jan-2011
Dixon Island (East)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (NE)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (SE)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Delambre Island (SW)	Line in	Day 1	Day 2	Day 3	Day 4	Day 5
Anketell Point East	No survey	No survey	Line in	Day 1	Day 2	Day 3
Anketell Point West	No survey	No survey	Line in	Day 1	Day 2	Day 3
Bells Beach	Line in	Day 1	Day 2	Day 3	Day 4	Day 5

Table 3 February Survey Schedule

Survey Locations	Adult turtle nesting/hatching survey	
	20-Jan-2011	21-Jan-2011
Dixon Island (East)	No survey	Line in
Delambre Island (NE)	Line in	Cyclone demob
Delambre Island (SE)	Line in	Cyclone demob
Delambre Island (SW)	Line in	Cyclone demob
Anketell Point East	No survey	Cyclone demob
Anketell Point West	No survey	Cyclone demob
Bells Beach	Line in	Cyclone demob

3.2 Data Collection

3.2.1 Track surveys

The survey methodology used for this program was based on techniques developed for beach surveys within the Barrow-Montebello-Lowendal Island complex (Pendoley, 2005) and is consistent with International Union for Conservation of Nature Species Survival Commission (IUCN SSC) Marine Turtle Specialist Group methodology (Schroeder & Murphy, 1999). This approach has been designed for industry to allow for rapid accumulation of indicative data.

Marine turtles nest at night on sandy beaches. Signs of their visit to the nesting ground can be seen as marks in the sand the following morning and up to several weeks afterwards, depending on weather conditions. Marine turtle nesting behaviour is well understood and with the correct training, marine turtle tracks and signs of digging and covering behaviour on the beach can be interpreted to quantify recent species-specific nesting effort at a particular site.

Track surveys at each location spanned two to four days. During track surveys, a line was drawn in the sand above the high tide mark on the first visit to the beach. On subsequent visits, all marine turtle tracks across the line (overnight) were documented and assigned to species. All surveys were undertaken during the day and nesting female turtles were therefore unlikely to be encountered on the beaches. Track and nest characteristics, for example track width, shape and orientation of flipper marks, tail drag marks, morphology and depth of nest pit and associated mound were used to determine the species of the nesting marine turtle.

3.2.2 Hatching success

Examining the contents of hatched clutches provides information pertaining to the reproductive output of each species at each site. It allows for positive confirmation of the species that has nested/hatched and for collection of data relating to abundance and initial survivorship of hatchlings at this site and the environmental conditions/suitability of the nesting beach.

Hatched clutches were excavated and the contents of the egg chamber were sorted into hatched eggs (empty eggshells which were more than 50% intact), live hatchlings, dead hatchlings, eggs with no discernable embryo, eggs with partially developed embryo and eggs with fully developed embryo. All the nest contents were inspected for signs of mould, maggots, root infestation and predation. The size of the clutch, hatch and emergence success for the nest were then determined.

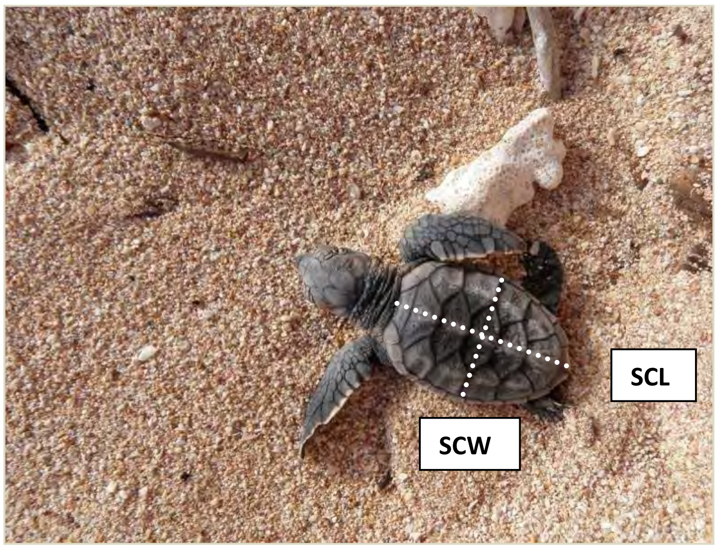

Figure 5: A live hawksbill hatchling is discovered during a nest excavation

3.2.3 Hatchling morphology

All hatchlings were measured and weighed according to Eckert *et al.* (1999).

Measurements of live hatchlings were taken follows:

- Straight carapace length (SCL, mm) and straight carapace width (SCW, mm) measurements were taken as shown in **Figure 5.**
- Mass (g) was recorded by weighing hatchlings in a calico sack using tared mini-Pesola spring scales.

3.2.4 Hatchling orientation

This tool provides an effective and rapid field method for monitoring the potential impacts from artificial light on hatchling sea-finding ability. Hatchling orientation is assessed to provide data with which to determine the path taken by hatchlings immediately following emergence from the clutch. As they head toward the ocean they typically follow natural light cues which may be interrupted by artificial light sources nearby. Any deviation from the most direct route to the ocean leaves hatchlings vulnerable to predators, dehydration and ultimately, death (Salmon, 2003).Hatchling orientation measurements were undertaken using the following methodology.

Emerged clutches were documented and a GPS location recorded for each. Emerged clutches are seen as expanding 'fans' of hatchling tracks from a distinct source point. Clutches were recorded as a successful emergence when five or more tracks were sighted (**Figure 6**). Hatchling orientation data were collected from suitable emergence sites. Where a clear 'fan' pattern not obscured by hatchling tracks from other hatched clutches or adult tracks, bird or other animal tracks was observed, the clutch was deemed suitable for assessment of orientation.

The methods used to document hatchling emergence pattern indices follow those developed by Pendoley (2005) and based on Witherington *et al.*, (1996). Typically the angle of spread of the tracks will increase under the influence of light (both natural and artificial) while lights behind, or at the end of the beach will cause overall hatchling orientation to shift away from a direct line to the ocean.

The spread of the hatchling tracks was measured using a sighting compass to record the bearing along the outside arms (A and B) of each fan (excluding outliers). The bearing was taken at the point where the tracks cross the high tide line, or from the nest for tracks that were orientated parallel to the ocean. The bearing of outliers (max. of 3 per nest) was measured and recorded separately. An angle of spread was then calculated from these bearings (**Figure 6**). The orientation of the tracks relative to the most direct line to the ocean is termed the 'offset angle' and is determined by calculating the angle between the most direct line to the ocean (X) and the bearing bisecting the angle of spread of all tracks observed (C).

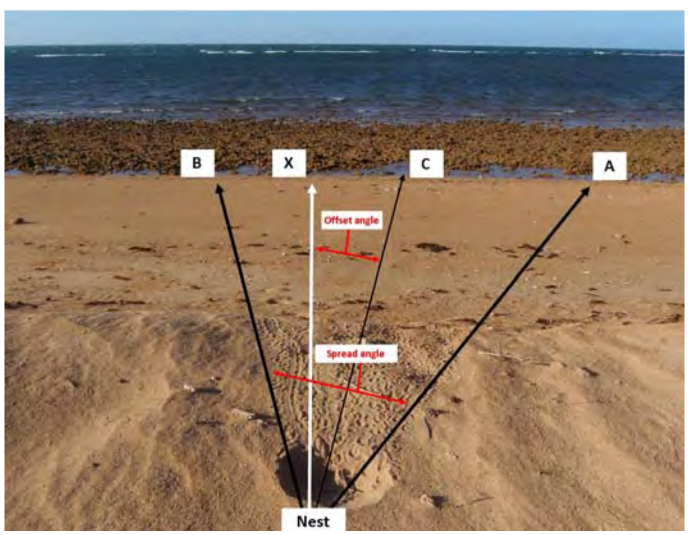

Figure 6: Hatchling emergence spread angle and offset angle. See text for explanation of A, B, C and X.

3.2.5 Sand temperatures

Sand temperature at nest depth varies by location and is dependent upon environmental conditions at each site. Temperature is one of the primary variables affecting incubation success, hatchling fitness and ultimately, reproductive output at each rookery. Embryo survival is dependent upon incubation within the thermal tolerance range (TTR) (26-35°C) (Ackerman, 1997). Further, marine turtles exhibit temperature-dependent sex determination and therefore any investigation into the primary sex-ratio at each location begins with investigation into site-specific temperatures.

Pivotal temperatures (above which females are produced and below which males are produced) for these species in this region are not yet known, therefore we have used data from studies conducted on the east coast of Australia. Green and hawksbill turtles (Standora & Spotila, 1985; Mrosovsky, 1994; Ackerman, 1997) and flatback turtles (Hewavisenthi & Parmenter, 2000). These are referred to throughout as 'estimated' pivotal temperatures'; study has yet to confirm that the pivotal temperature occurs at the same point for these species in Western Australia as it does on the east coast.

Ten (10) HOBO Data Loggers (model #: ua-001-008; accuracy 0.47°C; resolution 0.1°C) were deployed between 18 October 2010 and 19 February 2011 to log sand temperatures at known marine turtle nesting sites within vicinity of Anketell Point (**Figure 7**). Units were set to log temperatures at thirty minute intervals. Loggers were deployed at 500 mm depth. This depth represents mean nest depth for all three nesting species in the Anketell Point region. This depth is standard for all other projects of this kind in the Pilbara region.

Two sites were selected at each location; at the base of the primary dune (position 1) and on the beach flat (position 2; **Figure 7**). This aimed to capture intra-beach (horizontal) temperature variation resulting from proximity to the water table and high tide line. Where public may be present (Bell's Beach, Delambre Island) it was necessary to locate some loggers nearer to the dune than was ideal to avoid public interest and/or injury from the marker posts.

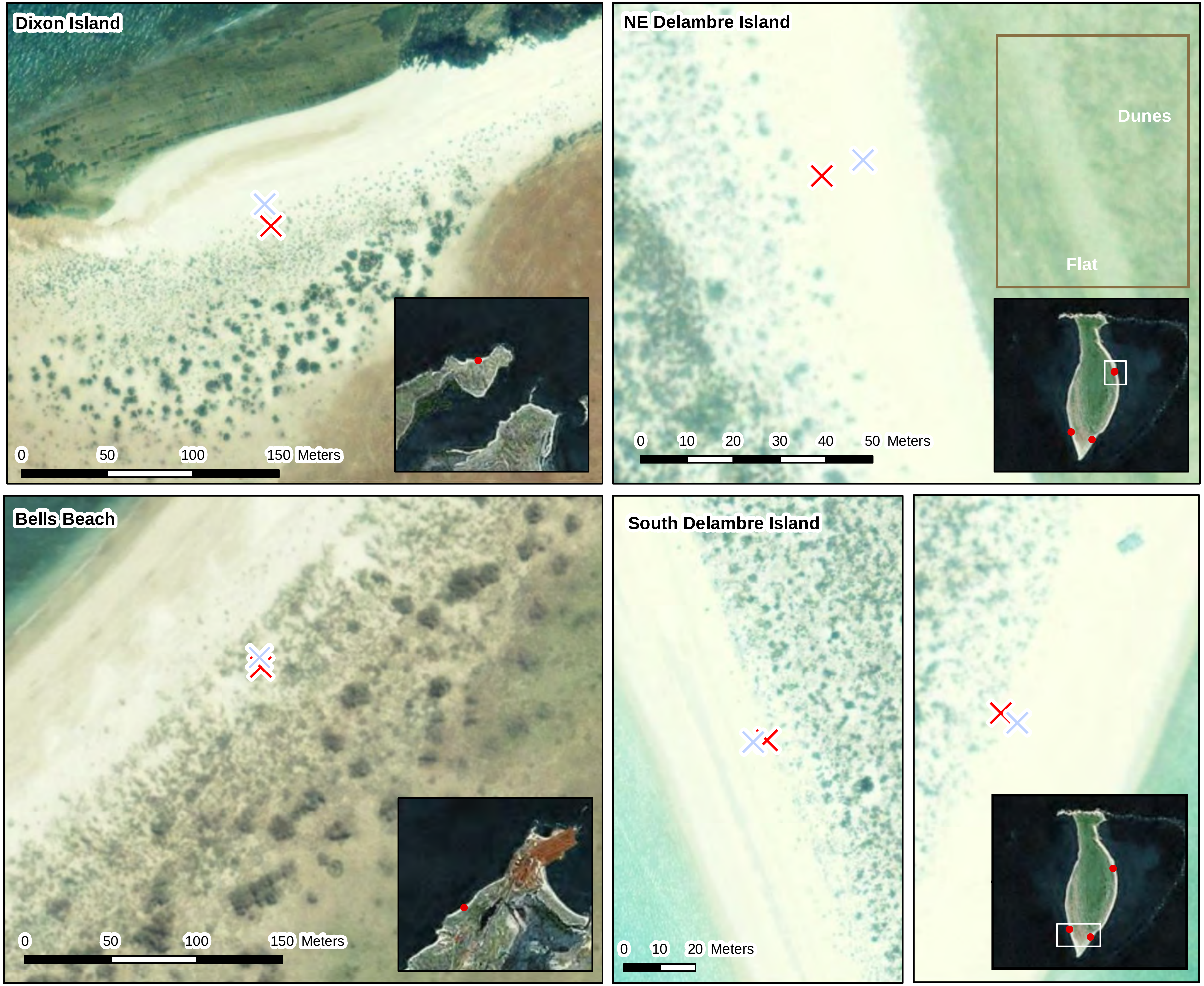

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Figure 7: Location of temperature loggers

Legend
Actual_logger_sites_2_Projec
Dunes_Flat
Dunes
Flat

Notes:
High level public activity at Bell's Beach prevented positioning of a logger marked by a star picket on the beach flat. Loggers were spaced as far apart as possible bearing these contraints in mind.

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3.2.6 In-water observations

Observations of marine turtles on the beach and in the water were recorded opportunistically during the surveys. Behaviour of animals in the water often provides an indication of habitat usage which may include mating aggregation areas, developmental habitat for juvenile or sub-adult animals or foraging grounds for animals of all life phases.

Turtles were opportunistically observed in-water during travel between survey sites. Sightings were typically observed in shallow water during the approach to the beach for survey. Sighting location has been assigned according to the nearest survey beach, regardless of whether they were seen during approach or departure.

3.2.6.1 Assigning maturity to marine turtles observed in water.

Where an extended tail was seen or the animal was > 80cm it was classified as adult. Animals of <80 cm were categorised as juvenile. It is recognised that there are likely resident sub-adults that have been included incorrectly in either the adult or juvenile category however without focused investigation (capture-mark-recapture) into in-water populations of marine turtles it is not possible to increase accuracy.

3.2.7 Observation and documentation of additional data

Other data and observations were opportunistically recorded as follows:

- Nest predation was recorded for nests that clearly showed evidence of animal footprints and digging to egg/hatchling depth. Eggs, egg shell or hatchling remains may also have been visible. Where possible, the predator was identified from tracks, dig marks etc.

- Stranded marine turtles, carcasses or skeletons were documented. Stranded marine turtles around the high-water mark indicate the presence of the species in nearby waters, although animals in advanced stages of decomposition which had been floating for several days may have come from areas further offshore.

3.2.8 Data analysis

Statistical tests typically assume that the populations being compared have Normal distributions. Therefore all data were tested for Normality before conducting the analyses using the Jarque-Bera, Anderson-Darling and Shapiro-Wilk tests.

Non-parametric analyses (Mann-Whitney/Kruskal-Wallis test) were used to analyse differences between survey sites in egg and hatchling morphology, clutch size and sand temperatures (XLStat, 2010). A p-value of less than 0.05 was considered to be a significant difference, such that there was a probability of 5 % or less of making a Type I error (or in this case something considered significantly different when it was not).

The relationship between sand temperatures and multiple variables were estimated using a non-parametric regression modelling approach known as Generalised Additive Modelling (GAM). The GAM approach incorporates an identity link, a robust quasi-likelihood error function, and a stiff cubic smoothing spline to estimate non-linear relationships between the response variable and continuous covariates. A quasi-binomial distribution was used for the hatch success data to account for the use of proportional data. Models were fitted using the *mgcv* package (Wood 2006) available for the open source statistical modelling program R (Ihaka & Gentleman 1996).

All data presented within are mean ± standard error (SE) (range, *n*).

3.3 Survey Limitations

- Bad weather due to approaching Tropical Cyclone Carlos during the February survey prevented collection of additional data regarding adult nesting activity. As this survey was outside the peak nesting period (as it was focused on hatching) these data would have served only to confirm the absence of nesting at this time. Data regarding hatching success and hatchling orientation during this time were also limited; however substantial data were collected during the October and January surveys and are considered adequate to support the findings of this report.

- In-water sightings of turtles are descriptive only. Sightings were primarily made when approaching each site (beach). This is likely due to a combination of these being the most densely populated areas and enhanced observation opportunity due to less turbid shallow waters and slower vessel speeds in these areas.

- Where 'number of animals per night' are presented in track survey findings, it was not possible to know if each pair of tracks did indeed represent a different animal or represented an additional nesting attempt by an animal that had previously been to the beach in that night. When a turtle has completed nesting she will not return for ~10-14 days however if the nesting attempt was unsuccessful she may return that night.

- It was not possible to fully investigate the impact of lunar cycle on hatchling orientation as data were collected primarily during the early phase of the cycle.

4 RESULTS

4.1 Track Surveys

4.1.1 Flatback turtles

Almost no flatback turtle nesting activity was seen during the October 2010 surveys. Activity was documented on two nights at Bells Beach and one night at SE Delambre Island (**Table 4**).

The January 2011 survey, scheduled during the peak of nesting for this species, documented higher levels of nesting at Delambre Island than in the previous survey conducted in January 2009 (**Figure 8**).

Nesting by flatback turtles was recorded at the eastern beach on Dixon Island in January 2011 although levels were considered very low (**Table 4**). The western beach on Dixon Island was visited once by biologists during this survey and it was confirmed that there was no nesting at this site and that it is unlikely that nesting would occur as this habitat is considered unsuitable. No flatback turtle nesting activity was recorded at Anketell Point in the 2010/2011 season.

Table 4: Flatback turtle nesting recorded during 2010/2011 surveys.

Month	Beach	Mean	Range	SE	Survey Days (*n*=)
October	Anketell Point	0	0	0	4
	Bell's Beach	0.4	0 - 2	0.3	5
	Delambre NE	0	0	0	5
	Delambre SE	0.1	0-1	0.1	5
	Delambre SW	0	0	0	5
	Dixon Island	0	0	0	5
	Huoy Island	0	0	0	3
January	Anketell Point	0	0	0	4
	Bell's Beach	2	0 - 5	1.0	5
	Delambre NE	45	15 - 79	10.9	5
	Delambre SE	47	34 - 63	5.2	5
	Delambre SW	48	16 - 83	11.3	5
	Dixon Island	3	1 - 5	0.7	5

Table presents mean number of animals on the beach per night.

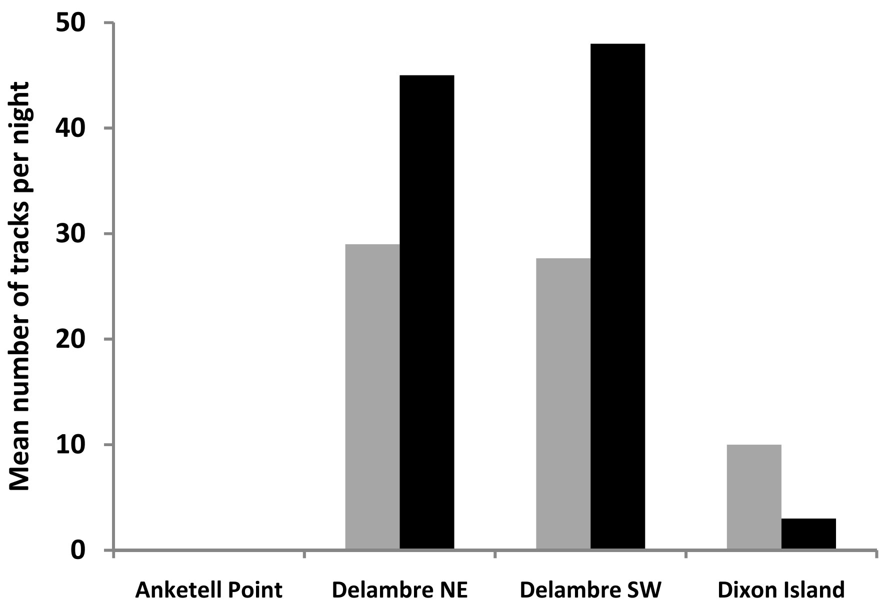

Figure 8: Mean flatback turtle tracks per night during peak nesting (January 2009, *n*=3 days; January 2011, *n*=3 days) at locations where track surveys have been conducted over two seasons. Grey shaded bars 2008; black shaded bars 2011

4.1.2 Hawksbill turtles

Hawksbill turtle nesting was documented in October 2010 at Delambre Island and reached a peak during the January 2011 survey, with up to 46 animals per night documented on the north-east (NE) beach of Delambre Island (**Table 5**). There was no nesting by hawksbill turtles recorded at Anketell Point, Bell's Beach or Dixon Island at any time during the 2010/2011 surveys.

Compared to the previous season, numbers during October were considerably lower (**Figure 9**) however numbers during January had increased from no animals recorded in 2009 to those shown in **Table 5** below in 2011.

Table 5: Hawksbill turtle nesting recorded during 2010/2011 surveys.

Month	Beach	Mean	Range	SE	Survey Days (*n*=)
October	Anketell Point	0	0	0	4
	Bell's Beach	0	0	0	5
	Delambre NE	2	1 - 2	0.2	5
	Delambre SE	2	0 - 3	0.6	5
	Delambre SW	1	0 - 1	0.2	5
	Dixon Island	0	0	0	5
	Huoy Island	0	0	0	3
January	Anketell Point	0	0	0	4
	Bell's Beach	0	0	0	5
	Delambre NE	19	6 - 46	7.1	5
	Delambre SE	8	3 - 13	1.9	5
	Delambre SW	2	0 -	1.0	5
	Dixon Island	0	0	0	5

Table presents mean number of animals on the beach per night.

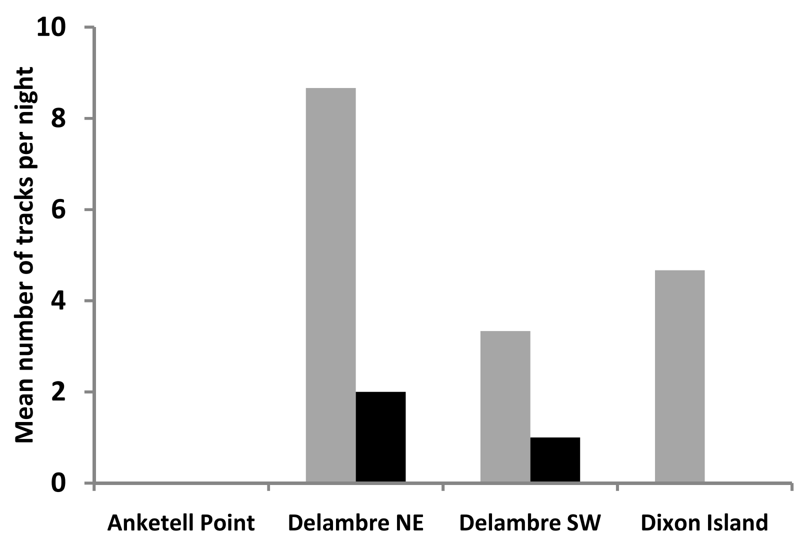

Figure 9: Mean hawksbill turtle tracks per night during October (2009, *n*=3 days; 2010, *n*=5 days) at locations where track surveys have been conducted over two seasons. Grey shaded bars = 2009; black shaded bars = 2010.

4.1.3 Green turtles

Green turtle nesting (**Table 6**) ranged from low to absent at all monitored sites in both survey seasons (**Figure 10**). No activity was recorded during October 2010. The east coast of Delambre Island supported very low level nesting activity by this species in January 2011.

Table 6: Green turtle nesting recorded during 2020/2011 surveys.

Month	Beach	Mean	Range	SE	Survey Days (*n*=)
October	Anketell Point	0	0	0	4
	Bell's Beach	0	0	0	5
	Delambre NE	0	0	0	5
	Delambre SE	0	0	0	5
	Delambre SW	0	0	0	5
	Dixon Island	0	0	0	5
	Huoy Island	0	0	0	3
January	Anketell Point	0	0	0	4
	Bell's Beach	0	0	0	5
	Delambre NE	0.4	0 - 2	0.4	5
	Delambre SE	0.2	0 - 1	0.2	5
	Delambre SW	0	0	0	5
	Dixon Island	0	0	0	5

Table presents mean number of animals on the beach per night.

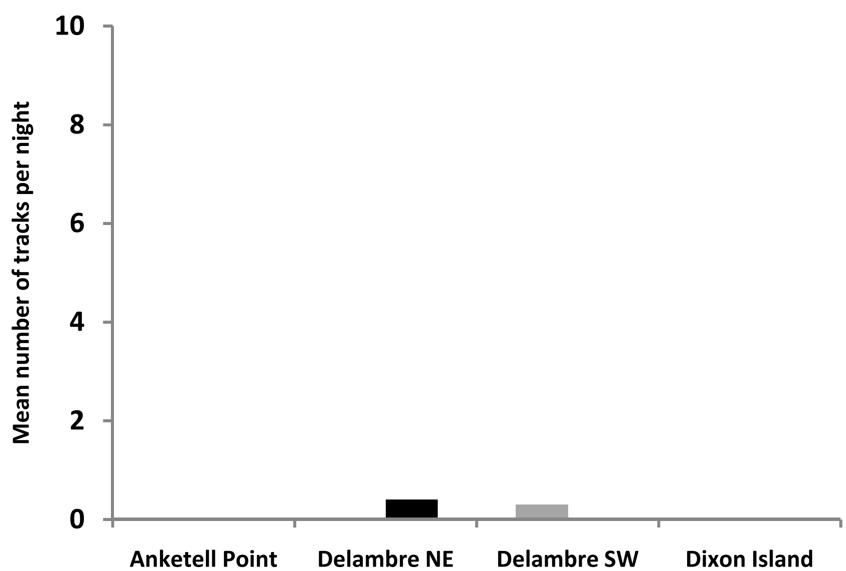

Figure 10: Mean number of green turtle tracks per night during January (2009, *n*=3 days; 2011, *n*=5 days) at locations where track surveys were conducted in two seasons. Grey shaded bars 2009; black shaded bars 2011

4.2 Hatch & Emergence Success

A total of 11 flatback and two hawksbill clutches were excavated and assessed for indicators of reproductive output and success. Flatback clutches were excavated at Bell's Beach, Dixon Island, NE and south-west (SW) Delambre Island. Hawksbill clutches were excavated at NE Delambre Island (**Figure 11**).

Hatch and emergence success were found to be significantly correlated (R^2=0.957, p=<0.0001) and therefore hatch success is used as a proxy for reproductive output throughout this report. Mean overall flatback hatch success was 79.5±7.4 % (27.5-97.5, *n*=11) and emergence success was 75.6±7.6 % (range 20.0-97.5, *n*=11) (**Appendix A**). Mean hawksbill hatch success was 77.9±10.8 (67.1-88.7, *n*=2) and emergence success was 75.2±13.5 (61.7-88.7, *n*=2) (**Appendix A**).

Multiple pairwise comparison of samples showed no significant difference in flatback turtle hatch success among locations (K=4.9, p = 0.299).

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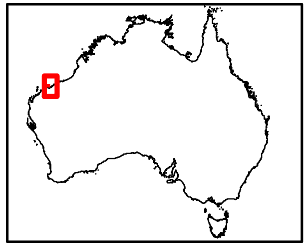
Figure 11: Hatch success: location of clutches

Legend
hatch_success_pro
spps
Flatback
Hawksbill



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4.3 Hatchling Morphology, Clutch count and Clutch Depth

Mean flatback hatchling straight carapace length (SCL) from all sites (Bell's Beach, Dixon Island, Delambre Island) was 61.3±0.2 mm (58-63, *n*=47). Straight carapace width (SCW) was 54.6±0.3 mm (42-58, *n*=48) and mass at all sites was 33.2±0.4 g (29-38, *n*=48). Mean flatback clutch count was 46.6±2.4 eggs (32-59, *n*=11) and mean clutch depth (mm) was 613±25.3 mm (430-750, n=11) to the top of the clutch and 743±22.2 mm (550-830, *n*=11) to the bottom of the clutch.

Mean hawksbill hatchling straight carapace length (SCL) from NE Delambre Island was 41.4±0.5 mm (40-45, *n*=10). Straight carapace width (SCW was 37.5±0.4 mm (36-39, *n*=10) and mass at all sites was 12.4±0.2 g (11.5-13.5, *n*= 10). Mean hawksbill clutch count was 113 ± 15 eggs (98-128, *n*=2) and mean clutch depth (mm) was 500±30 mm (470-530, *n*=2) to the top of the clutch and 625±25 mm (600-650, *n*=2) to the bottom of the clutch (**Appendix A**).

4.4 Hatchling Orientation

Hatchling orientation was assessed at all sites (**Figure 12**). Mean spread angles for flatback hatchlings were Bell's Beach 65.2±4.8° (47 -89, *n*=9), Dixon Island 71.8±6.9° (49 - 99, *n*=8), NE Delambre Island 55.7±3.3° (49 -59, *n*=2) south east (SE) Delambre Island 64.3±11.6° (34-125, *n*=7) and SW Delambre Island 43.1±6.1° (5 -98, *n*=20). Mean offset angles for flatback hatchlings were: Bell's Beach 9.9±2.7° (1.5-23.5, *n*=9), Dixon Island 10.8±3.9° (0.5-35.5, *n*=8), NE Delambre Island 13.5±0.0° (0.5-13.5, *n*=2), SE Delambre Island 7.4±2.6° (1.5-20.5, *n*=7) and SW Delambre Islands 11.2±1.8° (1.5-31.0, *n*=20) (**Figures 13- 16**).

Two samples were obtained from hawksbill hatchings at NE Delambre Island. Spread angles were 73±9.0° (55-82, *n*=2) and offset angles were 4.8±1.2° (2.5-6.0, *n*=2; **Figure 16**). For all data see **Appendix A**.

An Analysis of Variance (ANOVA) showed that there were no significant difference between beaches with respect to either spread ($p > 0.05$) or offset ($p > 0.05$) angles.

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Figure 12:
Location of all hatched clutches assessed for hatchling orientation

Legend
Hatched clutches

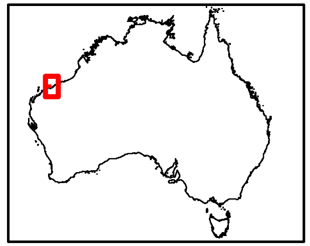

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Figure 13: Hatchling orientation showing spread and offset angles of emerged clutches

Legend

Legend

Nest Fan Offset1
Nest Fan Fill

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Figure 14: Hatchling orientation showing spread and offset angles of emerged clutches at Dixon Island

Legend

- Nest Fan Offset1
- Nest Fan Fill

N

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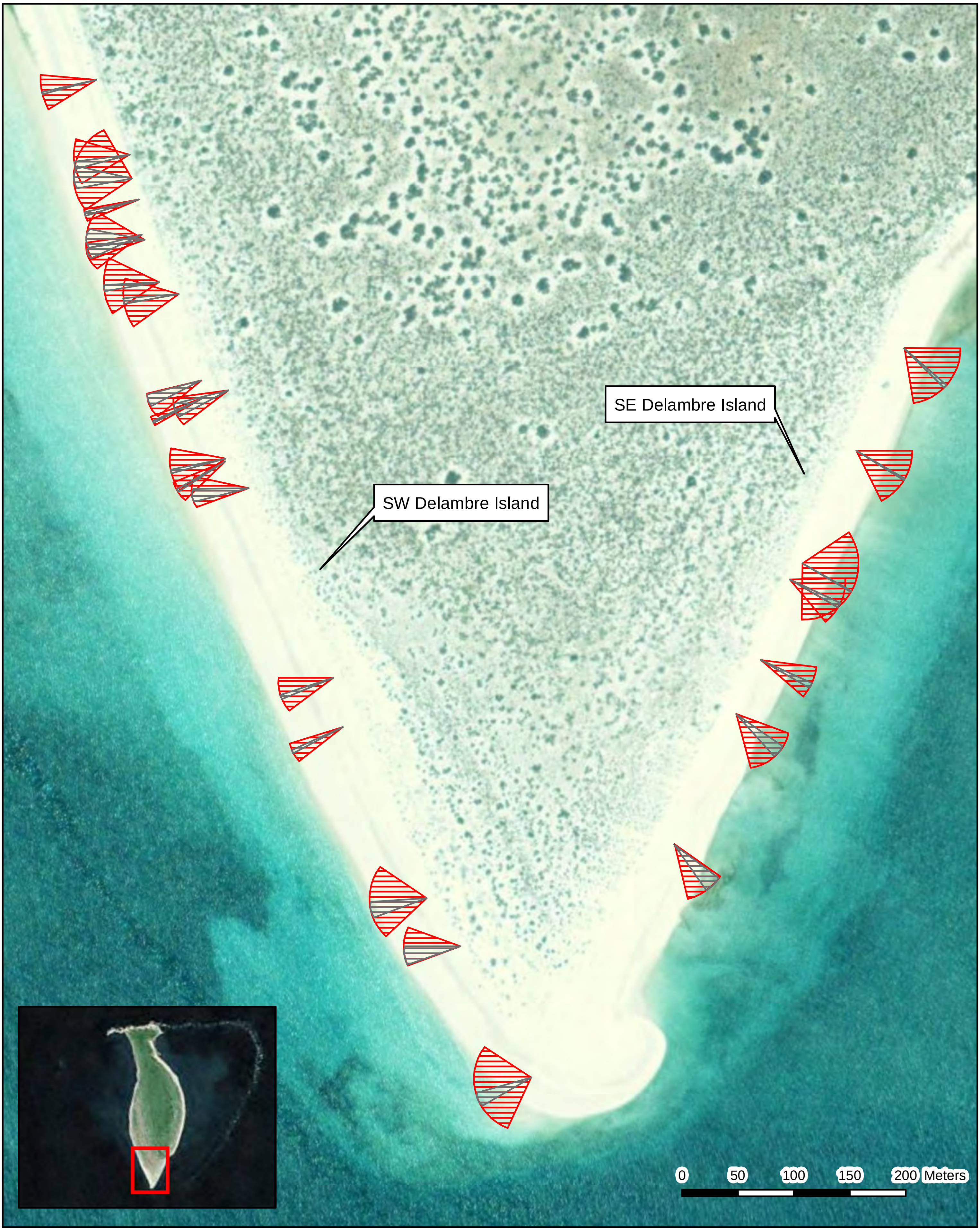

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Figure 15: Hatchling orientation showing spread and offset angles of emerged clutches at South Delambre Island

Legend
Nest Fan Offset1
Nest Fan Fill

N

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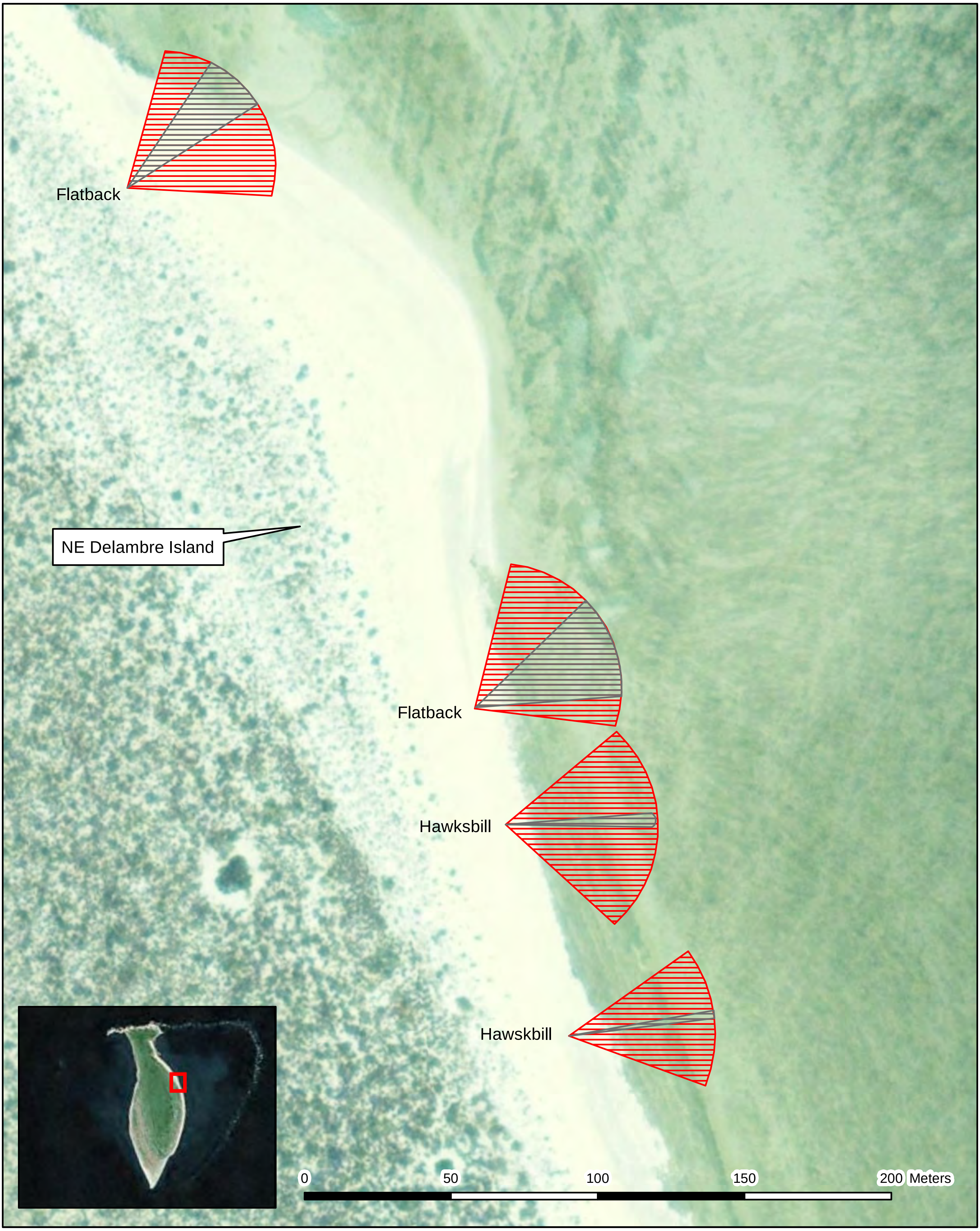

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Figure16: Hatchling orientation showing spread and offset angles of emerged clutches at Delambre Island

Legend
Nest Fan Offset1
Nest Fan Fill

N

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4.5 Sand Temperatures

Sand temperatures recorded ranged from 26.1°C to 36.4°C at all sites during the deployment period of 125 days. Overall mean sand temperatures during the deployment period are shown in **Table 7.** Daily mean temperature at each location is shown in **Appendix A.** Mean daily sand temperature (**Table 7**) did not exceed the thermal tolerance range for this species at any site at any time.

Beach aspect played a role in temperature as temperature was significantly hotter ($p < 0.001$) at the only beach with the north west aspect (Bells Beach) and temperature at both Dixon Island (north aspect) and north east Delambre (east aspect) were significantly hotter ($p=<0.001$) than either the south east or south west of Delambre Island (south east and south west aspect; **Figure 17a**).

Beaches at Delambre Island were significantly cooler overall than all other beaches (**Figure 17b**) and loggers placed on the beach flat (position 2), were significantly cooler than those deployed further up toward the dunes (position 1; **Figure 17c**).

Throughout the duration of the deployment period of 125 days, the amount of time (%) spent above estimated pivotal temperatures for each species varied by location (**Table 8**). Hawksbill and green turtle embryos were more likely to be exposed to feminising temperatures at all locations as they have a lower pivotal temperature.

Sand temperatures generally rose throughout summer until Tropical Cyclone Bianca (January 25, 2011) following which they began to decline (**Figures 18 & 19**). Drops in sand temperature patterns at Delambre Island (**Figure 18**) Bell's Beach and Dixon Island (**Figure 19**) are to some extent associated with drops in air temperature (**Figure 20**).

Table 7: Mean daily sand temperatures (°C)

Location	mean	stdev	range min	range max	SE
Bells Beach 1	31.9	1.2	29.3	34.4	0.02
Bells Beach 2	31.7	1.4	28.1	35.4	0.03
Dixon Is 1	32.2	1.6	28.5	36.4	0.03
Dixon Is 2	30.8	1.6	27.5	35.0	0.03
NE Delambre 1	30.2	1.6	26.4	32.9	0.03
NE Delambre 2	30.2	1.7	26.1	33.3	0.03
SE Delambre 1	29.9	1.7	26.2	32.7	0.03
SE Delambre 2	30.2	1.7	26.4	33.1	0.03
SW Delambre 1	29.9	1.3	27.1	32.3	0.02
SW Delambre 2	30.4	1.6	27.0	33.0	0.03

Table 8: The percentage of each deployment period where sand temperature was above the estimated pivotal temperatures for each species * See section 3.2.5.

		Flatback*	Hawksbill/Green*
Location	Position	% > 29.5°C	% >29°C
SW Delambre	1	56	76.8
SW Delambre	2	68	76.8
SE Delambre	1	55.2	71.2
SE Delambre	2	66.4	74.4
NE Delambre	1	69.6	79.2
NE Delambre	2	68.8	75.2
Bell's Beach	1	98.4	100
Bell's Beach	2	96	98.4
Dixon Island	1	95.2	97.6
Dixon Island	2	75.2	87.2

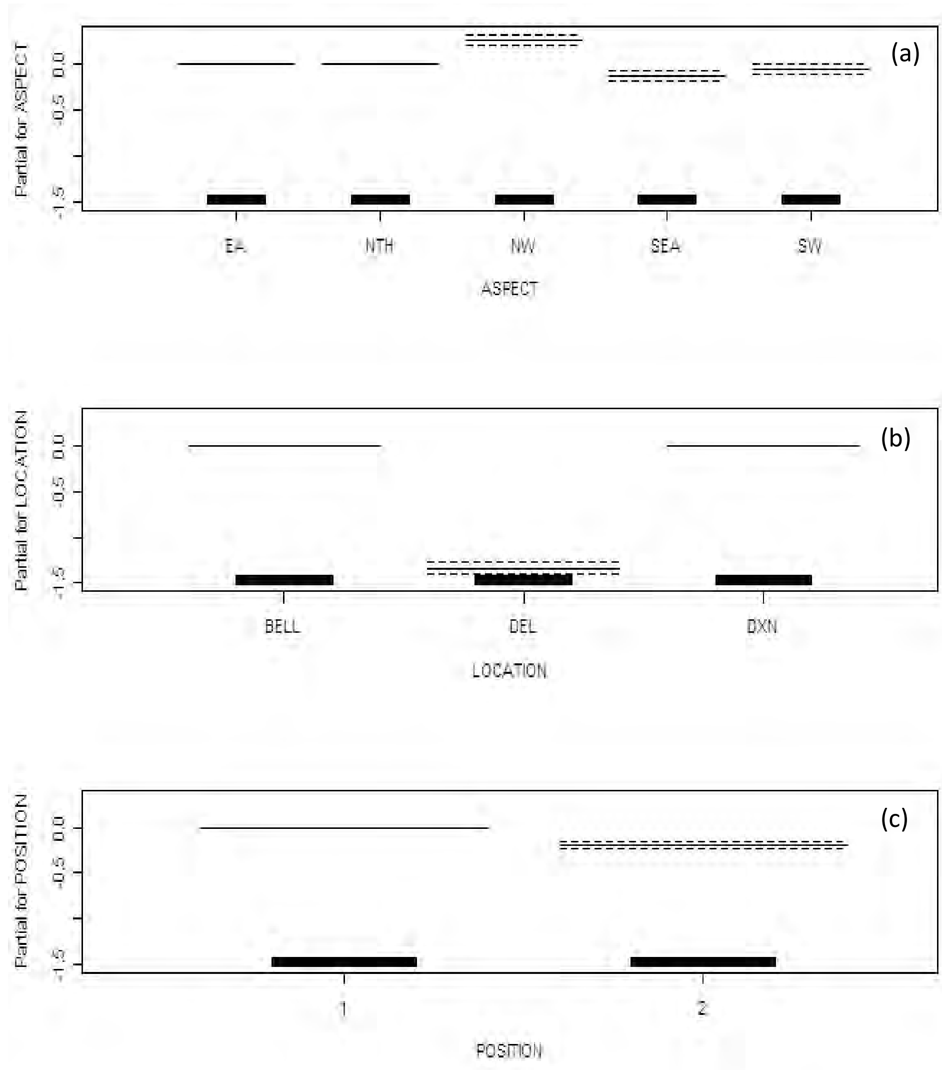

Figure 17: Graphical summary of GAM model fit for beach temperature as a function of (a) aspect (b) location and (c) logger position. **Response scale shown on y-axis as a centred smoothed function scale to ensure valid 95% point-wise confidence bands (dashed lines); black solid line shows relative mean; covariate shown on the x axis. The vertical bars on the lower x-axis panels are known as a 'rug', which shows the data distribution.**

17a: NW=Bell's Beach; NTH=Dixon Island; EA=NE Delambre Island; SEA=SE Delambre Island; SW=SW Delambre Island. This model sets NE Delambre Island at zero and measures data from locations with differing aspects against it. Dashed lines denote statistical significance and therefore Bell's Beach is significantly hotter than all other sites and the southern end of Delambre Island (SE & SW) is significantly cooler than all other sites. **b)** BELL=Bell's Beach; DEL = NE, SE & SW Delambre Island and DXN =Dixon Island. This model looks at temperature for each location and determines that sand temperatures at Delambre Island are significantly cooler than both Bell's Beach and Dixon Island. **c)** This looks at temperature by position on the beach. Data from all beaches have been grouped in this analysis. Loggers deployed in position 1 (dunes) were significantly hotter than those deployed in position two (beach flat.)

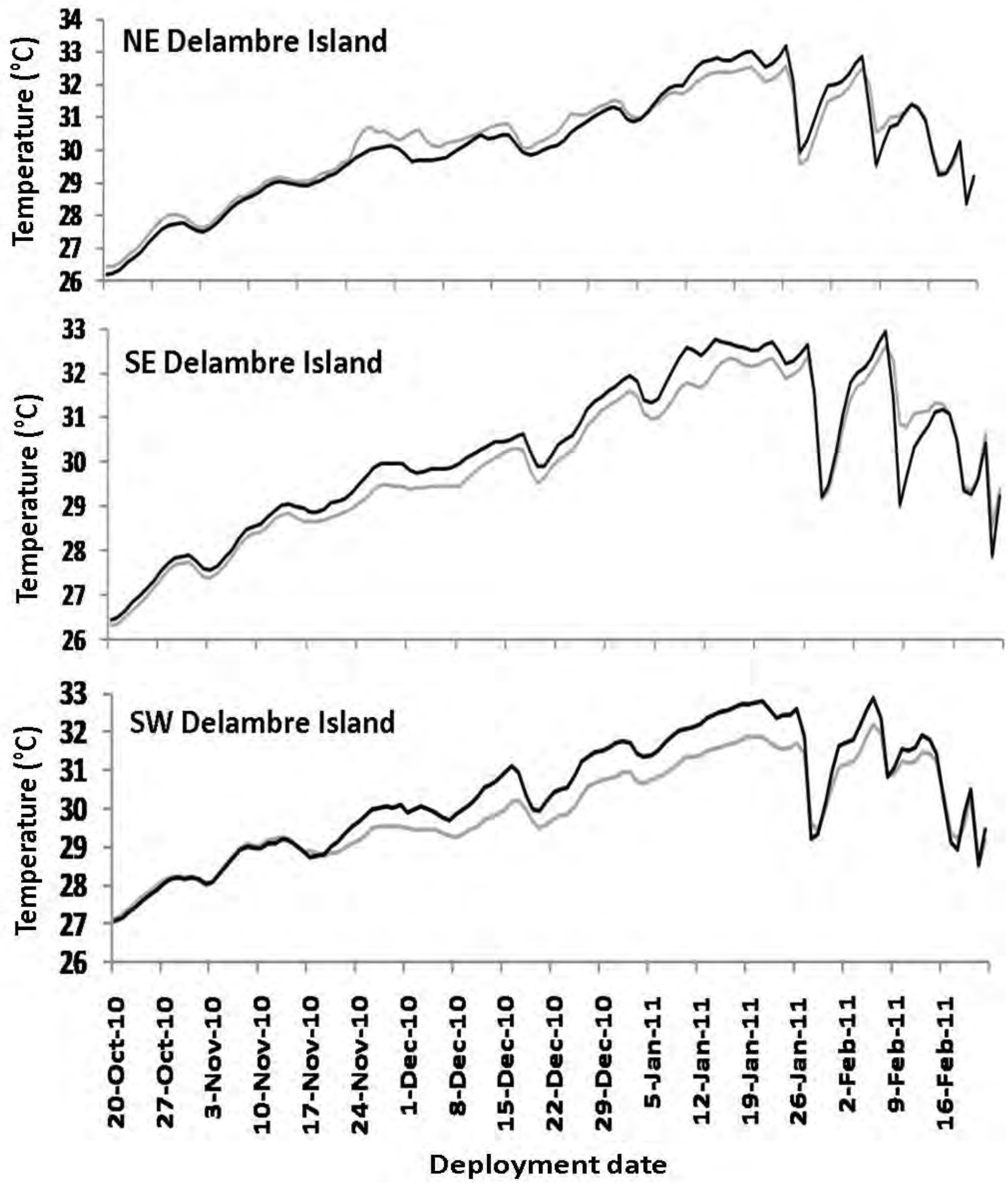

Figure 18: Mean daily sand temperatures (°C) at three locations at Delambre Island. Grey line indicates position 1 (base of primary dunes). Black line indicates position 2 (beach flat)

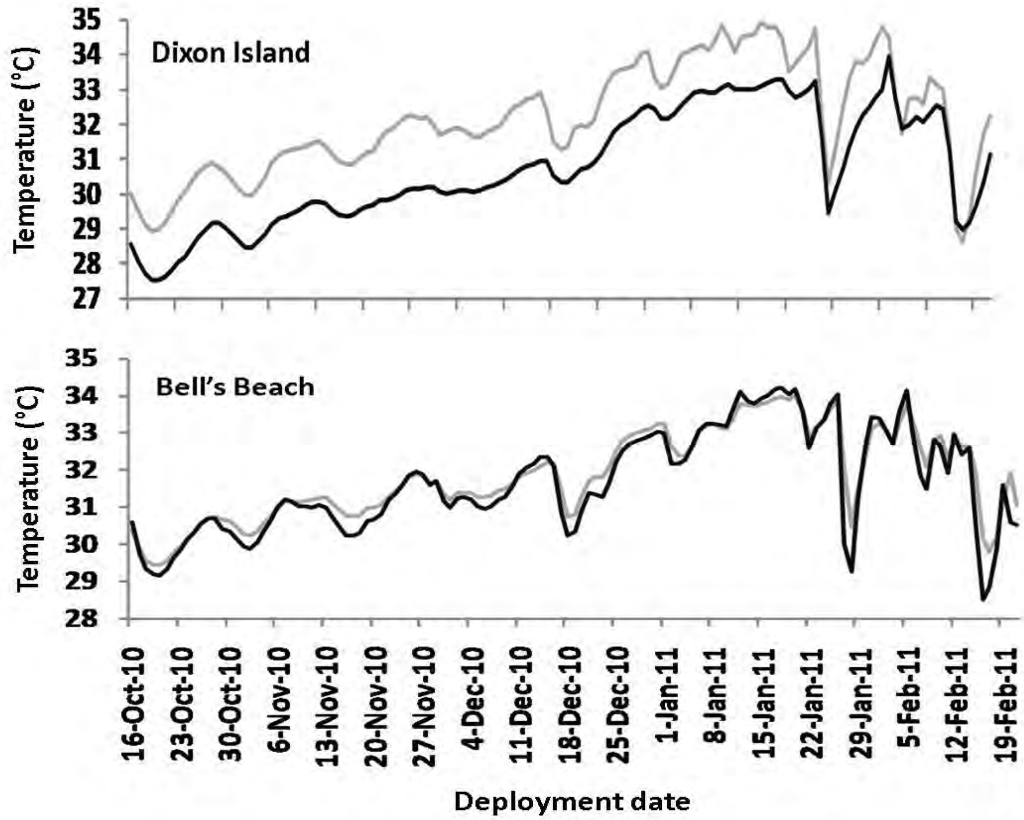

Figure 19: Mean daily sand temperatures (°C) at Dixon Island and Bell's Beach. Grey line indicates position 1 (base of primary dunes). Black line indicates position 2 (beach flat).

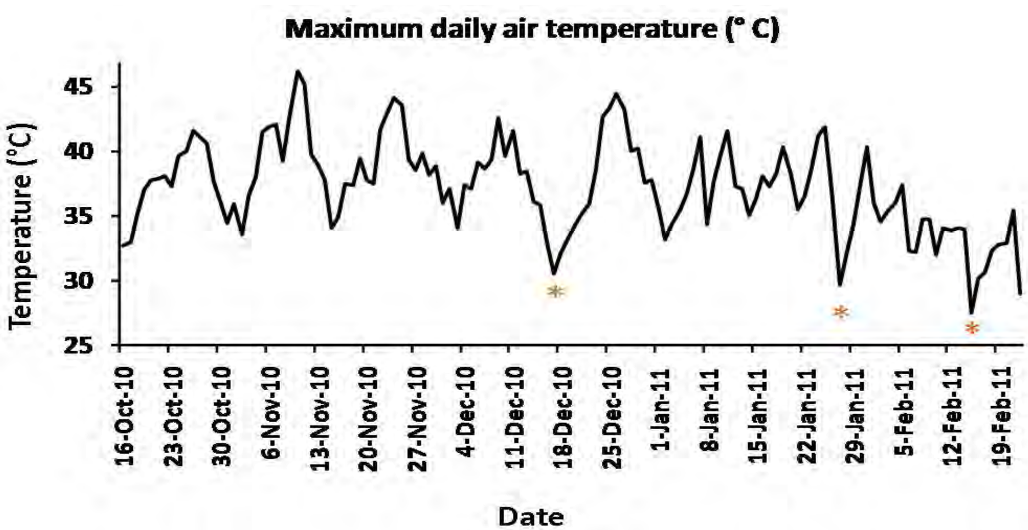

Figure 20: Maximum daily air temperatures for Roebourne, the nearest station to Anketell Point. Asterisks indicate drops in air temperature reflected clearly in sand temperature data at all sites.

4.6 In-water Observations

In the October 2010 surveys an adult loggerhead, and adult hawksbill and an adult green were sighted near Huay Island. One juvenile green turtle was observed in the vicinity of Bell's Beach and another near the north east of Delambre Island. Twenty adult hawksbill turtles were seen in the water along the west coast of Delambre Island (**Table 9**).

During January 2011, 28 adult flatback turtles, nine adult and 15 juvenile green turtles were sighted in the vicinity of Delambre Island (**Table 9**). Both juvenile and adult green turtles were documented in this area, while all in-water sightings of flatback turtles were adults.

No turtles were sighted during February.

Table 9: Opportunistic in-water sightings of marine turtles.

Date	Beach	Species	Life stage	*n=*
8/01/11	Delambre NE	Flatback	Adult	5
9/01/11	Delambre NE	Flatback	Adult	3
10/01/11	Delambre NE	Flatback	Adult	2
8/01/11	Delambre SE	Flatback	Adult	4
10/01/11	Delambre SE	Flatback	Adult	3
8/01/11	Delambre SW	Flatback	Adult	2
11/01/11	Delambre SW	Flatback	Adult	2
10/01/11	Delambre SW	Flatback	Adult	7
10/01/11	Delambre NE	Green	Juvenile	1
8/01/11	Delambre NE	Green	Juvenile	1
11/01/11	Delambre NE	Green	Juvenile	9
11/01/11	Delambre NE	Green	Adult	8
7/01/11	Delambre NE	Green	Adult	1
7/01/11	Delambre NE	Green	Juvenile	2
6/01/11	Delambre SE	Green	Juvenile	2
18/10/10	Huay Island	Loggerhead	Adult	1
18/10/10	Hauy Island	Green	Adult	1
18/10/10	Bells Beach	Green	Juvenile	1
19/10/10	Huoy Island	Hawksbill	Adult	1
20/10/10	Delambre NE	Green	Juvenile	1
20/10/10	Delambre NW/SW	Hawksbill	Adult	20

4.7 Additional Observations

Additional observations were made during field surveys and are summarised in **Table 10**.

Table 10: Additional observations (all species) during the 2010/2011 surveys

Date	Location	Species	Activity	Plate No.
20.10.10	Delambre NW	Hawksbill	Nesting during daylight hours. Observed at the base of the fore dune	
20.10.10	Delambre NW	Hawksbill	Nesting during daylight hours. Observed just above the high tide line	
08.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	1
08.01.11	Delambre SE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre SE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre SE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre SE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre SE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
08.01.11	Delambre SE	Flatback	Observed nesting during daylight hours	
08.01.11	Delambre SE	Flatback	Observed nesting during daylight hours	
09.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
09.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
09.01.11	Delambre NE	Flatback	Emerging from the water during daylight hours and engaging in nesting activity	
	Anketell Point	Green turtle	Remains of a slaughtered juvenile green turtle found near a camp at Anketell Point.	2

Plate 1: A flatback turtle on the beach at NE Delambre Island on 8th January 2011.

Plate 2: The remains of one dead juvenile green turtle found at Anketell Point.

5 DISCUSSION

5.1 Nesting Activity

In general, not all marine turtles nest in every year (Miller, 1997) and therefore levels of nesting activity fluctuate among years. It is therefore necessary to gather multiple years of data to understand the variation within each population. Evidence of this variation has been seen in the data collected in the 2010/2011 season compared to previous season's data.

5.1.1 Flatback turtles

Abundance for this species in this region has fluctuated over the two survey seasons with a greater number of tracks recorded in 2010/2011. Natural variation in the proportion of the nesting population migrating to the nesting beach in each year combined with limited survey periods are likely to have contributed to this variation.

Results from Bell's Beach and Dixon Island in 2010/2011 confirm nesting activity is low at these sites. Beaches at Delambre Island combined (i.e.NE, SE and SW) documented regionally substantial levels of activity (107-126 tracks per night). These numbers are comparable with the largest rookeries in the Western Australia Management Unit, Mundabullangana and Barrow Island rookeries (Bell *et al.,* in press; Chevron Australia, 2009; Pendoley *et al*., in press; **Table 11**).

Table 11: Comparison of flatback turtle rookeries in the Pilbara region for which tagging data are publicly available.

Location	Seasons monitored (n)	Number of nights monitored per season	Number of individual turtles	Number of turtles per night	Source
Delambre Island	2008/09 (1)	21	341	9 - 44	Biota (2009)
Legendre Island	2008/09 (1)	22	303	5 - 39	Biota (2009)
Bell's Beach	2008/09 (1)	26	40	0 - 10	Biota (2009)
Barrow Island	2005/09 – 2008/09 (4)	~54	1396 (mean) Range = 894 - 1658	-	Chevron Australia (2009)
Mundabullangana	1998/99 – 2008/09 (10)	~14	1692 (mean) Range = 1197 – 2171	-	Pendoley *et al.* (in press)

5.1.2 Hawksbill turtles

Data from the 2009/10 and 2010/11 seasons support the conclusion that hawksbill turtles use the beaches of the Dampier Archipelago as nesting habitat. The previous hawksbill turtle survey (October 2009) found a mean of up to nine hawksbill turtles per night at NE Delambre Island and up to five per night at Dixon Island (Pendoley Environmental, 2010). Including tracks found at Huay Island these data suggested that these sites combined may be comparable in size to the Rosemary Island rookery. Though published data are not yet available for this site, the population is believed to in the thousands and is the largest in the Indian Ocean and one of the largest in the world (Morris, 1990).

Results from surveys conducted during the 2010/11 season show a mean of two animals per night at NE Delambre Island in October and a mean of up to 19 animals per night at NE Delambre Island in January 2011. If January 2011 data for all three beaches (NE, SE, SW) at Delambre Island are combined we note up to 57 animals on the island in a single night. In tandem with multiple observations of hawksbill turtles in-water at this location (**Table 9**) and further nesting documented at Hauy Island, the closest suitable habitat to Delambre Island, these numbers confirm that this may be considered a sizeable rookery.

These two datasets (2009/10 & 2010/11) show inter and intra annual variation in spatial and temporal trends and it is therefore not possible to accurately determine the relative importance of Dixon Island as nesting habitat for hawksbill turtles. It may be stated however that of all the hawksbill nesting beaches identified within the survey area Dixon Island has consistently shown the lowest level of activity.

5.1.3 Green turtles

Within the Dampier Archipelago, green turtle nesting has in the past been documented as highest at Legendre Island (Pendoley Environmental, 2010). This site was outside the scope of the 2010/2011 surveys. At surveyed sites nesting was observed only on the east coast of Delambre Island and in very low numbers. These findings are consistent with the previous survey and confirm that there is little green turtle nesting at surveyed sites within the Archipelago in proximity to the Anketell Point project site.

5.2 Hatch & Emergence Success

5.2.1 Flatback turtles

Flatback turtle hatch and emergence success was within the reported range for this species, although lower than that reported from other sites within Western Australia (**Table 12**). This may be due to environmental conditions at the site which may be specific to this season. There was no significant variation among sites surveyed in this season suggesting that reproductive output is similar at all locations.

Table 12: Comparison of flatback turtle hatching and emergence success among the Western Australia Management Unit.

Location	Nesting Season	*n*	Hatching Success (%)	Emergence Success (%)	Source
Cape Domett, Nr. Kununurra, WA	2006/2007	49	88.2 (SD = 12.3)	80.4 (SD = 19.0)	Whiting *et al.* (2008)
Barrow Island, Pilbara, WA	2006/2007-2009/2010	162	81.0 (SE = 1.6)		Chevron Australia (2009)
Barrow Island, Pilbara, WA	2007/2008-2009/2010	134		75.4 (SE = 2.1)	Chevron Australia (2009)
Dampier/Nichol Bay incl. Bell's Beach, Delambre & Dixon Islands, Pilbara, WA	2010/2011	11	79.5 (SD=26.6)	75.6 (SD=25.8)	This study
Eco Beach, Broome, WA	2009/2010	3	87 (SD = NA)	NA	MacFarlane (2010)

5.2.2 Hawksbill turtles

Hawksbill turtle hatch and emergence success at NE Delambre Island were high, as is typical of marine turtles (Ackerman 1997). There are no published values for this species in Western Australia. Hatch and emergence success at Milman Island, Eastern Australia are reported as 86.7% and 84.5% respectively (Limpus & Miller 2007) and are similar to values found in the Dampier region.

5.3 Hatchling Morphology, Clutch Count and Nest Depth

5.3.1 Flatback turtles

Nest depth for flatback turtles was the deepest documented to date. This may be due to moisture content of the sand or the size of the adult digging the chamber. Depth has temperature implications for clutches deposited at these sites as deeper nests will provide cooler temperatures.

Clutch size was equal to that reported for this species at Eco Beach, Broome and Barrow Island and is typical of this species in Western Australia.

Table 13: Comparison of flatback turtle egg, hatchling and reproductive characteristics between breeding units.

Location	Nesting Season	Live Hatchling SCL (mm)	Egg Diameter at Oviposition (mm)	Clutch Count	Bottom Nest Depth (mm)	Source
Cape Domett	2006/2007	59 (SD=3.5) n=15	49 (SD=3) n=310	54.0 (SD=8.6) n=31	629 (SD=83) n=40	Whiting *et al.,* (2008)
Barrow Island	2006/2007 2007/2008 2008/2009		50.4 (SD=2.1)	46.0		Chevron Australia (2009)
Dampier/Nichol Bay incl. Bell's Beach, Delambre & Dixon Islands	2010/2011	61.3 (SE=0.2)	NA	46.6 (SE=2.4)	743 (SD=85)	This report
Eco Beach, Broome	2009/2010			46		MacFarlane (2010)

5.3.2 Hawksbill turtles

Few data are available for hawksbill turtles; however the Australian Hawksbill Turtle Dynamics Project reports hatchling SCL of 39.5 mm and mass of 13.8 g at Milman Island, Eastern Australia (Limpus and Miller 2007). Hatchlings assessed at Delambre Island showed similar values. More data are required before comparisons or conclusions can be made.

5.4 Hatchling Orientation

At all sites hatchlings of both species (hawksbill and flatback) appeared to have travelled directly toward the ocean and had not been either mis- or disorientated. This is evident in **Figures 13-16** which show the degree of offset from the most direct route to the ocean (grey shading) is within the path taken by the hatchlings to the ocean (red shading). Hatchling orientation was therefore not subject to interference from artificial light sources at any site during our surveys. It is known that lunar phase positively impacts the angle of spread in hatchling dispersion however the majority of samples in this survey were collected between days 3 and 7 of the lunar phase, with an additional four collected on day 17. Variation in spread angles was low and the amount of data was not sufficient for further investigation into the effect of lunar phase. .

5.5 Sand Temperatures

Incubation temperature influences hatchling size and fitness, and the amount of yolk material converted to tissue prior to hatch; specifically hatchlings from cooler incubation temperatures are larger than those from warmer nests (Booth *et al.,* 2004). Embryo survival is dependent upon incubation within the thermal tolerance range (TTR) (26-35°C) (Ackerman, 1997). Further, sex-determination is temperature dependant with females produced at higher temperatures (Miller, 1997).

It is the time spent at or above lethal temperatures, and not just the reaching of lethal temperatures that determines embryo survival (Valverde *et al*., 2010). Dixon Island and Bell's Beach are the hotter beaches in the region although neither of these beaches recorded temperatures close to the known thermal tolerance range (TTR) for species nesting in the region. Examination of daily mean sand temperatures identified no days where temperatures were either above or below the known TTR (26-35°C) for marine turtle embryos (Ackerman, 1997). Metabolic heating within the clutch increases the temperature embryos are exposed to during incubation. Recorded field values range from 0.1-2.6°C (Broderick *et al.,* 2001; Koch *et al.,* 2007). Our findings show an increase of this magnitude would not force clutches temperatures in the Anketell Point region over the TTR for any extended period of time.

Control loggers were buried at 500 mm to represent mean clutch depth for this species and this value was based on research from eastern Australian flatback turtle rookeries as data were not available for the northwest shelf MU. Following this survey, we now confirm mean mid clutch depth in the Dampier region for flatback turtles to be 678 mm and hawksbill turtles to be 563 mm. Deeper nests have cooler temperatures and this cooling effect may impact our predictions for primary sex-ratio production in the region, for both hawksbill and flatback turtles. These findings are valuable in a region characterised by excessive sand temperatures (Pendoley Environmental, *unpub data*) that are, at least, potentially feminising and easily reach lethal levels for part or all of the reproductive season at other locations.

5.5.1 Pivotal temperatures

While pivotal temperatures are not known for flatback turtles in this region, they are known to be ~29.5 °C for Eastern Australian flatback rookeries (Hewavisenthi & Parmenter, 2000) and ~29 °C in other turtle species studied to date (Standora & Spotila, 1985; Mrosovsky, 1994; Ackerman, 1997). This means that constant incubation at this temperature will yield a clutch with a 50%/50% female to male ratio.

Time spent above/below pivotal temperatures varied by location within the survey area. On the whole, this produces a less-skewed and more balanced primary sex-ratio than is found elsewhere in the region. Some surveyed beaches were predicted to be primarily male and some female. The southern section of Delambre Island provides cooler sand temperatures that may be capable of producing split-sex clutches for this species. This finding renders this location a valuable resource for production of a male turtles and preservation of primary sex-ratios in marine turtle species nesting at this location.

A recent study shows that flatback turtles in the northwest of Australia may have higher pivotal temperatures that those elsewhere in Australia (Box, 2010) and if confirmed, this may contribute to production of a more balanced sex-ratio.

5.6 In-water Observations

In-water observations made by field staff during this survey were opportunistic and not collected as part of a systematic survey. Spatial distribution was not fully assessed by field staff as animals were only observed when the vessel was moving slowly on approach to each survey site. This provided only a presence (rather than presence/absence) indicator of spatial distribution. It is apparent however, that near-shore areas are populated by marine turtles during the summer months, in particular flatback and hawksbill turtles in the vicinity of Delambre Island.

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Appendix A: Data Tables

Table 14: Animals (flatback turtles) X-line (on the beach) in each night of the survey.

N. depressus	**Survey day**					**Descriptive statistics**		
Anketell Point	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Bell's Beach	1	2	3	4	5	mean	range	SE
October	0	2	0	1	0	0.4	0 - 2	0.3
January	4	1	0	1	5	2.2	0 - 5	1.0
Delambre NE	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	48	15	52	79	29	44.6	15 - 48	10.9
Delambre SE	1	2	3	4	5	mean	range	SE
October	1	0	0	0	0	0.1	0 - 1	0.1
January	45	55	39	63	34	47	34 - 63	5.2
Delambre SW	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	33	54	16	83	55	48.1	16 - 83	11.3
Dixon Island	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	2	4	5	3	1	3	1 - 5	0.7
February								
Huay Island	1	2	3	4	5	mean	range	SE
October	0	0	*	*	*	*	*	*
January	*	*	*	*	*	*	*	*

Table 15: Animals (green turtles) X-line (on the beach) in each night of the survey.

C. mydas	Survey day					Descriptive statistics		
Anketell Point	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Bell's Beach	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Delambre NE	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	2	0	0.4	0 - 2	0.4
Delambre SE	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	1	0	0	0	0	0.2	0 - 1	0.2
Delambre SW	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Dixon Island	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Huay Island	1	2	3	4	5	mean	range	SE
October	0	0	*	*	*	*	*	*
January	*	*	*	*	*	*	*	*

Table 16: Animals (hawksbill turtles)X-line (on the beach) in each night of the survey.

E. imbricata	**Survey day**					**Descriptive statistics**		
Anketell Point	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Bell's Beach	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Delambre NE	1	2	3	4	5	mean	range	SE
October	1	1	2	2	2	1.5	1 - 2	0.2
January	6	46	17	8	19	19	6 – 46	7.1
Delambre SE	1	2	3	4	5	mean	Range	SE
October	2	3	1	0	3	1.7	0 - 3	0.6
January	13	8	11	4	3	7.8	3 - 13	1.9
Delambre SW	1	2	3	4	5	mean	range	SE
October	1	1	0	1	0	0.5	0 - 1	0.2
January	0	3	3	5	0	2.2	0 - 5	1.0
Dixon Island	1	2	3	4	5	mean	range	SE
October	0	0	0	0	0	0	0	0
January	0	0	0	0	0	0	0	0
Huay Island	1	2	3	4	5	mean	range	SE
October	0	0	*	*	*	*	*	*
January	*	*	*	*	*	*	*	*

Table 17: HOBO Data Logger (ua-001-008) deployment locations and date/time.

Date	Latitude	Longitude	Beach	SN#	Time of deployment	Beach position
15.10.10	-20.44437	117.08424	Delambre NE	9798273	09:20	Bottom of foredune
15.10.10	-20.44435	117.08433	Delambre NE	2416965	09:28	Middle of beach berm
18.10.10	-20.46150	117.07825	Delambre SE	9798272	07:50	Bottom of foredune
18.10.10	-20.46153	117.07829	Delambre SE	9798280	07:45	Middle of beach berm
16.10.10	-20.45960	117.07272	Delambre SW	2416959	07:50	Bottom of foredune
16.10.10	-20.45960	117.07264	Delambre SW	2416963	07:55	Middle of beach berm
15.10.10	-20.61726	117.08084	East Dixon	9798277	12:55	Bottom of foredune
15.10.10	-20.61714	117.08082	East Dixon	2416967	13:00	Middle of beach berm
15.10.10	-20.61165	117.15526	Bells Beach	9798283	15:50	Bottom of foredune
15.10.10	-20.61162	117.15526	Bells Beach	2416961	15:45	Middle of beach berm

Table 18: Flatback turtle hatch and emergence success, clutch morphology and clutch count.

Location	Clutch depth - top (mm)	Clutch depth - bottom (mm)	Clutch count	Hatch success (%)	Emergence success (%)
Delambre SW	700	820	43	93.0	90.7
Delambre SW	600	770	59	89.8	86.4
Delambre NE	560	700	32	81.3	81.3
Delambre NE	600	760	54	88.9	79.6
Dixon Island	660	750	46	93.5	93.5
Delambre SE	750	830	51	82.4	80.4
Bell's Beach	430	550	40	27.5	20.0
Dixon Island	660	740	39	97.4	97.4
Dixon Island	600	740	55	96.4	94.5
Dixon Island	560	760	49	89.8	73.5
Dixon Island	620	750	44	34.1	34.1

Table 19: Hawksbill turtle hatch and emergence success, clutch morphology and clutch count.

Location	Clutch depth - top (mm)	Clutch depth - bottom (mm)	Clutch count	Hatch success (%)	Emergence success (%)
Delambre NE	470	600	98	88.8	88.8
Delambre NE	530	650	128	67.2	61.7

Table 20: Spread and offset angles for all assessed clutches.

Date	Beach	Latitude	Longitude	Species	Spread°	Offset°	Confirmed	Predated
10/01/11	Bell's Beach	20.61209	117.15441	Flatback	57	18.5	Y	N
11/01/11	Bell's Beach	20.61176	117.15485	Flatback	89	1.5	Y	Fox
11/01/11	Bell's Beach	20.61176	117.15485	Flatback	48	6	Y	Fox
11/01/11	Bell's Beach	20.61138	117.15538	Flatback	83	3.5	Y	Fox
11/01/11	Bell's Beach	20.6109	117.15599	Flatback	74	6	Y	N
11/01/11	Bell's Beach	20.61086	117.15609	Flatback	47	23.5	Y	N
11/01/11	Bell's Beach	20.61227	117.15410	Flatback	62	3	Y	N
11/01/11	Bell's Beach	20.61213	117.15419	Flatback	65	9.5	Y	Y
11/01/11	Bell's Beach	20.61227	117.15410	Flatback	62	18	Y	Y
10/01/11	Dixon Island	20.61707	117.08205	Flatback	50	5	Y	Fox, bird
10/01/11	Dixon Island	20.61702	117.08163	Flatback	99	8.5	Y	N
10/01/11	Dixon Island	20.61703	117.08161	Flatback	84	11	Y	N
10/01/11	Dixon Island	20.61706	117.08127	Flatback	54	5	Y	N
10/01/11	Dixon Island	20.61707	117.08114	Flatback	94	16	Y	N
10/01/11	Dixon Island	20.61708	117.08082	Flatback	71	4.5	Y	N
10/01/11	Dixon Island	20.61729	117.08071	Flatback	73	0.5	Y	N
11/01/11	Dixon Island	20.61703	117.08155	Flatback	49	35.5	Y	N
8/01/11	NE Delambre	20.44233	117.08346	Flatback	59	13.5	Y	N
7/01/11	NE Delambre	20.44369	117.07425	Flatback	49	13.5	Y	Y
8/01/11	NE Delambre	20.44233	117.08346	Flatback	59	13.5	Y	N
8/01/11	NE Delambre	20.44444	117.08440	Hawksbill	82	6	Y	N
8/01/11	NE Delambre	20.44444	117.08440	Hawksbill	82	6	Y	N
11/01/11	NE Delambre	20.44512	117.08452	Hawksbill	55	2.5	Y	N
11/01/11	SE Delambre	20.46458	117.07632	Flatback	41	20.5	Y	N
11/01/11	SE Delambre	20.4636	117.07700	Flatback	55	12.5	Y	N
11/01/11	SE Delambre	20.46161	117.07833	Flatback	63	1.5	Y	Perentie
9/01/11	SE Delambre	20.46709	117.07872	Flatback	81	4.5	Y	N
9/01/11	SE Delambre	20.46246	117.07774	Flatback	125	1.5	Y	N
9/01/11	SE Delambre	20.46257	117.07761	Flatback	51	5.5	Y	N
9/01/11	SE Delambre	20.46319	117.07727	Flatback	34	6	Y	Y
11/01/11	SW Delambre	20.4578	117.07227	Flatback	37	1.5	Y	N
11/01/11	SW Delambre	20.45844	117.07247	Flatback	47	7.5	Y	N
11/01/11	SW Delambre	20.46033	117.07282	Flatback	26	12	Y	N
11/01/11	SW Delambre	20.46099	117.07294	Flatback	45	3.5	Y	N
11/01/11	SW Delambre	20.46517	117.07438	Flatback	40	20	Y	N
11/01/11	SW Delambre	20.46517	117.07438	Flatback	85	5.5	Y	N
6/01/11	SW Delambre	20.45863	117.07246	Flatback	94	23	N	N
6/01/11	SW Delambre	20.45881	117.07250	Flatback	9	7.5	N	N
6/01/11	SW Delambre	20.45909	117.07248	Flatback	23	17.5	N	N
7/01/11	SW Delambre	20.45914	117.07250	Flatback	38	31	Y	N
7/01/11	SW Delambre	20.45949	117.07258	Flatback	59	5.5	Y	N
7/01/11	SW Delambre	20.46047	117.07282	Flatback	5	7.5	N	N

Date	Beach	Latitude	Longitude	Species	Spread°	Offset°	Confirmed	Predated
7/01/11	SW Delambre	20.46101	117.07293	Flatback	22	3	Y	N
7/01/11	SW Delambre	20.46327	117.07363	Flatback	20	3	Y	Y
7/01/11	SW Delambre	20.46474	117.07415	Flatback	77	15.5	N	N
7/01/11	SW Delambre	20.4663	117.07483	Flatback	98	14	N	N
20/02/11	SW Delambre	-20.4629	117.07361	Flatback	36	4	Y	Perentie
20/02/11	SW Delambre	-20.4613	117.07311	Flatback	26	19	Y	Perentie
20/02/11	SW Delambre	-20.4596	117.07273	Flatback	52	6	y	N
20/02/11	SW Delambre	-20.4604	117.07304	Flatback	23	17.5	y	N

Table 21: Hatchling morphology.

SCL (mm)	SCW (mm)	Mass (g)	Location
62	56	36	Bell's Beach
61	55	34	Bell's Beach
63	55	34	Bell's Beach
61	55	32	Bell's Beach
63	55	32.5	Bell's Beach
62	56	31.5	Bell's Beach
63	56	32	Bell's Beach
62	56	31.5	Bell's Beach
61	55	30.5	Dixon Island
60	55	31	Dixon Island
59	54	30	Dixon Island
61	55	30	Dixon Island
60	53	29	Dixon Island
59	53	29.5	Dixon Island
60	58	29.5	Dixon Island
58	50	29	NE Delambre Island
62	55	32.5	NE Delambre Island
61	55	29	NE Delambre Island
60	52	29.5	NE Delambre Island
61	55	31	NE Delambre Island
60	54	30	NE Delambre Island
60	55	34.5	NE Delambre Island
62	55	36.5	NE Delambre Island
63	56	37	NE Delambre Island
60	55	35	NE Delambre Island
62	56	37	NE Delambre Island
62	56	37	NE Delambre Island
61	55	36	NE Delambre Island
62	56	37	NE Delambre Island
61	56	37	NE Delambre Island
63	56	36.5	NE Delambre Island
62	56	36	NE Delambre Island
63	56	38	NE Delambre Island
63	56	37.5	NE Delambre Island
61	55	37.5	NE Delambre Island
62	56	35.5	SE Delambre Island
60	56	35	SE Delambre Island
62	55	36	SE Delambre Island
63	55	34	SE Delambre Island
62	55	35.5	SE Delambre Island
59	52	30	SE Delambre Island

SCL (mm)	SCW (mm)	Mass (g)	Location
62	56	32.5	SE Delambre Island
62	55	32.5	SE Delambre Island
60	54	32	SE Delambre Island
60	54	31.5	SE Delambre Island
61	52	31	SE Delambre Island
NR	42	33	SW Delambre Island
62	54	29	SW Delambre Island

Table 22: Mean daily sand temperatures (°C) at each logger deployment location.

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
16-Oct-10	*	*	*	*	27.1	26.6	30.4	30.6	30.0	28.6
17-Oct-10	27.2	27.1	*	*	27.0	26.5	29.9	29.7	29.5	28.0
18-Oct-10	27.2	27.2	*	*	26.7	26.4	29.5	29.3	29.1	27.7
19-Oct-10	27.1	27.1	*	*	26.5	26.3	29.4	29.2	28.9	27.5
20-Oct-10	27.1	27.1	26.3	26.4	26.4	26.2	29.4	29.2	29.0	27.5
21-Oct-10	27.2	27.1	26.4	26.5	26.4	26.2	29.5	29.3	29.1	27.6
22-Oct-10	27.4	27.3	26.5	26.6	26.6	26.4	29.8	29.6	29.5	27.8
23-Oct-10	27.6	27.5	26.7	26.8	26.8	26.6	29.9	29.9	29.8	28.0
24-Oct-10	27.7	27.6	26.8	27.0	26.9	26.7	30.1	30.1	30.1	28.2
25-Oct-10	27.9	27.7	27.0	27.1	27.1	26.9	30.4	30.3	30.3	28.5
26-Oct-10	28.0	27.9	27.2	27.3	27.4	27.2	30.6	30.5	30.6	28.8
27-Oct-10	28.1	28.0	27.3	27.5	27.7	27.4	30.7	30.7	30.8	29.0
28-Oct-10	28.2	28.2	27.6	27.7	27.9	27.6	30.7	30.7	30.9	29.2
29-Oct-10	28.3	28.2	27.7	27.8	28.0	27.7	30.7	30.4	30.8	29.2
30-Oct-10	28.2	28.2	27.7	27.9	28.0	27.7	30.6	30.3	30.6	29.0
31-Oct-10	28.2	28.2	27.8	27.9	28.0	27.8	30.5	30.2	30.4	28.9
1-Nov-10	28.1	28.2	27.6	27.8	27.8	27.7	30.3	29.9	30.1	28.6
2-Nov-10	28.0	28.0	27.4	27.6	27.7	27.5	30.2	29.9	30.0	28.5
3-Nov-10	28.1	28.1	27.4	27.6	27.6	27.5	30.3	30.0	30.0	28.5
4-Nov-10	28.3	28.3	27.5	27.7	27.8	27.6	30.6	30.3	30.2	28.7
5-Nov-10	28.6	28.5	27.7	27.8	28.0	27.8	30.8	30.6	30.5	28.9
6-Nov-10	28.8	28.7	27.9	28.0	28.2	28.0	31.0	31.0	30.9	29.1
7-Nov-10	29.0	28.9	28.1	28.3	28.4	28.2	31.2	31.2	31.1	29.3
8-Nov-10	29.1	29.0	28.3	28.5	28.5	28.4	31.1	31.2	31.2	29.4

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
9-Nov-10	29.0	29.0	28.4	28.5	28.6	28.5	31.1	31.0	31.3	29.4
10-Nov-10	29.1	29.0	28.4	28.6	28.7	28.6	31.2	31.0	31.3	29.5
11-Nov-10	29.2	29.1	28.5	28.7	28.8	28.7	31.2	31.0	31.4	29.7
12-Nov-10	29.2	29.1	28.7	28.9	29.0	28.9	31.2	31.1	31.5	29.8
13-Nov-10	29.3	29.2	28.8	29.0	29.1	29.0	31.3	31.0	31.5	29.8
14-Nov-10	29.2	29.2	28.8	29.1	29.2	29.1	31.1	30.7	31.4	29.7
15-Nov-10	29.0	29.1	28.8	29.0	29.1	29.0	30.9	30.5	31.1	29.5
16-Nov-10	28.9	28.9	28.7	29.0	29.1	29.0	30.8	30.2	30.9	29.4
17-Nov-10	28.9	28.7	28.7	28.9	29.0	28.9	30.8	30.2	30.9	29.4
18-Nov-10	28.8	28.8	28.7	28.9	29.1	28.9	30.8	30.3	30.8	29.4
19-Nov-10	28.8	28.8	28.7	28.9	29.1	29.0	31.0	30.6	31.0	29.5
20-Nov-10	28.9	29.0	28.8	29.1	29.3	29.1	31.0	30.7	31.2	29.6
21-Nov-10	28.9	29.1	28.8	29.1	29.3	29.2	31.0	30.8	31.2	29.7
22-Nov-10	29.0	29.3	28.9	29.2	29.4	29.3	31.3	31.2	31.5	29.8
23-Nov-10	29.1	29.5	29.0	29.3	29.6	29.5	31.4	31.3	31.8	29.8
24-Nov-10	29.2	29.7	29.1	29.5	29.7	29.6	31.6	31.6	31.9	29.9
25-Nov-10	29.3	29.8	29.2	29.7	30.3	29.8	31.8	31.9	32.1	29.9
26-Nov-10	29.5	30.0	29.4	29.9	30.6	29.9	31.9	32.0	32.2	30.1
27-Nov-10	29.6	30.0	29.5	30.0	30.7	30.0	31.8	31.9	32.2	30.2
28-Nov-10	29.6	30.0	29.5	30.0	30.6	30.1	31.6	31.6	32.2	30.2
29-Nov-10	29.6	30.0	29.5	30.0	30.6	30.1	31.7	31.7	32.2	30.2
30-Nov-10	29.6	30.1	29.5	30.0	30.5	30.1	31.3	31.2	32.0	30.2
1-Dec-10	29.5	29.9	29.4	29.8	30.3	30.0	31.2	31.0	31.7	30.0
2-Dec-10	29.5	30.0	29.4	29.8	30.4	29.9	31.4	31.2	31.8	30.0
3-Dec-10	29.5	30.0	29.4	29.8	30.5	29.7	31.4	31.3	31.9	30.1
4-Dec-10	29.5	30.0	29.5	29.9	30.6	29.7	31.4	31.2	31.9	30.1

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
5-Dec-10	29.5	29.9	29.5	29.9	30.3	29.7	31.3	31.0	31.8	30.1
6-Dec-10	29.4	29.8	29.5	29.9	30.1	29.7	31.3	31.0	31.7	30.1
7-Dec-10	29.3	29.7	29.5	29.9	30.1	29.8	31.3	31.0	31.7	30.1
8-Dec-10	29.3	29.8	29.4	30.0	30.2	29.8	31.5	31.2	31.8	30.2
9-Dec-10	29.4	30.0	29.6	30.1	30.3	29.9	31.5	31.3	31.9	30.3
10-Dec-10	29.4	30.1	29.8	30.2	30.3	30.1	31.6	31.5	32.0	30.3
11-Dec-10	29.5	30.3	29.9	30.3	30.4	30.2	31.8	31.9	32.3	30.4
12-Dec-10	29.7	30.5	30.0	30.4	30.5	30.4	31.9	32.1	32.5	30.6
13-Dec-10	29.8	30.6	30.1	30.5	30.5	30.5	32.0	32.2	32.6	30.7
14-Dec-10	29.9	30.8	30.2	30.5	30.7	30.4	32.1	32.4	32.7	30.8
15-Dec-10	30.0	31.0	30.3	30.5	30.8	30.4	32.2	32.3	32.8	30.9
16-Dec-10	30.2	31.1	30.3	30.6	30.8	30.5	32.2	32.1	32.9	30.9
17-Dec-10	30.2	30.9	30.3	30.6	30.8	30.5	31.4	30.9	32.4	30.9
18-Dec-10	30.0	30.3	29.8	30.2	30.4	30.2	30.7	30.2	31.5	30.5
19-Dec-10	29.7	30.0	29.5	29.9	30.1	29.9	30.8	30.3	31.3	30.3
20-Dec-10	29.5	30.0	29.6	29.9	30.0	29.9	31.3	30.9	31.4	30.3
21-Dec-10	29.6	30.2	29.9	30.1	30.2	29.9	31.7	31.4	31.9	30.5
22-Dec-10	29.7	30.4	30.0	30.4	30.3	30.0	31.8	31.3	32.0	30.7
23-Dec-10	29.8	30.5	30.2	30.5	30.4	30.1	31.8	31.3	31.9	30.8
24-Dec-10	29.9	30.6	30.3	30.6	30.5	30.1	32.1	31.6	32.1	30.9
25-Dec-10	30.1	30.9	30.5	30.9	30.8	30.3	32.5	32.2	32.7	31.2
26-Dec-10	30.4	31.2	30.8	31.2	31.1	30.5	32.8	32.5	33.2	31.5
27-Dec-10	30.6	31.4	31.0	31.4	31.1	30.7	32.9	32.7	33.5	31.8
28-Dec-10	30.7	31.5	31.2	31.5	31.1	30.8	33.0	32.8	33.6	32.0
29-Dec-10	30.7	31.5	31.3	31.6	31.2	31.0	33.1	32.9	33.6	32.1
30-Dec-10	30.8	31.6	31.4	31.7	31.3	31.1	33.1	32.9	33.7	32.3

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
31-Dec-10	30.8	31.7	31.5	31.8	31.4	31.2	33.2	33.0	34.1	32.4
1-Jan-11	31.0	31.8	31.6	31.9	31.5	31.3	33.2	33.0	34.1	32.6
2-Jan-11	30.9	31.7	31.5	31.8	31.5	31.3	32.6	32.2	33.3	32.4
3-Jan-11	30.7	31.4	31.1	31.4	31.2	31.0	32.4	32.2	33.0	32.2
4-Jan-11	30.7	31.4	31.0	31.3	31.0	30.9	32.4	32.3	33.2	32.1
5-Jan-11	30.7	31.4	31.0	31.4	31.0	31.0	32.7	32.7	33.6	32.3
6-Jan-11	30.8	31.5	31.2	31.7	31.1	31.2	33.0	33.1	34.0	32.5
7-Jan-11	30.9	31.7	31.4	32.1	31.3	31.4	33.2	33.2	34.1	32.7
8-Jan-11	31.0	31.9	31.6	32.3	31.5	31.7	33.2	33.3	34.2	32.9
9-Jan-11	31.2	32.0	31.8	32.6	31.7	31.9	33.2	33.2	34.3	33.0
10-Jan-11	31.4	32.1	31.7	32.5	31.8	32.0	33.1	33.2	34.1	32.9
11-Jan-11	31.3	32.1	31.7	32.4	31.7	32.0	33.5	33.7	34.4	32.9
12-Jan-11	31.4	32.2	31.8	32.6	31.9	32.2	33.8	34.1	34.8	33.1
13-Jan-11	31.5	32.4	32.1	32.8	32.1	32.5	33.8	33.9	34.5	33.1
14-Jan-11	31.5	32.4	32.2	32.7	32.2	32.7	33.7	33.8	34.1	33.0
15-Jan-11	31.6	32.5	32.3	32.7	32.3	32.8	33.8	33.9	34.5	33.0
16-Jan-11	31.7	32.6	32.3	32.6	32.4	32.8	33.8	34.0	34.6	33.0
17-Jan-11	31.7	32.6	32.2	32.6	32.4	32.7	33.9	34.2	34.6	33.0
18-Jan-11	31.8	32.7	32.2	32.5	32.4	32.8	34.0	34.2	34.9	33.1
19-Jan-11	31.9	32.7	32.2	32.5	32.4	32.9	33.9	34.0	34.8	33.2
20-Jan-11	31.9	32.8	32.3	32.6	32.5	33.0	34.0	34.2	34.8	33.3
21-Jan-11	31.9	32.8	32.3	32.7	32.6	33.0	33.6	33.6	34.4	33.3
22-Jan-11	31.8	32.6	32.1	32.5	32.3	32.8	32.9	32.6	33.5	33.0
23-Jan-11	31.6	32.3	31.9	32.2	32.1	32.6	33.2	33.1	33.8	32.8
24-Jan-11	31.6	32.4	32.0	32.3	32.2	32.7	33.4	33.4	34.0	32.9
25-Jan-11	31.6	32.4	32.1	32.4	32.3	32.9	33.7	33.8	34.2	33.0

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
26-Jan-11	31.7	32.6	32.4	32.6	32.6	33.2	33.9	34.0	34.7	33.2
27-Jan-11	31.4	31.9	31.6	31.5	31.8	32.1	32.0	30.0	32.2	31.7
28-Jan-11	29.6	29.2	29.2	29.2	29.6	29.9	30.4	29.3	30.3	29.4
29-Jan-11	29.5	29.3	29.4	29.5	29.7	30.3	31.5	31.2	31.3	30.1
30-Jan-11	30.0	30.1	30.0	30.2	30.3	30.9	32.4	32.6	32.5	30.7
31-Jan-11	30.6	31.0	30.8	31.1	30.9	31.5	33.1	33.4	33.3	31.3
1-Feb-11	31.1	31.7	31.4	31.8	31.5	32.0	33.3	33.4	33.8	31.9
2-Feb-11	31.1	31.7	31.7	32.0	31.6	32.0	33.1	33.1	33.8	32.3
3-Feb-11	31.2	31.8	31.8	32.1	31.7	32.1	32.7	32.7	33.9	32.5
4-Feb-11	31.5	32.1	32.0	32.3	31.9	32.3	33.2	33.6	34.4	32.8
5-Feb-11	31.9	32.6	32.3	32.7	32.3	32.7	33.7	34.2	34.8	33.0
6-Feb-11	32.2	32.9	32.6	32.9	32.5	32.9	33.3	32.9	34.5	33.9
7-Feb-11	32.0	32.4	32.3	31.5	32.0	31.2	32.6	31.8	32.8	32.7
8-Feb-11	30.9	30.8	30.8	29.0	30.6	29.5	32.1	31.5	31.8	31.9
9-Feb-11	30.9	31.1	30.8	29.7	30.7	30.2	32.8	32.8	32.7	32.0
10-Feb-11	31.2	31.5	31.1	30.3	31.0	30.7	32.9	32.6	32.8	32.2
11-Feb-11	31.2	31.5	31.1	30.6	31.1	30.8	32.3	31.9	32.6	32.1
12-Feb-11	31.3	31.6	31.1	30.8	31.2	31.1	32.8	33.0	33.4	32.3
13-Feb-11	31.5	31.9	31.3	31.1	31.4	31.4	32.6	32.4	33.1	32.5
14-Feb-11	31.5	31.8	31.3	31.2	31.3	31.3	32.6	32.6	33.0	32.4
15-Feb-11	31.2	31.4	31.1	31.1	31.0	30.9	32.0	30.6	31.5	31.3
16-Feb-11	30.4	30.3	30.5	30.5	30.1	30.0	30.1	28.5	29.0	29.2
17-Feb-11	29.4	29.1	29.4	29.4	29.4	29.3	29.8	28.8	28.6	29.0
18-Feb-11	29.2	28.9	29.4	29.3	29.3	29.3	30.2	29.9	29.3	29.2
19-Feb-11	29.5	29.9	29.6	29.6	29.5	29.6	31.2	31.6	30.6	29.6
20-Feb-11	30.4	30.5	30.6	30.4	30.1	30.3	31.9	30.6	31.8	30.3

Date	SWDelambre	SW Delambre	SE Delambre	SE Delambre	NE Delambre	NE Delambre	Bell's Beach	Bell's Beach	Dixon Island	Dixon Island
	1	2	1	2	1	2	1	2	1	2
21-Feb-11	28.5	28.5	28.5	27.9	28.5	28.3	31.1	30.5	32.3	31.1