BCI MINERALS LTD

MARDIE SALT PROJECT: MARINE TURTLE MONITORING PROGRAM 2018/19

Prepared by

Pendoley Environmental Pty Ltd

For

BCI Minerals Ltd

4th April 2019

DOCUMENT CONTROL INFORMATION

TITLE: MARDIE SALT PROJECT: MARINE TURTLE MONITORING PROGRAM 2018/19

Disclaimer and Limitation

This report has been prepared on behalf of and for the use of BCI Minerals Ltd. Pendoley Environmental Pty Ltd. takes no responsibility for the completeness or form of any subsequent copies of this Document. Copying of this Document without the permission BCI Minerals Ltd is not permitted.

Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		25/03/2019	Dr C. Bell
Rev A	Internal Review	25/03/2019	31/03/2019	Dr K. Pendoley
Rev B	Technical Review	31/03/2019	01/04/2019	Dr P. Whittock
Rev C	Client review	02/04/2019		Neil Dixon
Rev 0	Final report issued			

Printed:	2 April 2019
Last saved:	2 April 2019 06:02 PM
File name:	J59 BCI/RP59001_BCIMardieProject_MarineTurtleMonitoring_RevC.docx
Author:	Dr C. Bell / Dr K. Pendoley]
Project manager:	Dr Kellie Pendoley
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Mardie Salt
Client	BCI Minerals Ltd
Client representative:	Neil Dixon
Report number:	RP-59001
Cover photo:	Scott Pendoley (Mardie Creek East coastline section)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

BCI Minerals Ltd requested that Pendoley Environmental conduct field surveys in December and February of the 2018/19 marine turtle reproductive season to describe populations that use suitable mainland and island habitat in proximity to the proposed footprint of their salt project at Mardie Creek in the Pilbara region.

Two field surveys of fourteen days in duration were completed at mainland and island monitoring sites; one survey during the peak flatback and green turtle nesting period in December, and a second survey during the peak flatback and green turtle hatching period in February. The survey duration represented the mean inter-nesting period for flatback and green turtles in the region and was consistent with recommendations of the WA Department of Biodiversity Conservation and Attractions for providing the most reliable abundance estimates from track counts.

Nesting by flatback (224 tracks), hawksbill (12 tracks), and green (15 tracks) turtles was recorded on Long and Sholl Islands. There was limited flatback (3 tracks) and hawksbill (2 tracks) turtle activity on the mainland coastline, with no green turtle nesting activity recorded. Nesting activity by flatback and hawksbill turtles was recorded on Angle, Middle, and Round Islands and green turtle nesting activity was recorded on Middle and Round Islands. Total nesting effort during the February survey (42 tracks) was substantially lower than the December survey (256 tracks), confirming capture of nesting activity during the peak reproductive period for flatback and green turtles at this location.

Based on successful nest counts, the number of nesting females using Sholl Island and Long Island is similar (~ 50 females on each island) and consistent with regional nearshore island usage. In contrast the mainland beaches supported no flatback nesting and a single hawksbill female (noting the survey occurred past the peak period for hawksbill nesting). The nesting effort recorded on the mainland was trivial compared to the nesting seen at other mainland Pilbara rookeries such as Cemetary Beach, Mundabullangana, Onslow Back Beach and the Ashburton River Delta.

Mean flatback turtle clutch size was 52.5 ± 13.2 eggs (n = 20). Overall mean hatch success for flatback turtles was 49.5 ± 14.7 % (n = 20). Mean flatback turtle hatch success was lower on Long Island (52.3 %; n = 10) compared to Sholl Island (46.6 %; n = 10). The recorded hatch success was generally lower when compared to the previously recorded hatch success at nearby rookeries in the same region (57 % at Cemetery beach, Port Hedland; 68% at Mundabullangana south of Port Headland, 83 % at Barrow Island).

Temperature loggers were retrieved from marked clutches following their incubation on Long and Sholl Islands. Temperature data showed the mean incubation period was 43.3 ± 3.1 days (n = 3), mean clutch temperature was 32.0 ± 0.9 ^{o}C, and the proportion of the incubation period spent above the thermal tolerance range (>33 °C; above which embryo survival may be impaired) was 33 %. Beach sand temperature at 500 mm depth on the mainland (33.7 ± 1.5 ^{o}C) was significantly warmer than beach sand temperature on the islands (32.7 ± 1.5 ^{o}C) at the same depth.

Measured artificial light at all monitored sites during clear and cloudy sky conditions was greater than 21.99 Vmag/arcsec^2 which represents pristine dark natural skies unaffected by artificial light. The only visible light source was the Sino Iron facility to the east. Hatchling sea-finding behaviour on Long Island was not significantly different to Sholl Island and all hatchlings oriented successfully toward the ocean.

The monitoring surveys found the abundance, species composition, and distribution of nesting turtles on undisturbed habitat was typical of the region; flatback turtle nesting dominating on offshore island habitat and relatively less activity on the mainland. The mainland coast adjacent to the project site was characterised by very low nesting activity relative to other mainland sites such as Mundabullangana, Onslow Back Beach, and Ashburton Delta (near Onslow) and may be a reflection of the nesting habitat geomorphology which is characterised by narrow, low energy, hot, dark coloured terrigenous based moderately coarse sediments, with limited primary dune development.

1 INTRODUCTION

1.1 Project Background

BCI Minerals Ltd (BCI) proposes to build a salt mining facility on the coastline near Mardie Station in the Pilbara region of Western Australia. Preliminary environmental surveys in December 2017 and January 2018 recognized the previously undocumented presence of marine turtle nesting activity on the sandy beaches adjacent to the project footprint. Consequently, BCI requested Pendoley Environmental (PENV) conduct marine turtle surveys to describe the populations that use suitable habitat in proximity to the proposed project footprint.

The project design has since been modified to include an offshore loadout facility and bitterns discharge pipe between 9 km and 13 km inshore of Angle, Long, Middle Passage, Round, and Sholl Islands (**Figure 1**). The islands are all recognized rookeries for green, hawksbill, and flatback turtles (see Pendoley et al. 2016 and Supplemental Material, Attachment 1).

Information gathered in these surveys and presented in this report will address the requirements for assessment of potential project impacts on sensitive receptors (marine turtles) to be submitted to government for project approval as part of the environmental impact assessment documentation.

1.2 Marine Turtles in the Pilbara Region

Marine turtle nesting in the Pilbara is dominated by flatback (*Natator depressus*), green (*Chelonia mydas*), and hawksbill turtles (*Eretmochelys imbricata*) (Pendoley et al. 2016; Pendoley 2005). Green turtles typically use high energy offshore island beaches while flatback turtles generally utilise inshore, lower energy, island's and the mainland coast. Hawksbill turtles nest in lower numbers on island beaches and less frequently on the mainland.

Of the mainland flatback turtle rookeries monitored in the Pilbara, the annual female nesting effort estimates range from: 1000's at Mundabullangana; 100's on the Ashburton Delta near Onslow and Cemetery Beach in Port Hedland; 10s – 100s on nearshore islands and 10's at Onslow Back Beach and Cape Preston. Very minor green turtle nesting (1 - 10 per year) occurs on the mainland and nearshore islands, while hawksbill turtle nesting ranges from 1 - 100 on nearshore islands (Pendoley 2005; Pendoley et al. 2014, 2016).

Sholl Island, immediately offshore from the project site (**Figure 1**), has been identified as a regionally important hawksbill turtle rookery (Pendoley et al. 2016).

As juveniles, green, hawksbill, and potentially flatback turtles, can be found in creeks and inlets associated with coastal mangrove habitat, offshore aggregations of adult and juvenile hawksbill, flatback, and green turtles are therefore likely to utilise the waters of the project site for foraging (Pendoley 2005; Whittock et al. 2016a, 2016b) and inter-nesting (period of time spent offshore between successive nesting events) purposes (Whittock et al. 2014; Pendoley 2005).

1.3 Scope of Works

Based on the outcome of preliminary surveys in December 2017 and January 2018, BCI commissioned PENV to conduct field surveys of known and potential marine turtle habitat in the proximity to the proposed project area (**Figure 1**).

The Mardie Salt Project: Marine Turtle Monitoring Program was designed to collect baseline data to meet the following objectives:

- Identify the species of turtles nesting on the beaches;
- Identify the abundance and distribution of adult tracks on the nesting beaches;
- Collect baseline data on the health of the nesting habitat;
- Collect baseline data on hatchling orientation; and
- Measure the intensity and extent of light sources visible from nesting beaches.

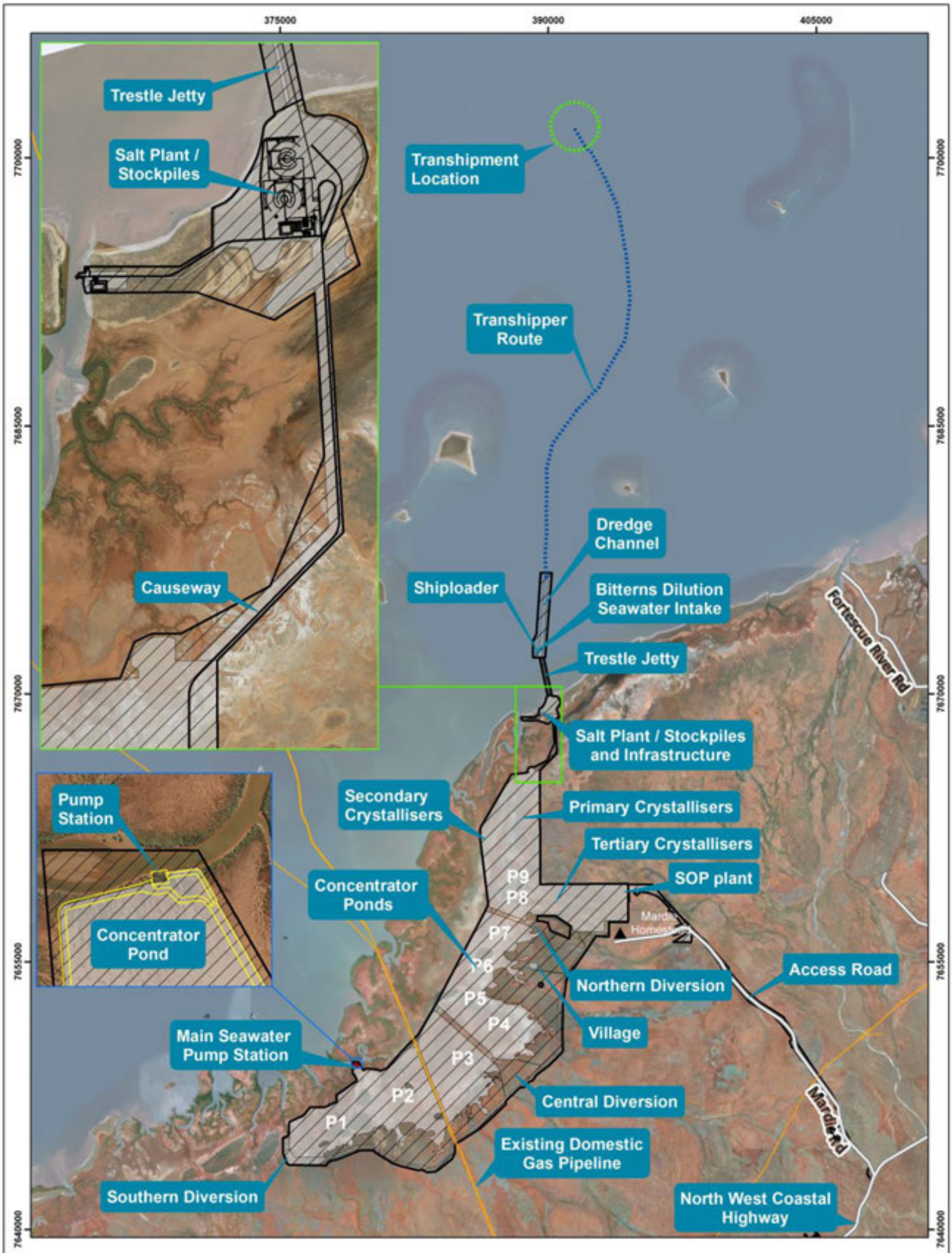


Figure 1: Mardie Project development envelope, indicative disturbance footprint, and coastal islands.

2 METHODOLOGY

2.1 Monitoring Survey Effort

2.1.1 Survey Location

All suitable sections of sandy coastline in the vicinity of the project footprint were monitored together with nearby offshore islands (**Figure 2**).

2.1.1.1 Mainland: Mardie Creek East

Mardie Creek East is situated on the mainland coastline. The surveyed section commenced from Mardie Creek at its western end and extended ~15 km to the east (**Figure 2**). Beyond this, the coastline is bound by mangrove trees and there is no suitable point at which nesting turtles could access the beach. A 1 km subsection of this coast (situated 3 km east of the creek; **Figure 2**) was marked with a line and monitored by the ground based field personnel three times per week to ground truth the aerial survey data. This stretch of coastline was selected because marine turtle nesting activity had been previously recorded in this section during past surveys.

2.1.1.2 Mainland: Mardie Creek West

Mardie Creek West is situated on the mainland coastline. The surveyed section began at Mardie Creek and extended ~2.5 km to the west until reaching a point where the coastline is bound by mangrove trees and there is no suitable point at which nesting turtles could access the beach. An additional 1 km subsection of this beach was also selected for ground truthing, involving the ground based field personnel monitoring the section of beach three times per week (**Figure 2**).

2.1.1.3 Offshore: Long Island

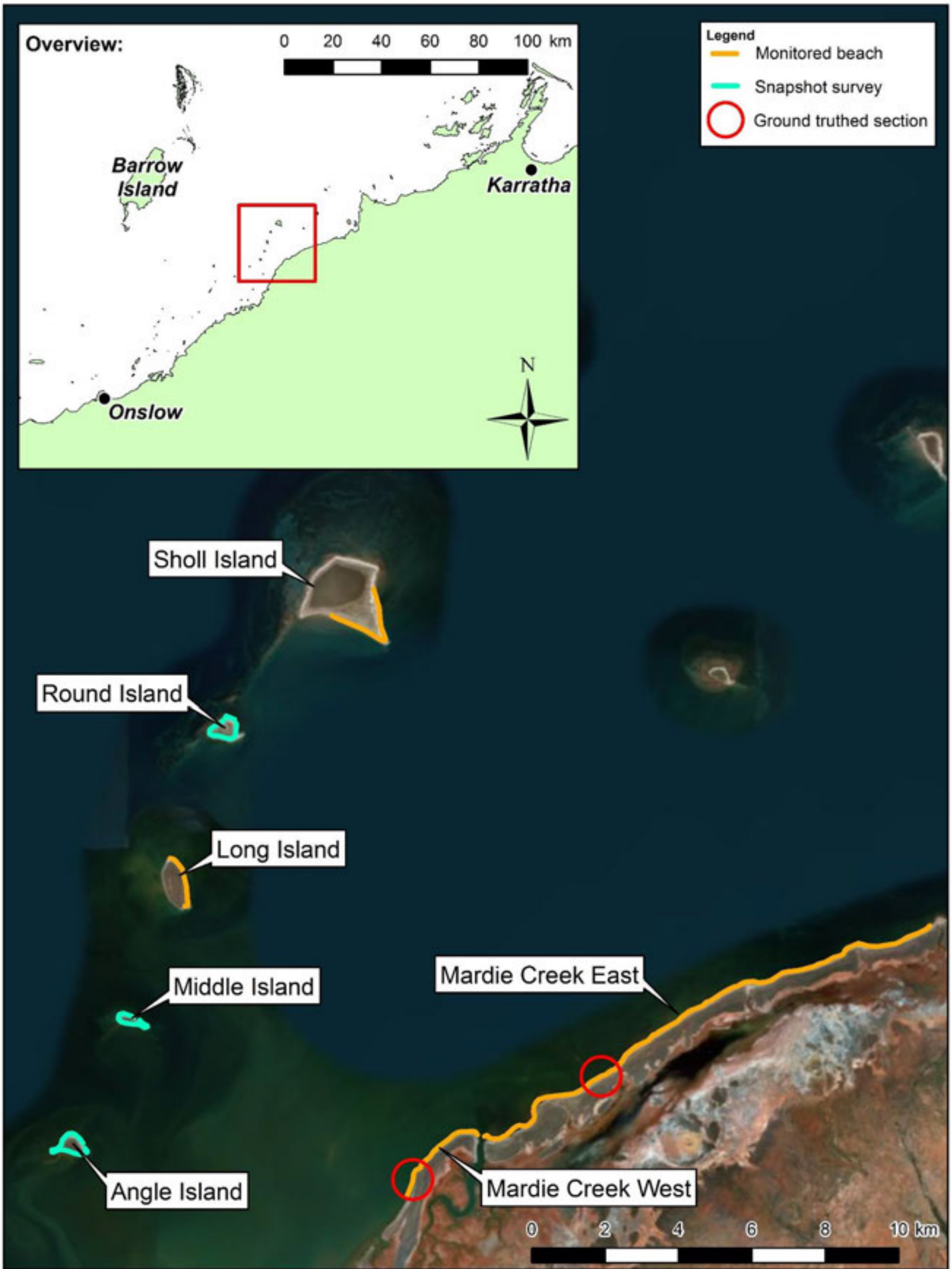
Long Island is located ~10 km north-west of the entrance to Mardie Creek on the Pilbara coastline. Sandy beaches surround the entire island, however a 1 km long section on the east coast facing the project location was selected for daily ground-based monitoring (**Figure 2**).

2.1.1.4 Offshore: Sholl Island

Sholl Island is located ~13 km north-north-west of the entrance to Mardie Creek on the Pilbara coastline. All suitable marine turtle nesting habitat in located on the southern coasts of the island. Two survey transects of ~1 km length were selected for daily ground based monitoring on the south-east and the south-west coast of the island (**Figure 2**).

2.1.1.5 Offshore: Angle, Middle, and Round Islands

These three islands are part of the Passage Islands and are 10 - 15 km offshore to the east of the entrance to Mardie Creek on the Pilbara coastline (**Figure 2**). Snapshot surveys of sandy beach sections were undertaken on Angle Island (1.5 km), Middle Island (1.5 km), and Round Island (2 km).



J59001 Mardie Project Marine Turtle Monitoring Program 2018/19

Drawn: P. Whittock
Date: 29/03/2019
Drawing File Ref: PENV-J59001-922-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES

Figure 2: Location map showing routine and snapshot monitoring sites.

2.1.2 Survey Schedule

Two discrete field surveys were scheduled to capture the peak nesting (December) and peak hatching (February) periods for green and flatback turtles in this region.

Each survey was 14 days duration to encompass one complete inter-nesting cycle. This duration was based on observations of the inter-nesting cycle at Mundabullangana (13 ± 3.3 days), Barrow Island (14.1 ± 2.2 days), and Cemetery Beach (12.2 ± 1.2 days) (Pendoley et al. 2014). This duration was also consistent with recommendations of the WA Department of Biodiversity Conservation and Attractions (DBCA), for providing the most reliable abundance estimates from the peak of the flatback and green turtle nesting season.

Survey dates were:

- Field Survey 1 (nesting): 1st - 15th December 2018 ('December survey'); and
- Field Survey 2 (hatching): 30th January - 12th February 2019 ('February survey').

Both surveys were scheduled during the new moon phase of the lunar cycle. The new moon fell on 6th December and 4th February, respectively.

2.2 Data Capture

2.2.1 Nesting Habitat Assessment: Track Census

Data Capture

All visible tracks were marked during a 'line-in' day prior to the commencement of the track census survey to ensure an accurate overnight assessment of nesting activity during the subsequent first day of the census survey. All tracks marked during the 'line-in' day were not considered in any further analysis because it was not known exactly when the nesting activity occurred prior to the survey.

On each survey day, marine turtle nesting activity was identified during an initial aerial survey of the monitored beach sections. On the ground, overnight activity was confirmed from fresh tracks left in the sand since the previous day's survey. Marine turtle species and the resulting nesting activity category (false crawl, attempt or nest) were determined using track and nest characteristics, including track width, shape and orientation of flipper marks, tail drag marks, movement of sand, morphology and depth of nest pit and associated mound (Eckert et al. 1999). All identified tracks were marked to avoid being recounted on subsequent days (**Figure 3**).

Predator activity was identified by tracks left in the vicinity of the turtle nesting activity. Categories of predation included digging at and around the nest site, or egg shells scattered at the sand surface.

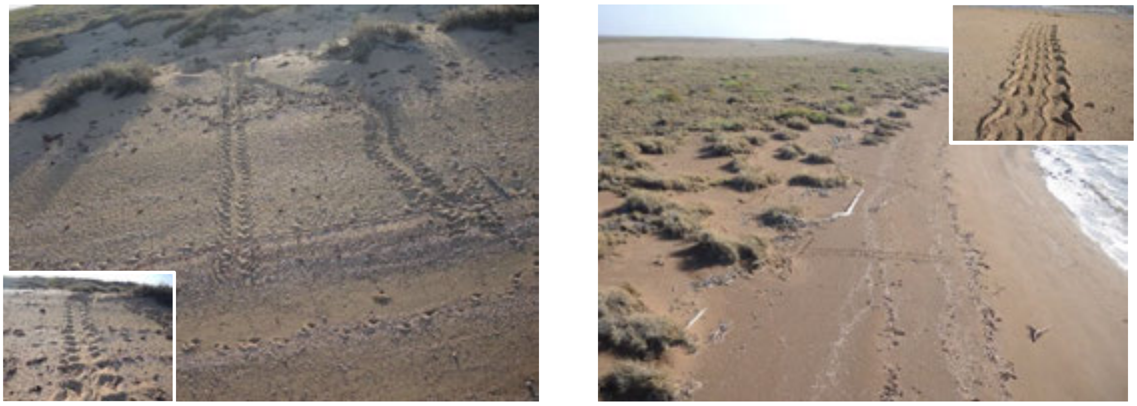


Figure 3: Aerial view of fresh turtle tracks as viewed from the helicopter and ground truthing of activity (inset). Images are from Long Island (left) and Mardie Creek East (right).

2.2.1 Nesting Habitat Assessment: Incubation Success

2.2.1.1 Nest Marking

Nests were randomly selected for marking in order to minimise the potential bias in their distribution across the beach caused by the field team starting work at the same end of the survey area each day (**Figure 4**).

The field personnel found the clutch by digging into a fresh nest and locating the eggs at the top of the nest. A Hobo temperature logger (model: UA-001-64; accuracy 0.53 °C; resolution 0.14 °C; weight 18 g) was placed amongst the eggs at the top of the nest to record the temperature profile during incubation (every 30 minutes) and tethered to a marking post. Temperature loggers were also buried on each beach at 500 mm depth to collect control temperature data from the survey beaches (**Figure 4**).

2.2.1.2 Nest Excavation

Excavations of marked clutches were conducted with caution to avoid disturbance to live hatchlings within the clutch or to developing embryos that may not yet have hatched.

The contents of the egg chamber were counted and sorted into live hatchlings, dead hatchlings, egg shells, undeveloped embryos or no discernible embryos (as per Shigenaka 2003; Pendoley et al. 2014).

Figure 4: Location of marked clutches, excavated clutches, control loggers, and light monitoring sites.

2.2.2 Artificial Light Monitoring

Sky42™ (Sky42) light monitoring cameras were deployed on each monitored beach section during the December and February surveys (**Figure 4**).

Images of night-time light emissions on a 360° horizon were captured automatically by the deployed camera at 15-minute intervals between sunset and sunrise.

2.2.3 Hatchling Orientation

A nest fan was recorded if five or more hatchling tracks were sighted from a hatched clutch (defined by a depression in the sand from which the hatchling tracks were seen to emerge). A sighting compass was used to measure the bearing along the outside arms of emergent hatchling tracks (vectors A and B; **Figure 5**). Bearings were taken at either the point where the track crossed the high tide line, or five metres from the clutch emergence point (whichever distance was shortest).

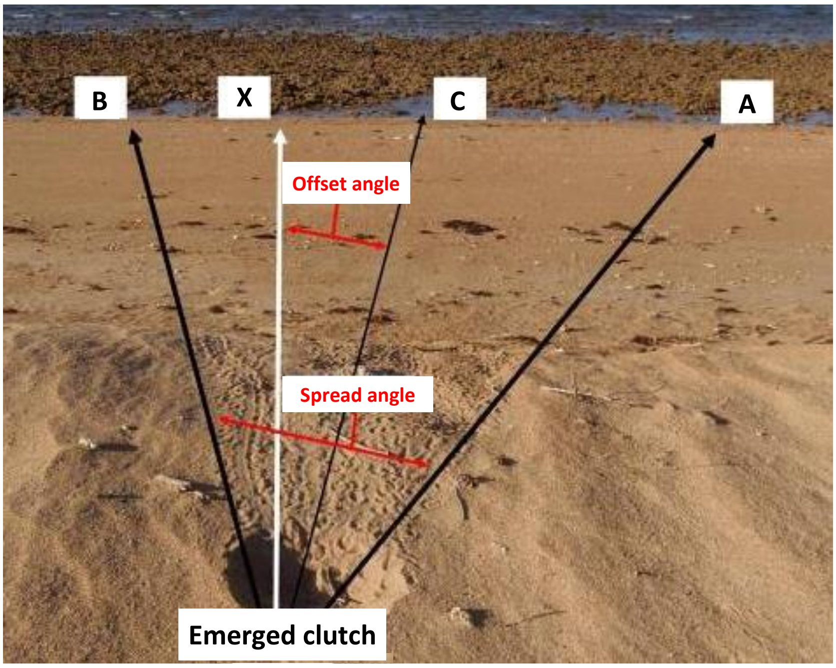


Figure 5: Hatchling orientation indices and emergence spread and offset angles.

2.3 Data Analysis

2.3.1 Nesting Habitat Assessment: Track Census

2.3.1.1 Abundance of Adult Tracks

Statistical output describing abundance (consisting of mean ± StDev, range and *n*) was generated for the following parameters for each recorded species on each monitored beach section during the December survey:

- overnight nests; and
- overnight tracks (includes false crawls and false-crawl attempts).

Nesting success (i.e. the number of successful nesting events as a proportion of the total number of overnight emergences) was calculated using the overnight nest and track counts.

2.3.2 Nesting Habitat Assessment: Incubation Success

2.3.2.1 Clutch Fate

Clutch fate was separated into the following categories:

- Complete: entire clutch could be relocated and excavated.
- Lost: If a clutch could not be located by observers (due to sand movement, excavation by other nesting turtles or predators, or displacement of picket used to mark nest).
- Inundated: If the temperature profile for a clutch showed a sudden substantial decrease in temperature.
- Disturbed/predated: If the temperature profile for a clutch showed a sudden substantial increase in temperature.

2.3.2.2 Hatch and Hatchling Emergence Success

Hatch success was calculated by dividing the number of hatched eggs by the overall clutch size. Hatchling emergence success (the percentage of hatchlings successfully leaving the nest) was calculated by subtracting the hatched egg count with the number of live and dead hatchlings encountered within the egg chamber and then dividing by the overall clutch size.

2.3.2.3 Incubation Period

The incubation period (IP) was the duration between the date the clutch was marked and the date the clutch hatched. The hatch date was identified by comparing the clutch temperature and control temperature profiles.

2.3.2.4 Thermal Environment: Clutch Temperatures

Following manual identification of the hatch date (see **Section 2.3.2.3**), statistical output (consisting of mean ± StDev, range and *n*) was generated for the following temperature parameters for each clutch:

- mean clutch temperature (°C) during the incubation period (IP);
- mean clutch temperature (°C) during the thermo-sensitive period (TSP); the incubation temperature during the middle trimester of development (determines whether hatchlings are male or female; Yntema & Mrosovsky 1980, 1982; Hewavisenthi & Parmenter 2002); and
- proportion of incubation period where mean daily temperature >33 °C.

2.3.2.5 Thermal Environment: Sand Temperatures

Temperature loggers, deployed at control sites at 500 mm (mean nest depth) on each beach section, were retrieved at the end of the February survey. Mean daily temperature (°C) for the entire incubation period (i.e. December to February) was calculated.

2.3.3 Artificial Light Monitoring

2.3.3.1 Identification of Potential Light Sources

Potential sources of artificial light that were visible from each Sky42 camera monitoring site were identified using Google Earth.

2.3.3.1 Measurement Units

Artificial light is measured in units of magnitudes per arcsec^2 (Vmag/arcsec^2), which quantifies light intensity on an inverted logarithmic scale, i.e. higher values represent lower intensity light, while lower values represent higher intensity light (**Table 1**).

For example, dark sky under natural conditions and in the absence of moonlight is magnitude 22, whilst brighter sky over urban areas is magnitude 17 (**Table 1**).

Table 1: Qualitative interpretation of magnitude band values (Source: Unihedron Sky Quality Meter). Use as guide only. **Values <17 Vmag/arcsec^2 not provided by source (considered to represent light level greater than 'very high' and representative of skies brighter than an urban night sky horizon).

Magnitude (Vmag/arcsec^2)	Qualitative Intepretation	Qualitative Example of Interpretation
21 – 22	Very low	Ideal natural dark night sky horizon
20 – 21	Low	Typical rural night sky horizon
19 – 20	Moderate	Typical suburban night sky horizon
18 – 19	High	Typical urban night sky horizon
17 – 18	Very High**	Poor urban night sky horizon

2.3.3.2 Data Processing

The quality of an image captured by a Sky42 light monitoring camera can be influenced by atmospheric factors such as the presence of the moon, twilight, cloud, rain, dust, humidity or physical factors such as accumulation of sand on the lens. Any images that were affected by physical factors were therefore removed from the analysis, as well as any images that were affected by the moon or twilight.

All remaining images were batch processed using specialised software (Sky Quality Camera, Euromix Pty Ltd). The processing involved converting each image into an isophote (light level) contour map and calculating the mean sky brightness value (Vmag/arcsec^2) for all pixels in the map and at zenith (0 – 30^o field of view). The isophote map with the median sky brightness value out of all isophote maps processed during the night that featured the least amount of cloud was then converted to an equirectangular panorama for inclusion in this report.

Note that the colour coding used in the isophote map represents the scale of intensity of light and is not representative of the colour of light as perceived by a human/turtle eye or Sky42 camera.

3 RESULTS

3.1 Nesting Habitat: Characteristics

Mardie Creek East and Mardie Creek West are long, narrow, low energy beaches with a broad shallow offshore subtidal and intertidal zone, a narrow supratidal zone, with large sections of little or no primary dune development. The beach sediment was typically dark and reddish in colour and ranged from gravel in the vicinity of Mardie Creek, to medium-coarse sand further away from the creek.

Long and Sholl Islands were typical of the regional islands, with light coloured fine to medium grained marine sand, a moderately wide and sloped intertidal zone, a wide supratidal zone, and a well-defined primary dune immediately behind the beach. The offshore approach to the nesting sand is moderately deep, permitting access for marine turtle nesting on all tides. The islands also featured a well-developed and mobile east facing sand spit.

3.2 Nesting Habitat: Track Census

3.2.1 Abundance and Distribution: Regular Monitoring

The total number of turtle tracks recorded on all surveyed beaches during the December survey was 256, consisting of 88 nests (34.3 %) and 168 false crawls (65.7 %). Nesting activity was greater on monitored islands (*n* = 250 tracks) compared to mainland sections (*n* = 6 tracks).

Marine turtle species recorded were flatback, hawksbill, and green turtles. Flatback turtles were the most abundant species (227 tracks; 88.6 %), then hawksbill turtles (14 tracks; 5.5 %) and green turtles (15 tracks; 5.9 %).

The temporal variation of nesting activity by each species during both surveys is provided in **Appendices 1 – 3** and basic statistics for the December survey are provided in **Appendix 4**. Nesting activity was only recorded on the offshore islands during the February survey (at the end of the peak nesting season) and was lower (42 flatback tracks, 1 hawksbill track, and 0 green tracks) when compared to the December survey.

Table 2: Track census results summary by beach section and species.

Beach Section	Survey Transect Length	Marine Turtle Activity	Marine Turtle Species			
			Flatback	Hawksbill	Green	Total
Long Island	1 km	Nests	41	3	2	46
		False crawls	94	5	7	106
		Total activity	135	8	9	152
Sholl Island	2 km	Nests	39	1	1	41
		False crawls	50	3	5	58
		Total activity	89	4	6	99
Mardie Creek West	2.5 km	Nests	0	0	0	0
		False crawls	0	1	0	1
		Total activity	0	1	0	1
Mardie Creek East	15 km	Nests	0	1	0	1
		False crawls	3	0	0	3
		Total activity	3	1	0	4

3.2.2 Abundance and Distribution: Snapshot Survey

Flatback and hawksbill turtle nesting activity was recorded on Angle, Middle, and Round Islands during the December snapshot survey. Green turtle nesting activity was recorded on Middle and Round Islands during the December snapshot survey (**Table 3**)

Table 3: Marine turtle nesting activity recorded during the snapshot survey of Angle, Middle, and Round Islands during the December survey. Unid. = Unidentified.

Beach Section	Marine Turtle Activity	Marine Turtle Species				
		Flatback	Hawksbill	Green	Unid.	Total
Angle Island	Nests	9	1	0	2	12
	False crawls	13	1	0	1	15
	Total activity	22	2	0	3	27
Middle Island	Nests	2	1	0	1	4
	False crawls	8	4	4	3	19
	Total activity	10	5	4	4	23
Round Island	Nests	6	0	0	1	7
	False crawls	11	4	1	3	19
	Total activity	17	4	1	4	26

3.3 Nesting Habitat: Nesting Success

3.3.1 Flatback Turtles

Mean flatback turtle nesting success at all four sites combined was 35 % during the December survey and 52 % during the February survey.

Overall nesting success was greater on Sholl Island (42 %) compared to Long Island (34 %) and Mardie Creek East (0 %).

3.3.2 Hawksbill Turtles

Mean hawksbill turtle nesting success at all sites combined was 36 % during the December survey and 50 % during the February survey.

Nesting success was greatest at Mardie Creek East (100 %) where the one recorded nest was successfully laid on the first attempt. Nesting success was greater on Sholl Island (40 %) compared to Long Island (33 %) and Mardie Creek West (0 %).

3.4 Nesting Habitat: Incubation Success

3.4.1 Clutch Fate

A total of five clutches were marked for incubation success on Long (n = 1) and Sholl (n = 4) Islands during the December survey. Three of these marked clutches were recovered and excavated during the February survey (Long Island = 1; Sholl Island = 2) and temperature loggers retrieved. The remaining two nests were lost to the observer.

An additional 18 clutches were excavated during the December and February surveys, combined. During the December survey, one hawksbill clutch was excavated on Sholl Island and during the February survey, 8 flatback clutches were excavated on Sholl Island and 9 clutches excavated on Long Island.

3.4.2 Clutch Size

Mean clutch size for the excavated flatback turtle nests was 52.5 ± 13.2 eggs (34 – 86; n = 20) and for the excavated hawksbill turtle clutch was 123 eggs (n = 1).

3.4.3 Hatch and Emergence Success

Mean hatch success for all flatback turtle nests was 49.5 ± 14.7 % (18.8 – 79.5; n = 20). Mean emergence success for all flatback turtle nests was 41.7 ± 18.1 % (3.5 – 72.7; n = 20) (**Table 4**). There was no significant difference in either hatch success or emergence success of flatback turtle clutches on Sholl Island compared to Long Island ($p > 0.05$).

The hatch and emergence success for the hawksbill turtle clutch was 79 % and 70 %, respectively.

Table 4: Hatch and emergence success rate of excavated flatback turtle clutches at Long and Sholl Islands during the February survey.

Beach Section	Value	Clutch Size (*n*)	Hatch Success (%)	Emergence Success (%)
Long Island	Mean	50.1	52.3	44.9
	St. Dev	15.2	11.8	18.6
	Min.	34.0	29.3	3.5
	Max.	86.0	68.3	68.3
Sholl Island	Mean	54.9	46.6	38.5
	St. Dev	11.1	17.3	17.8
	Min.	35.0	18.8	15.2
	Max.	69.0	79.5	72.7
All	Mean	52.5	49.5	41.7
	St. Dev	13.2	14.7	18.1
	Min.	34.0	18.8	3.5
	Max.	86.0	79.5	72.7

3.4.4 Incubation Period

The incubation period of the two clutches marked on Sholl Island was 40 and 46 days. The incubation period of the marked clutch on Long Island was 44 days.

Mean incubation period of all marked clutches was 43.3 ± 3.1 days (range 40 – 46, n = 3).

3.4.5 Thermal Environment

3.4.5.1 Air Temperature and Rainfall

The mean daily maximum air temperature during the overall incubation period of the marked clutches (between 7th December 2018 and 11th February 2019) was 37.7 °C (range = 29.2 – 48.9 °C) (**Figure 6**).

A total rainfall of 12.4 mm was recorded at Mardie Weather Station. The spike in rainfall on and around 26th January 2019 was associated with Tropical Cyclone Riley (**Figure 6**).

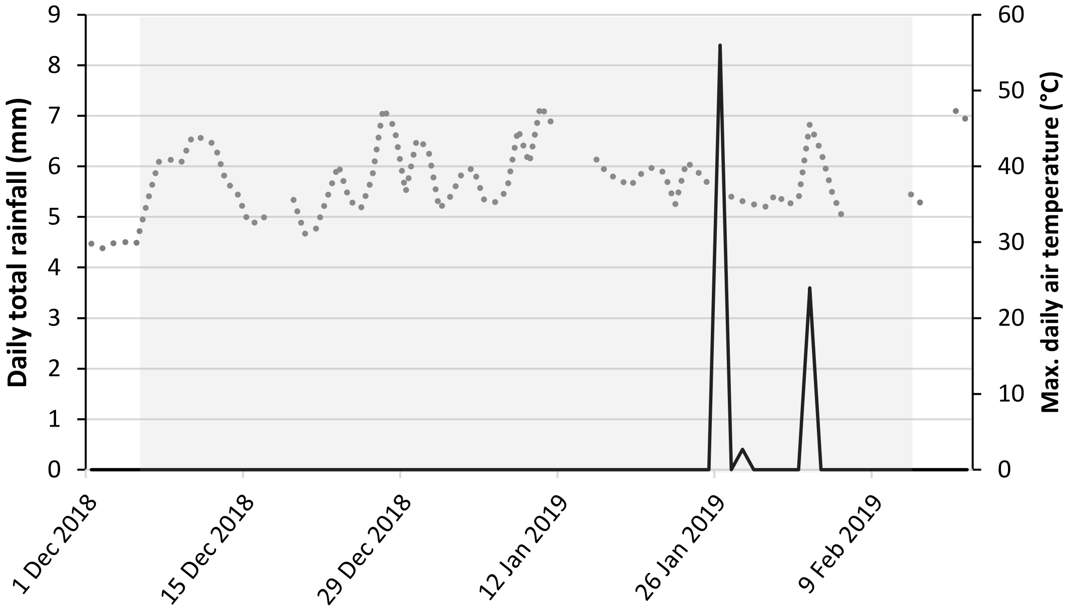


Figure 6: Daily total rainfall (mm) and max daily air temperature (°C) recorded at Mardie Weather Station between 1st December 2018 and 28th February 2019. Solid black line = rainfall (mm); dashed grey line = air temperature (°C). Data provided by Bureau of Meteorology. Shaded area indicates the overall incubation period i.e. when marked clutches were incubating.

3.4.5.2 Sand Temperature

Control temperature loggers recorded hourly sand temperature at 500 mm depth on Mardie Creek East and Mardie Creek West on the mainland and on Long and Sholl Islands. Loggers were deployed for up to 67 days between 7th December 2018 and 11th February 2019. The deployment duration included the entire incubation period of all marked clutches.

Mean daily sand temperatures recorded by control loggers (at 500 mm depth) during the overall incubation period of marked clutches was significantly warmer on the mainland (33.7 ± 1.5 °C, range = 3.5 – 36.1, *n* = 67) compared to island beach sections (32.7 ± 1.5 °C, range = 3.5 – 36.1, *n* = 67) (p <0.0001) (**Table 5**).

Table 5: Mean daily sand temperature at 500 mm depth during the overall incubation period of marked clutches.

Beach Section	Temperature (°C)		p-value
	Mean ± StDev	Range	
Long Island	32.8 ± 1.4	30.4 – 34.7	>0.05
Sholl Island	32.4 ± 1.6	29.9 – 34.4	
Mardie Creek East	33.8 ± 1.2	31.7 – 35.5	>0.05
Mardie Creek West	33.4 ± 1.7	30.4 – 35.9	
Island Sites (combined)	32.7 ± 1.5	30.0 – 34.8	<0.0001
Mainland Sites (combined)	33.7 ± 1.5	30.5 – 36.1	

3.4.5.3 Clutch Temperature

The mean daily temperature of marked clutches on Sholl Island (*n* = 2) was 31.0 °C and 32.8 °C and at Long Island (*n* = 1) was 32.2 °C. The mean daily temperature for all marked clutches combined was 32.0 ± 0.9 °C (*n* = 3).

3.4.5.4 Thermosensitive Period

The mean daily clutch temperature during the thermosensitive period on Sholl Island (*n* = 2) was 30.7 °C and 32.6 °C, and on Long Island was 31.9 °C (*n* = 1).

3.4.5.1 Thermal Tolerance Range

The proportion of the incubation period spent above the Thermal Tolerance Range (TTR) of 33 °C on Sholl Island (*n* = 2) was 17.4 % and 47.5 %, and on Long Island was 34.1 % (*n* = 2).

3.5 Artificial Light Monitoring

3.5.1 Night Time Light Emissions

At all monitoring sites, in clear and cloudy sky conditions, measured whole-of-sky brightness ranged from 23.87 (Mardie Creek East) to 21.99 Vmag/arcsec^2 (Mardie Creek East) and zenith ranged from a maximum dark value of 25.00 (Sholl Island) to 22.56 Vmag/arcsec^2 (Mardie Creek West). The only light source was the Sino Iron facility, visible in the east from all deployment sites. Skies at Sholl Island were the darkest overall. Measured sky brightness in 2018/19 from all locations and in both clear and cloudy sky conditions, described pristine, natural dark skies, and unaffected by artificial light.

3.5.1.1 Mardie Creek East

During clear sky conditions, whole-of-sky brightness was 23.87 Vmag/arcsec^2 and zenith was 25.00 Vmag/arcsec^2. These measurements represent an ideal natural dark sky horizon, unmodified by artificial light. Mardie Creek East was the darkest out of all monitored sites. The only visible light source was the Sino Iron facility in the east.

During cloudy sky conditions, whole-of-sky brightness was 21.99 Vmag/arcsec^2 and zenith was 23.29 Vmag/arcsec^2. Despite an increase of approximately two magnitude bands compared to clear sky conditions, measured brightness remains that of natural dark skies unaffected by light pollution (**Table 6**; **Figure 7**).

Table 6: Average magnitude for whole-of-sky and zenith captured at each monitored beach section during both 2018/19 surveys.

Beach Section	Clear Sky (Vmag/arcsec^2)		Cloudy Sky (Vmag/arcsec^2)	
	Whole-of- Sky	Zenith	Whole-of- Sky	Zenith
Mardie Creek East	23.87	25.5	21.99	23.29
Mardie Creek West	22.55	24.55	22.02	22.56
Long Island	22.84	25.16	22.7	24.28
Sholl Island	23.05	25.51	22.53	25.4

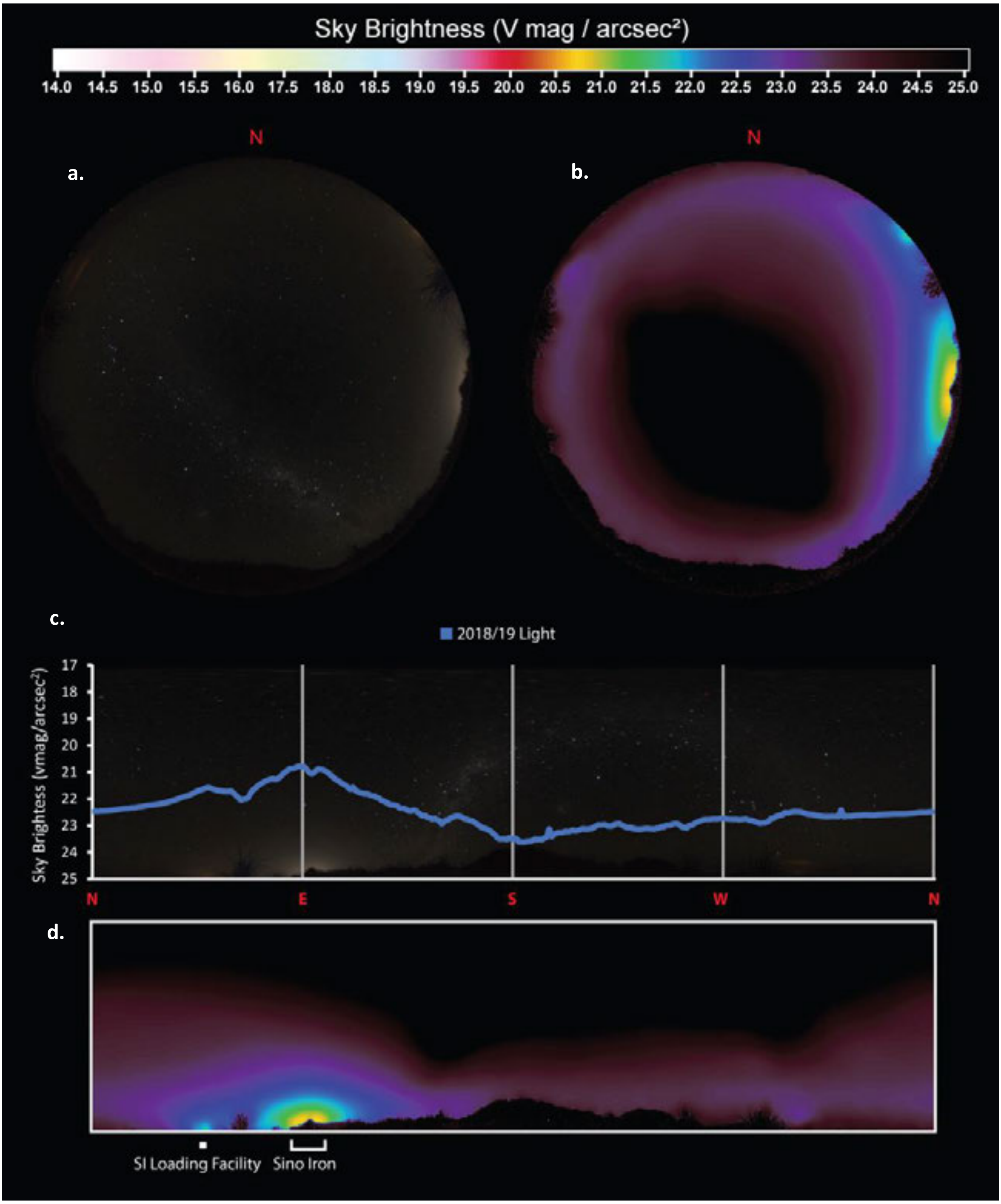


Figure 7: Artificial light monitoring results at Mardie Creek East in 2018/19; a. Clearest available raw image; b. Processed isophote image; c. Light bearing graph showing sky brightness in 2018/19; d. Equirectangular panorama of the 360° clear sky view (looking north) showing location of visible light sources.

3.5.1.2 Mardie Creek West

During clear sky conditions, whole-of-sky brightness was 22.55 Vmag/arcsec^2 and zenith was 24.55 Vmag/arcsec^2. These measurements represent an ideal natural dark sky horizon, unmodified by artificial light. The only visible light source was the Sino Iron facility in the east.

During cloudy sky conditions, whole-of-sky brightness was 22.02 Vmag/arcsec^2 and zenith was 22.56 Vmag/arcsec^2. Although brighter in cloudy compared to clear sky conditions, measured brightness is that of natural dark skies unaffected by light pollution (**Table 6**; **Figure 8**).

3.5.1.3 Long Island

During clear sky conditions, whole-of-sky brightness was 22.84 Vmag/arcsec^2 and zenith was 25.16 Vmag/arcsec^2. These measurements represent an ideal natural dark sky horizon, unmodified by artificial light. The only visible light source was the Sino Iron facility in the east.

During cloudy sky conditions, whole-of-sky brightness was 22.70 Vmag/arcsec^2 and zenith was 24.28 Vmag/arcsec^2. Although brighter during cloudy compared to clear sky conditions, measured brightness remains that of natural dark skies unaffected by light pollution (**Table 6**; **Figure 9**).

3.5.1.4 Sholl Island

During clear sky conditions, whole-of-sky brightness was 23.05 Vmag/arcsec^2 and zenith was 25.51 Vmag/arcsec^2. These measurements represent an ideal natural dark sky horizon, unmodified by artificial light. There were no visible light sources from this location.

In cloudy sky conditions, whole-of-sky brightness was 22.53 Vmag/arcsec^2 and zenith was 25.40 Vmag/arcsec^2. There were no light sources visible from this location. Measured sky brightness is considered to be exceptionally dark (**Table 6**; **Figure 10**).

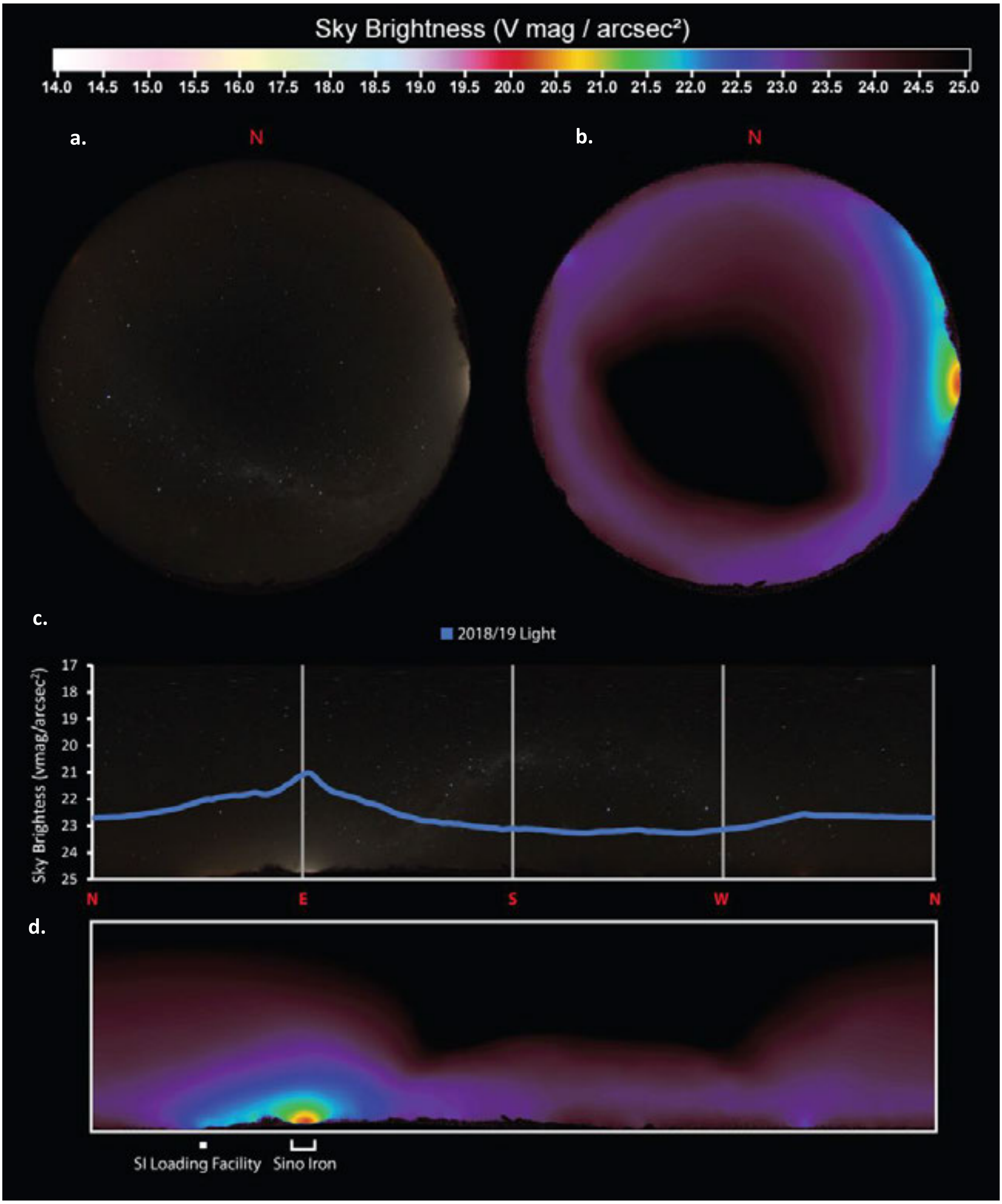


Figure 8: Artificial light monitoring results at Mardie Creek East in 2018/19; a. Clearest available raw image; b. Processed isophote image; c. Light bearing graph showing sky brightness in 2018/19; d. Equirectangular panorama of the 360° clear sky view (looking north) showing location of visible light sources.

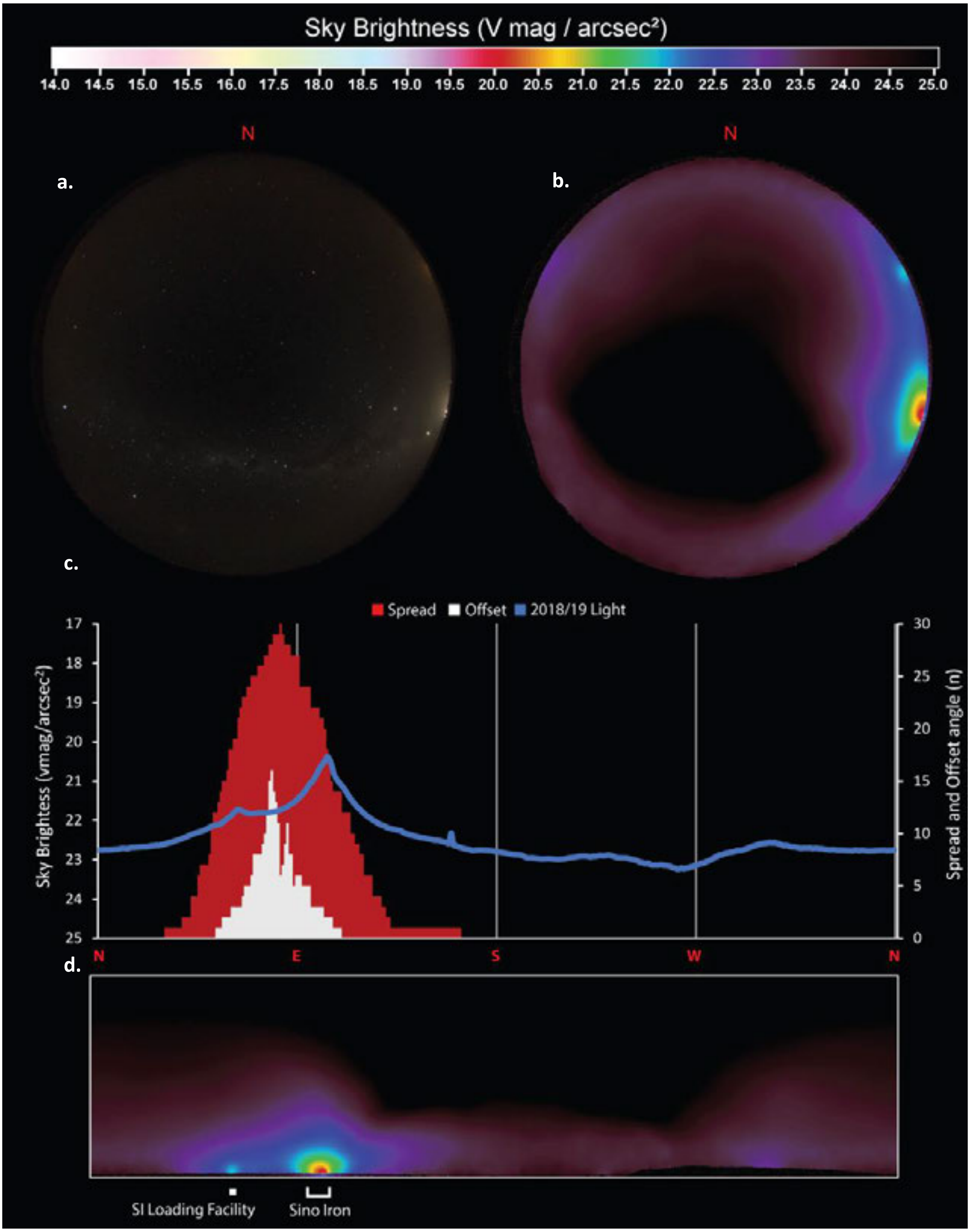


Figure 9: Artificial light monitoring results at Long Island in in 2018/19; a. Clearest available raw image; b. Processed isophote image; c. Light bearing graph showing sky brightness in 2018/19 and associated hatchling bearing frequency for spread (red bars) and offset (white bars); d. Equirectangular panorama of the 360° clear sky view (looking north) showing location of visible light sources.

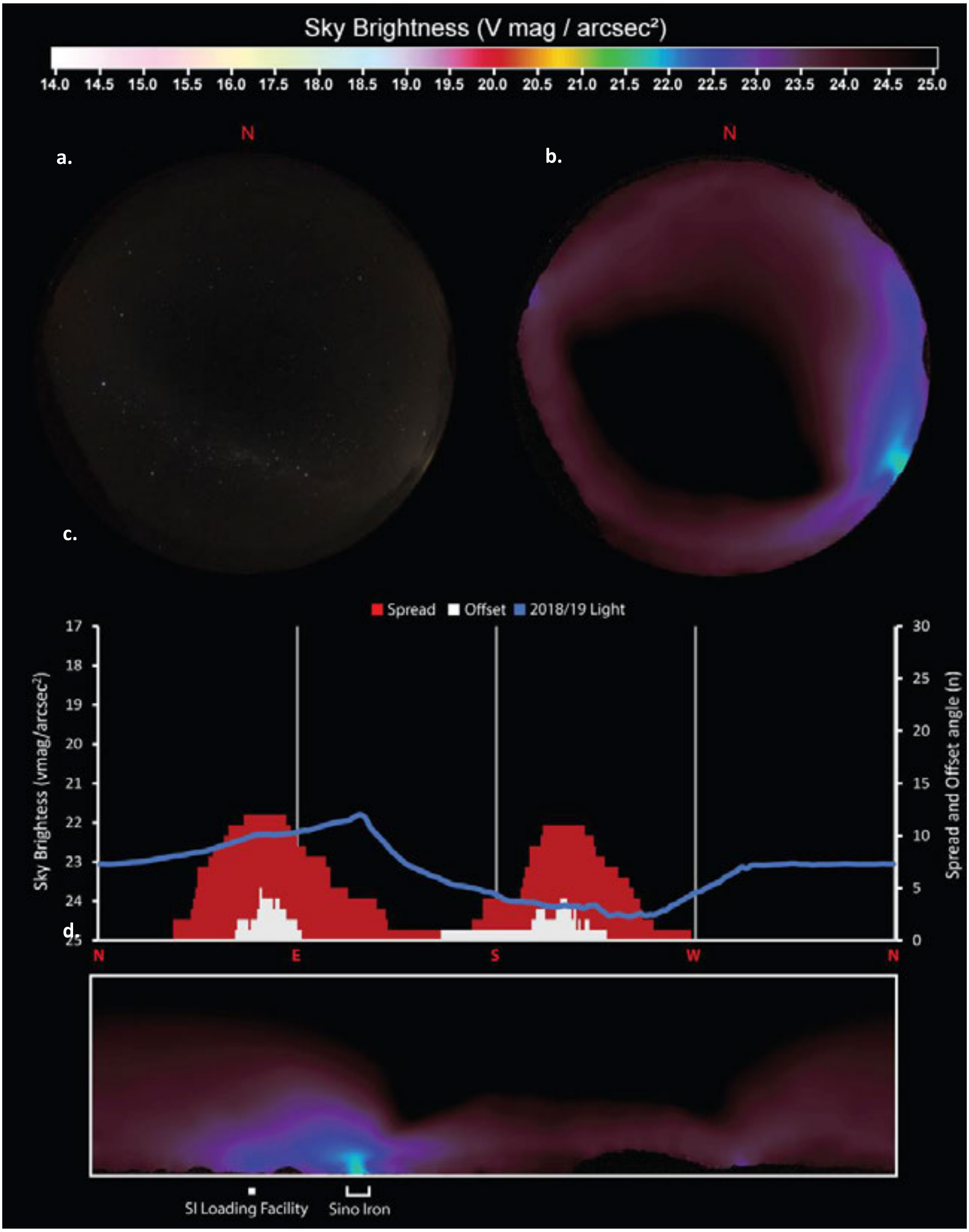


Figure 10: Artificial light monitoring results at Sholl Island in 2018/19; a. Clearest available raw image; b. Processed isophote image; c. Light bearing graph showing sky brightness in 2018/19 and associated hatchling bearing frequency for spread (red bars) and offset (white bars) for the northeast (left bar graph) and the southeast (right bar graph) survey zones; d. Equirectangular panorama of the 360° clear sky view (looking north) showing location of visible light sources.

3.6 Hatchling Orientation

The hatchling orientation data, as represented by the track fans left in the sand, are shown in **Figure 11** (Long Island) and **Figure 12** (Sholl Island).

Mean ± StDev spread angle of hatchlings emerging on:

- Long Island = 51.7 ± 20.0º (25 – 108; *n* = 30); and
- Sholl Island = 59.5 ± 31.8º (28 – 180; *n* = 24).

Mean ± StDev offset angle of hatchlings emerging on:

- Long Island = 10.1 ± 9.3º (0 – 44; *n* = 30); and
- Sholl Island = 8.7 ± 11.7º (1 – 58; *n* = 24).

The spread and offset angles recorded on Long Island were not significantly different to those recorded on Sholl Island ($p > 0.05$).

No hatchling orientation data was recorded on the mainland due to the lack of nesting activity and subsequent nest emergences there.

A plot of the hatchling fans in **Figures 11** and **12** shows their spatial distribution and differences in orientation at both Sholl and Long Islands. Note that fans recorded on the north and the south shorelines of Sholl Island appear different, though hatchlings were still orienting seaward from both beaches on the island (**Figure 12**).

Figure 11: Flatback hatchling fan orientation data recorded on Long Island during the February survey.

J59001 Mardie Project Marine Turtle Monitoring Program 2018/19

Drawn: P. Whittock
Date: 29/03/2019
Drawing File Ref:
PENV-J59001-925-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES

Figure 12: Flatback hatchling fan orientation data recorded on Sholl Island during the February survey.

4 DISCUSSION

The majority of marine turtle nesting activity was recorded during the December survey on the offshore islands. The main species recorded was flatback turtles, with relatively less nesting effort seen for hawksbill and green turtles at the same locations. In contrast, there was no evidence of any nesting attempts on the mainland coast west of Mardie Creek and very minor nesting effort by flatback turtles and a single hawksbill turtle, along the 15 km stretch of coastline to the east of the creek. The snapshot monitoring data from Round, Middle, and Angle Islands confirmed similar species composition and abundance at these sites. These results are consistent with turtle activity throughout the Pilbara where flatback and hawksbill nesting is dominant on nearshore island habitat, and flatback turtles are the most common mainland nesting species (Pendoley et al. 2016).

Based on successful nest counts for the 14 day interesting period in December, the size of the nesting populations on the Sholl and Long Island is estimated to be at least 50 females which is consistent with the estimates for regional nearshore island rookeries. On the mainland the lack of any successful flatback nesting and the presence of a single hawksbill nest (albeit past the peak of the hawksbill nesting season) suggests this area is not currently a regionally important rookery.

Nesting effort was substantially reduced in February, confirming the December survey captured the peak of the nesting season for flatback and green turtles. It is however important to note that since the December timing of the survey was planned to capture the peak of the flatback and green nesting, these results do not represent peak hawksbill nesting for this region which generally occurs in October.

With the exception of the single hawksbill nest recorded on the mainland in December, turtles nested most successfully on the offshore islands; 34 – 42 % of flatback and 36 – 50 % of hawksbill nesting attempts on the islands resulted in a nest. None of the three flatback nesting attempts on the mainland resulted in a nest. This variation in nesting success may be related to the varying nesting habitat characteristics between the island and mainland monitoring sites. For example, the island sites featured a wide supratidal zone, a well defined primary dune, and fine-medium grained sand size that may have facilitated the successful deposition of a clutch, whereas the mainland sites featured a narrow supratidal zone, little or no primary dune development, and medium-coarse grained sand size that may have hindered successful clutch deposition.

Out of the 21 excavated clutches, 20 were flatback turtle nests and one was a hawksbill turtle nest. While the sample size in this study is much smaller, the nesting habitat parameters for flatback turtles at Long and Sholl Islands can be compared to results from flatback rookeries elsewhere in the Pilbara region (Pendoley et al. 2014). The mean clutch size in this study (52.5 eggs) was slightly higher than reported at Barrow Island (BWI), Mundabullangana, and Cemetery Beach (mean 46.6 eggs). The hatching success rate in this study (49 %) was substantially lower than at Cemetery Beach (57 %), Mundabullangana (68 %), and BWI (83 %), as was the emergence success rate (42 %) compared to Cemetery Beach (48 %), Mundabullangana (58 %), and at BWI (79 %). The hatching and emergence success rates suggest the 2018/19 season productivity of Long and Sholl Island beaches was low compared to historical data from other regional rookeries.

The mean incubation period of 43 days recorded from the three marked nests in this study was much shorter when compared to the incubation period previously reported for BWI, Mundabullangana, and Cemetery Beach (between 46 – 47 days). Incubation period is a function of temperature, with warmer temperatures producing shorter incubation periods. High incubation temperatures during incubation can also cause hatchling mortality and the longer the eggs are exposed to temperatures in excess of 33°C (the upper end of the TTR), the greater the impact on egg hatching rates. The three monitored clutches in this study spent between 17 % and 47 % of their incubation period above the upper TTR, which potentially contributed to their lower hatching success rates.

The short incubation period, together with the relatively low hatching and emergence success rates, are often indicators of high incubation temperatures (Miller 1985). However, elsewhere within Western Australia, an increased tolerance has been reported for both flatback turtles (Delambre Island; Van Lohuizen et al. 2016) and loggerhead turtles (Dirk Hartog Island; Tedeschi et al. 2015), with both species demonstrating mechanisms that offer some resilience to thermal stress, potentially allowing them to survive in a warmer nest environment.

While no nests were marked and excavated on the mainland due to the lack of nesting observed there, temperature loggers were installed to understand the thermal environment of this habitat. The loggers confirmed that the mainland beaches were significantly warmer than the offshore islands, potentially impacting the success rate of any marine turtle nests on these beaches.

Baseline artificial light results found the overhead skies of the project site are typically very dark and representative of pristine, natural dark skies unaffected by artificial light. The only light source visible from all mainland and offshore light monitoring sites was the Sino Iron facilities located over 30 km away on the easterly horizon.

The hatchling orientation results indicate marine turtle hatchlings successfully oriented seaward, regardless of the orientation of the beach (e.g. Sholl Island north and south) or the visibility of the glow from the Sino Iron facilities. While hatchling orientation generally coincided with the direction of the horizon glow from the Sino Iron facilities, it is unlikely that the relatively small spatial extent of the sky glow visible from the nesting beach influenced hatchling orientation over the 30 km distance.

5 REFERENCES

ACKERMAN, R.A. (1997) The nest environment and the embryonic development of sea turtles. In: P. LUTZ & J. MUSICK (Eds), *Biology of Sea Turtles*. Boca Raton, CRC Press.

ECKERT, K.L., BJORNDAL, K.A., ABREU-GROBOIS, F.A. & DONNELLY, M. (1999) Research and management techniques for the conservation of sea turtles. International Union for Conservation of Nature/Species Survival Commission, Marine Turtle Specialist Group Publication No 4.

HEWAVISENTHI, S. & PARMENTER, C.J. (2002) Thermosensitive period for sexual differentiation of the gonads of the flatback turtle (*Natator depressus Garman*). *Australian Journal of Zoology*, 50, 521 – 527.

MILLER, J.D., LIMPUS C.L. & GODFREY, M.H. (2003) Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead sea turtles, p. 125-143. In: BOLTEN, A.B. & WITHERINGTON, B.E. (Eds). Loggerhead Sea Turtles. Washington, D.C., Smithsonian Books.

PENDOLEY, K.L. (2005) *Sea turtles and the environmental management of industrial activities in north west Western Australia* (Doctoral dissertation, Murdoch University).

PENDOLEY, K.L., BELL, C.D., MCCRACKEN, R., BALL, K.R., SHERBORNE, J., OATES, J.E., BECKER, P., VITENBERGS, A. & WHITTOCK, P.A. (2014) Reproductive biology of the flatback turtle Natator depressus in Western Australia. *Endangered Species Research*, *23*(2), pp.115-123.

PENDOLEY, K.L., WHITTOCK, P.A., VITENBERGS, A. & BELL, C. (2016) Twenty years of turtle tracks: marine turtle nesting activity at remote locations in the Pilbara, Western Australia. *Australian Journal of Zoology*, *64*(3), pp.217-226.

SHIGENAKA, G. (2003) Oils and sea turtle: biology, planning, and response. Office of Response and Restoration, NOAA Ocean Service, Seattle, WA.

TEDESCHI, J.N., KENNINGTON, W.J., BERRY, O., WHITING, S., MEEKAN, M. & MITCHELL, N.J. (2015) Increased expression of Hsp70 and Hsp90 mRNA as biomarkers of thermal stress in loggerhead turtle embryos (*Caretta Caretta*). *Journal of Thermal Biology*, **47**, 42 – 50.

VAN LOHUIZEN, S., ROSSENDELL, J., MITCHELL, N.J. & THUMS, M. (2016) The effect of incubation temperatures on nest success of flatback sea turtles (*Natator depressus*). *Marine Biology*, **163**, 150.

WHITTOCK, P.A., PENDOLEY, K.L. & HAMANN, M. (2014) Inter-nesting distribution of flatback turtles Natator depressus and industrial development in Western Australia. *Endangered Species Research*, *26*(1), pp.25-38.

WHITTOCK, P.A., PENDOLEY, K.L. & HAMANN, M. (2016) Flexible foraging: Post-nesting flatback turtles on the Australian continental shelf. *Journal of Experimental Marine Biology and Ecology*, *477*, pp.112-119.

WHITTOCK, P.A., PENDOLEY, K.L. & HAMANN, M. (2016a) Using habitat suitability models in an industrial setting: the case for internesting flatback turtles. *Ecosphere*, *7*(11).

YNTEMA, C. & MROSOVSKY, N. (1980) Sexual differentiation in hatchling loggerheads (*Caretta caretta*) incubated at different controlled temperatures. *Herpetologica*, 36, 33 – 36.

YNTEMA, C. & MROSOVSKY, N. (1982) Critical periods and pivotal temperatures for sexual differentiation in loggerhead sea turtles. *Canadian Journal of Zoology*, 60, 1012 – 1016.

Appendix 1: Flatback turtle nesting activity during the December and February surveys

Date	Long Island		Sholl Island		Mardie Creek East		Mardie Creek West	
	Nests	Tracks	Nests	Tracks	Nests	Tracks	Nests	Tracks
3-Dec	3	2	1	0	0	0	0	0
4-Dec	1	9	2	1	0	0	0	0
5-Dec	0	0	0	0	0	0	0	0
6-Dec	6	23	7	13	0	0	1	0
7-Dec	3	3	2	2	0	0	0	0
8-Dec	4	9	4	5	0	1	0	0
9-Dec	3	7	2	5	0	1	0	0
10-Dec	8	7	6	2	0	0	0	0
11-Dec	2	13	0	11	0	1	0	0
12-Dec	2	4	4	4	0	0	0	0
13-Dec	4	5	4	4	0	0	0	0
14-Dec	1	5	4	3	0	0	0	0
15-Dec	4	7	3	0	0	0	0	0
1-Feb	2	2	1	3	0	0	0	0
2-Feb	1	0	0	0	0	0	0	0
3-Feb	1	3	0	4	0	0	0	0
4-Feb	1	1	1	3	0	0	0	0
5-Feb	3	0	0	0	0	0	0	0
6-Feb	1	0	0	0	0	0	0	0
7-Feb	2	0	1	2	0	0	0	0
8-Feb	2	0	2	2	0	0	0	0
9-Feb	0	0	4	0	0	0	0	0
10-Feb	0	0	0	0	0	0	0	0
11-Feb	0	0	0	0	0	0	0	0
12-Feb	0	0	0	0	0	0	0	0
December	**41**	**94**	**39**	**50**	**0**	**3**	**1**	**0**
February	**13**	**6**	**9**	**14**	**0**	**0**	**0**	**0**
All Surveys	**54**	**98**	**47**	**64**	**0**	**3**	**1**	**0**

Appendix 2: Hawksbill turtle nesting activity during the December and February surveys

Date	Long Island		Sholl Island		Mardie Creek East		Mardie Creek West	
	Nests	Tracks	Nests	Tracks	Nests	Tracks	Nests	Tracks
3 Dec	0	0	0	0	0	0	0	0
4-Dec	0	0	0	0	0	0	0	0
5-Dec	0	0	0	0	0	0	0	0
6-Dec	2	1	3	1	1	2	1	0
7-Dec	0	2	2	0	1	1	0	0
8-Dec	1	1	2	0	0	0	0	0
9-Dec	0	0	0	0	1	1	0	0
10-Dec	0	0	0	0	0	0	0	0
11-Dec	0	0	0	0	0	0	0	0
12-Dec	0	0	0	0	0	0	0	0
13-Dec	0	1	1	0	0	0	0	0
14-Dec	0	0	0	0	0	0	0	0
15-Dec	0	0	0	0	0	0	0	0
1-Feb	0	1	1	1	0	1	0	0
2-Feb	0	0	0	0	0	0	0	0
3-Feb	0	0	0	0	0	0	0	0
4-Feb	0	0	0	0	0	0	0	0
5-Feb	0	0	0	0	0	0	0	0
6-Feb	0	0	0	0	0	0	0	0
7-Feb	0	0	0	0	0	0	0	0
8-Feb	0	0	0	0	0	0	0	0
9-Feb	0	0	0	0	0	0	0	0
10-Feb	0	0	0	0	0	0	0	0
11-Feb	0	0	0	0	0	0	0	0
12-Feb	0	0	0	0	0	0	0	0
December	**3**	**5**	**1**	**3**	**1**	**0**	**0**	**1**
February	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**
All Surveys	**3**	**6**	**2**	**3**	**1**	**0**	**0**	**1**

Appendix 3: Green turtle nesting activity during the December and February surveys

Date	Long Island		Sholl Island		Mardie Creek East		Mardie Creek West	
	Nests	Tracks	Nests	Tracks	Nests	Tracks	Nests	Tracks
3-Dec	1	1	0	0	0	0	0	0
4-Dec	0	0	0	0	0	0	0	0
5-Dec	0	0	0	0	0	0	0	0
6-Dec	0	0	0	0	0	0	10	0
7-Dec	0	2	0	0	0	0	0	0
8-Dec	0	1	0	1	0	0	0	0
9-Dec	0	0	1	0	0	0	0	0
10-Dec	0	1	0	1	0	0	0	0
11-Dec	0	1	0	0	0	0	0	0
12-Dec	1	0	0	1	0	0	0	0
13-Dec	0	0	0	1	0	0	0	0
14-Dec	0	0	0	1	0	0	0	0
15-Dec	0	1	0	0	0	0	0	0
1-Feb	0	0	0	0	0	0	0	0
2-Feb	0	0	0	0	0	0	0	0
3-Feb	0	0	0	0	0	0	0	0
4-Feb	0	0	0	0	0	0	0	0
5-Feb	0	0	0	0	0	0	0	0
6-Feb	0	0	0	0	0	0	0	0
7-Feb	0	0	0	0	0	0	0	0
8-Feb	0	0	0	0	0	0	0	0
9-Feb	0	0	0	0	0	0	0	0
10-Feb	0	0	0	0	0	0	0	0
11-Feb	0	0	0	0	0	0	0	0
12-Feb	0	0	0	0	0	0	0	0
December	**2**	**7**	**1**	**5**	**0**	**0**	**0**	**0**
February	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
All Surveys	**2**	**7**	**1**	**5**	**0**	**0**	**0**	**0**

Appendix 4: Statistical analysis of all track data recorded during the December survey

Table 1: Mean ± StDev (range, *n*) overnight nests by each marine turtle species on each monitored beach section during the December survey.

Beach Section	Flatback			Hawksbill			Green		
	Mean ± StDev	Range	*n*	Mean ± StDev	Range	*n*	Mean ± StDev	Range	*n*
Long Island	3.2 ± 2.2	0 - 8	41	0.2 ± 0.6	0 -2	3	0.2 ± 0.4	0 - 1	1
Sholl Island	2.9 ± 2.2	0 - 7	39	0.1 ± 0.3	0 - 1	1	0.0 ± 0.0	0 - 0	1
Mardie Creek East	0.0 ± 0.0	0 - 1	0	0.1 ± 0.3	0 - 0	1	0.1 ± 0.3	0 - 0	0
Mardie Creek West	0.1 ± 0.3	0 - 0	1	0.0 ± 0.0	0 - 1	0	0.0 ± 0.0	0 - 1	0

Table 7: Mean ± StDev (range, *n*) overnight false crawl tracks by each marine turtle species on each monitored beach section during the December survey.

Beach Section	Flatback			Hawksbill			Green		
	Mean ± StDev	Range	*n*	Mean ± StDev	Range	*n*	Mean ± StDev	Range	*n*
Long Island	3.8 ± 4.1	0 - 23	92	0.2 ± 0.4	0 - 2	5	0.1 ± 0.3	0 - 2	6
Sholl Island	7.2 ± 5.8	0 - 13	50	0.4 ± 0.7	0 - 1	3	0.5 ± 0.7	0 - 1	5
Mardie Creek East	0.0 ± 0.0	0 - 0	3	0.1 ± 0.3	0 - 0	0	0.0 ± 0.0	0 - 0	0
Mardie Creek West	0.2 ± 0.4	0 - 1	0	0.0 ± 0.0	0 - 0	1	0.0 ± 0.0	0 - 0	0