BCI MINERALS LIMITED

MARDIE SALT PROJECT: MARINE TURTLE MONITORING PROGRAM 2023/24

Prepared by

Pendoley Environmental Pty Ltd

For

BCI MINERALS LIMITED

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EXECUTIVE SUMMARY

Mardie Minerals Pty Ltd (Mardie Minerals) is a wholly owned subsidiary of BCI Minerals Limited (BCI), and is the proponent developing the Mardie Salt and Potash Project, a greenfield high-volume salt production venture in the Pilbara region of Western Australia. The project will produce salt and sulphate of potash for export via the evaporation of seawater, with a proposed production of 5 million tonnes per annum of concentrated salt, and 140,000 tonnes per annum of Sulphate of Potash (SoP). Prior to the commencement of Project, Mardie Minerals was required to undertake a pre-construction marine turtle survey to characterise the abundance of turtle species utilising nesting habitat within and adjacent to the Project Development Envelope.

As a condition of their approvals, Mardie Minerals is required to conduct an ongoing annual marine turtle monitoring survey to monitor marine turtle nesting and hatchling activity on beaches nearby the facility, including those on the mainland coast and offshore islands.

In accordance with best practise monitoring requirements, three field surveys were undertaken at suitable nesting habitat on mainland and island beaches in October 2023 (Field Survey 1; FS1), December 2023 (FS2) and February 2024 (FS3). The surveys were designed to target the peak nesting and hatching periods for hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*) and green turtles (*Chelonia mydas*). Each field survey was 14 days in duration, to represent the mean inter-nesting period for marine turtles and the peak hatching period for green and flatback turtle hatchlings.

A daily track census (‘routine monitoring’) was undertaken on the mainland to the east and west of Mardie Creek (the location of the proposed secondary seawater intake facility) and at Sholl and Long Islands. Round, Middle Passage, Angle and Passage islands were surveyed three times per week during each field survey, while once weekly surveys were undertaken at Fortescue, Mardie, South Passage and Stewart islands. A one-off opportunistic survey was conducted at Solitary Island during FS1. Nests encountered in FS1 on Long and Sholl islands were randomly marked for excavation in FS2 or FS3 (dependent upon time to hatching). Hatchling orientation data was recorded in FS2 and FS3, to coincide with the peak hatchling period for hawksbill turtles (December) and flatback and green turtles (February).

At the mainland beaches and smaller, opportunistically monitored islands, marine turtle nesting activity was lower than on the routinely monitored islands and not as regionally significant as Sholl or Long islands. Flatback and Green turtles were recorded on the mainland beaches in 2023/24 in very small numbers.

Flatback nesting activity was greater than recorded in 2019 and 2021/22, accounting for the greatest number of tracks in the overall monitoring period, with 40 tracks recorded in FS1, 630 tracks in FS2 and 33 tracks in FS3. The majority of flatback tracks occurred on Sholl and Long islands, with nesting activity occurring on all other monitored islands. Mean nesting success was lower for flatback turtles across the Mardie offshore islands when compared with the 2019 and 2021/22 seasons, and was 36% during FS1, 17% during FS2 and 11% during FS3.

Hawksbill turtle nesting activity was lower than recorded in 2019 and 2021/22, occurring on all routine monitoring islands in FS1 (16 tracks), FS2 (23 tracks) and FS3 (1). Mean nesting success during FS1 was 65%, 14% during FS2 and negligible in FS3.

Green nesting activity occurred on Sholl, Round, Long and Middle Passage islands in low numbers. Nesting success was 33.3% for FS1, 25% for FS2 and 67% for FS3. No green turtle nests were marked for excavation.

When compared to the routinely monitored islands, nesting activity on the mainland coast was minor. A total of 13 flatback and one green turtle tracks were recorded at mainland beaches across all surveys, with one of the flatback tracks being a nesting attempt. Nesting success for flatback turtles on the mainland beaches was 0% for all surveys.

Excavation of marked and opportunistic clutches in FS2 and FS3 indicated the mean flatback turtle clutch size across all islands was 50 ± 6 eggs (*n* = 11). Mean hatch success for all flatback nests was 81% ± 22.1 (n=11).

Mean hawksbill turtle clutch size was 98 ± 25 eggs (*n* = 9), and the mean hatch success of nests was 79% ± 13.2 (*n* = 6). This hatch success does not include the results of three nests that were inundated during the incubation period, with the mean hatch success of inundated nests being <1% (*n* = 3).

Temperature data retrieved from marked nests indicated the mean incubation period for flatback clutches was 48 days (*n* = 6) and for hawksbill clutches was 50 days (*n* = 2). Flatback nests had a mean daily temperature of 31.0°C over the incubation period, and 30.5°C over the thermosensitive period (middle trimester of incubation), which lasted 16 days on average. The incubation environment for hawksbill nests was similar, with a mean temperature of 31.5°C over the incubation period, and 30.9°C over the thermosensitive period, which lasted 18 days on average.

From the 49 hatchling fans analysed in the 2023/24 season, marine turtle hatchlings successfully oriented seaward, regardless of the visibility of light sources. When this data was compared with baseline data from 2021/22, there was one trigger level spread angle exceedance for Sholl Island West, which was not considered to be due to any artificial light emissions within the Mardie region as there were no new light sources on the horizon and the hatchling sample size for this location was low (n=8). This result suggests that the trigger limits for this metric are too low. This is likely due to the relatively small benchmark data sample sizes not capturing the variance typically found in biological datasets. All other locations were below exceedance criteria, which was also the case for offset angle metrics analysis.

Artificial light data indicated the night skies at the monitoring locations were representative of an ideal natural dark night sky. The brightest light sources from the mainland were the Sino Iron ore mine and the port at Cape Preston. Mardie Village was a new source of light in 2021/22 which is visible from monitoring locations on Long and Sholl islands.

The 2023/24 Marine Turtle Monitoring Program collected census data of marine turtle nesting and hatching activity in the Mardie region, to meet the state and federal environmental approval conditions of the Mardie Project. The data collected during this season during the ongoing construction and operational stages of the Mardie Project has been compared with baseline data provided in the Marine Turtle Monitoring Plan (2023), to ensure artificial light emissions from the Project site are not having an impact on adult nesting, or hatchling sea-finding behaviours. The data collected in the 2023/24 season for the Marine Turtle Monitoring Program suggests that the Mardie Project operational light emissions are not having an impact upon turtle nesting behaviour or hatchling orientation behaviour at the beaches monitored.

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GLOSSARY

Term	Definition
False crawl	When a female turtle crawls onto the beach and makes no digging attempt and then returns to the ocean without laying.
Hatch success	The percentage of eggs in a clutch that produce live hatchlings.
Emergence success	The percentage of eggs in a clutch that produce live hatchlings that leave the nest chamber.
Incubation period	The duration between the date a clutch was laid and the date a clutch hatched.
Nester abundance	Determined through successful nest counts over one complete inter-nesting period at the peak of the nesting season. Represents an estimation of the total number of females nesting at a particular beach for the season.
Nesting activity	May be a false crawl, nesting attempt, or nest.
Nesting attempt	When a female turtle crawls onto the beach and attempts to lay a clutch of eggs by digging a nest, or part thereof, but not actually depositing eggs.
Nesting success	The number of successful nests as a percentage of the total number of overnight tracks.
Thermal tolerance range	The range of suitable temperatures for marine turtle incubation, outside of which embryo development is impaired.
Thermosensitive period	The middle trimester of development that determines the sex ratio of a clutch.
Track census	The process of identifying marine turtle tracks and classifying the turtle species and nesting activity.

1 INTRODUCTION

1.1 Project Background

Mardie Minerals Pty Ltd (Mardie Minerals) is developing the Mardie Salt and Potash Project (the Project), a greenfield high-volume salt production venture in the Pilbara region of Western Australia. The Project will produce salt via evaporation of seawater, with a proposed production of 5 million tonnes per annum of concentrated salt, and 140,000 tonnes per annum of Sulphate of Potash (SoP). Mardie Minerals is a wholly owned subsidiary of BCI Minerals Limited (BCI).

The Project will comprise a series of evaporation and crystalliser ponds extending over an area ~30 km long, built predominately over existing mud and salt flat habitat. It will also feature a processing plant, a bitterns disposal pipeline and outfall, a trestle jetty and supporting infrastructure to produce and export salt and SoP (Preston Consulting 2018). Bitterns will be the only waste product produced during operations.

The Project received approval under the *Environmental Protection Act 1986* (EP Act) in November 2021 and was approved as a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in January 2022. Construction and operation of the Project is subject to approval conditions prescribed under Ministerial Statement No. 1175 (MS 1175; EP Act) and EPBC2018/8236 (EPBC Act). Significant amendments to the original proposal were later outlined within the Optimised Mardie Salt Proposal, which was submitted to the EPA in March 2022 (Preston Consulting, 2022) and approved under Ministerial Statement 1211 in October 2023 (MS 1211; EP Act, EPA, 2023b) and later under EPBC2022/9169 (EPBC Act). Ministerial Statement 1211 supersedes Statement 1175 (BCI Minerals 2023) and includes conditions B5-1, B6-1 and B6-4 (**Appendix A**). The *BCI Illumination Plan ("The Plan")* was developed in support of the Optimised Mardie Project and aligns with the requirements of Condition 9-1 and 9-4 of Ministerial Statement 1175 and Condition 24 of EPBC 2018/8236 (BCI Minerals, 2023). The purpose of *The Plan* is to avoid where possible, and otherwise minimise impacts of artificial light to fauna of conservation significance and their habitats. Condition 9-4 requires the Proponent to review, propose and submit any amendments to *The Plan* every 5 years.

The ministerial statements referred to above contain approval conditions pertaining to the protection of marine turtles from impacts due to artificial light associated with the Optimised Mardie Salt Proposal. Outcome-based indicators from *The Plan* that will be used to ensure that significant impacts from artificial light on marine turtles are minimised and managed include:

- the spatial distribution of marine turtle beach usage shows a statistically significant change in a single season compared to the baseline data for that site, and
- marine turtle hatchling behaviour (i.e. nest fan metrics) displays a variation in spread and/or offset angles that exceed trigger and threshold metrics when compared to the baseline data.

The Studies undertaken by Pendoley Environmental (PENV) in the austral summer of 2018/19 and 2021/22 identified that marine turtles utilise sandy beach habitat along the mainland coast and offshore islands in the vicinity of the Project for nesting activities (Pendoley Environmental 2019; 2022; 2023). Flatback (*Natator depressus*), hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia* *mydas*) were recorded nesting at offshore islands, and nests or nesting attempts were recorded for flatback and hawksbill turtles on mainland beaches to the east and west of Mardie Creek (Pendoley Environmental 2019; 2022). The data obtained from these studies provide the baseline data for the marine turtle monitoring that has taken place in 2023/24 (and reported here).

1.2 Scope of Works and Objectives

This report details the outcomes of marine turtle monitoring undertaken in 2023/24 and meets certain approval conditions of MS 1175 and MS 1211; EPBC2018/8236 and EPBC2022/9169 (**Appendix A**).

The 2023/24 Marine Turtle Monitoring Program (this report) was designed to collect monitoring data over the entire breeding and hatching season of hawksbill, flatback and green turtles utilising mainland and island beaches in the vicinity of the Project. Data was collected 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.

This report provides monitoring data to allow comparison with baseline data provided by Pendoley Environmental (2019; 2023).

2 METHODS

2.1 Survey Location and schedule

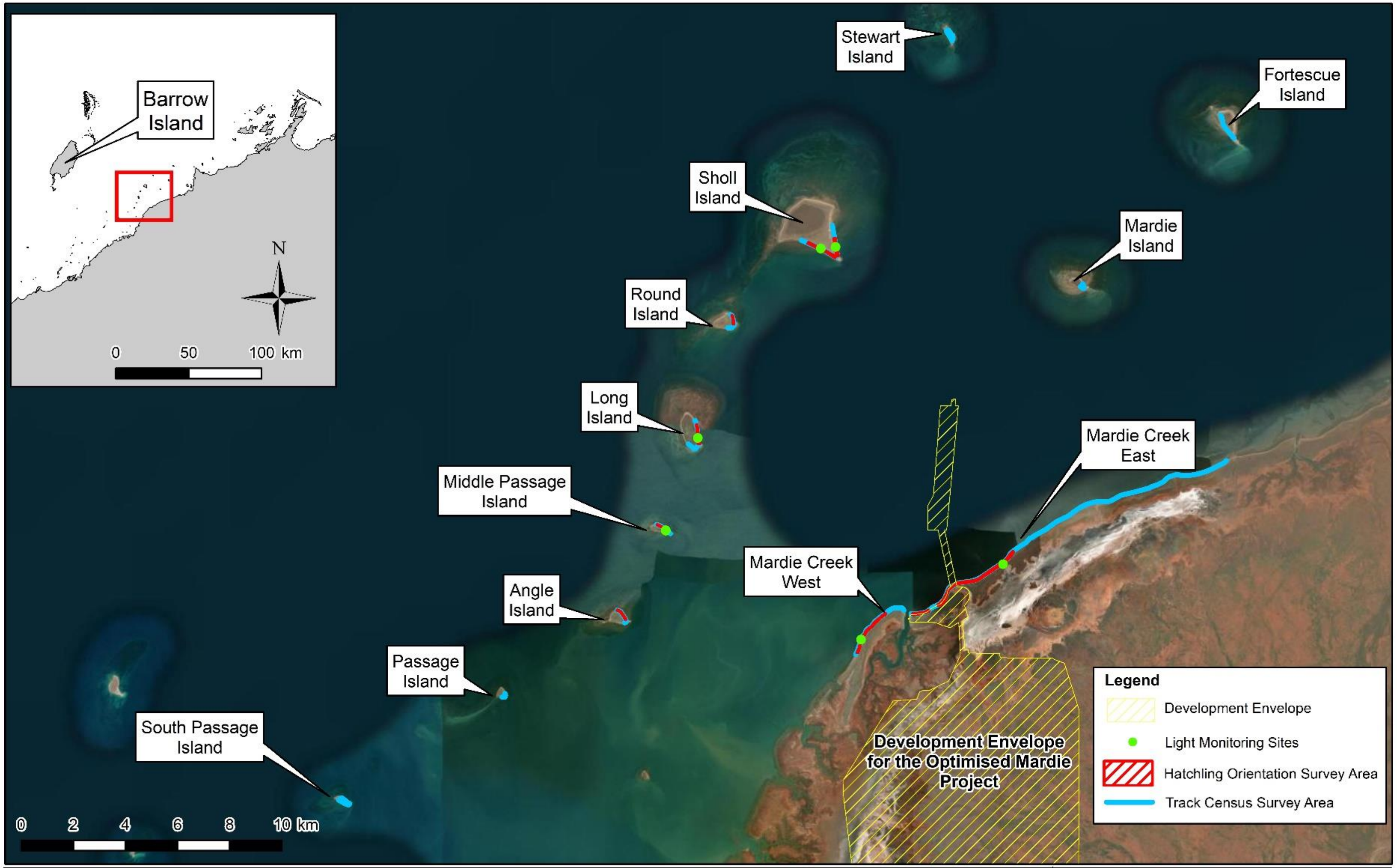
Marine turtle nesting and hatching surveys were conducted at islands and along the mainland coast in the vicinity of the Project over the 2023/24 marine turtle nesting season (**Figure 1**). Three field surveys were undertaken over October 2023–February 2024, including:

- **Field Survey 1 (FS1; 16th October – 30th October 2023):** Targeted the peak of the hawksbill turtle nesting season over one 14-day internesting period (pers com T Hunt, DBCA 2022; Commonwealth 2007).
- **Field Survey 2 (FS2; 4th December – 18th December 2023):** Targeted the peak green and flatback turtle nesting season over one 14-day internesting period and peak hawksbill hatching season (Pendoley et al. 2016, Fossette et al. 2021).
- **Field Survey 3 (FS3; 5th February – 19th February 2024):** Targeted the peak green and flatback hatching season (Pendoley et al. 2014, 2016).

Sandy beach habitat was surveyed to determine the presence and abundance of nesting activity. Islands routinely surveyed in each field campaign (i.e., daily throughout each field survey) included Sholl and Long islands. Round, Middle Passage and Angle islands were surveyed tri-weekly (**Figure 1**). Fortescue, Mardie, Passage and South Passage islands were surveyed weekly, while Stewart and

Solitary islands were surveyed opportunistically to provide a snapshot of turtle nesting activity. Coastline to the east and west of Mardie Creek was surveyed daily by helicopter and on foot.

A summary of the survey schedule for October 2023–February 2024 is provided in **Appendix B**.



J59009 BCI Marine Turtle Monitoring 2023/24

Figure 1: Monitoring locations for 2023/24.

Drawn: J. Kelly
Date: 22/07/2024
Drawing File Ref: PENV-J59009-1377-B
Coordinate System: GDA 2020 MGA Zone 50

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2.2 Work Scopes

2.2.1 Work Program

An overview of the work scopes conducted for each field survey is provided in **Table 1,** with methodology detailed in the following sections. A daily location schedule for each field survey is provided in **Appendix B**.

Table 1: Field survey work program. Shaded cells indicate work scope was not conducted at any location during the survey. Track Census codes: “x” indicates daily, “3” indicates three times per week; “2” indicates twice per week, “O” indicates opportunistic (snapshot or once per week).

Location	Track Census			Incubation Success			Hatchling Orientation			Light Monitoring		
	FS1	FS2	FS3	FS1	FS2	FS3	FS1	FS2	FS3	FS1	FS2	FS3
Sholl Island	x	x	x		X	X		x	x		x	x
Long Island	x	x	x		X	x		x	x		x	x
Round Island	3	3	2					x	x			
Middle Passage Island	3	2	2									
Angle Island	3	2	2					x	x			
Passage Island	O	1	1									
South Passage Island	O	1	1					x	x			
Stewart Island	O	1	1					x	x			
Fortescue Island	O	1	1									
Mardie Island	O	1	1									
Solitary Island	O	-	-									
Mainland Mardie Creek East	x	x	x		-	-		-	-		x	x
Mainland Mardie Creek West	x	x	x		-	-		-	-		x	x

2.2.2 Nesting Habitat: Track Census

A track census involves recording the type of marine turtle nesting activity and species derived from tracks encountered on a nesting beach. A track census could be of one of the following:

- A one-off, opportunistic survey: for sites that were not frequently monitored, but where there was a need to determine the presence/absence of nesting activity. The age of tracks recorded during a snapshot survey typically cannot be determined.
- A routine survey: for sites that were monitored daily or three times per week throughout a survey. All visible tracks are marked during a ‘line-in’ day (i.e. first day of each survey) prior to the commencement of the track monitoring to ensure only new tracks from overnight nesting activity are recorded on subsequent survey days.

On each survey day for FS1–3, marine turtle nesting activity was identified by walking sections of suitable sandy beach on each of the islands and mainland. Overnight activity was confirmed from fresh tracks left in the sand since the previous day’s survey. Marine turtle species and nesting activity (false crawl, attempt, or nest) were determined using track and nest characteristics, including track width, shape and orientation of flipper marks, trail drag marks, displaced sand, and the depth of the nest pit and associated mound (CCG 2015). All identified tracks were marked with a line in the sand to prevent recounts on the following survey days.

Predator activity was identified by tracks, scratchings and holes dug in the sand in the vicinity of a nest, which may have resulted in eggshells being scattered at the sand surface.

2.2.3 Nesting Habitat: Incubation Success

2.2.3.1 Nest Marking

When nests were identified during the track census on islands surveyed daily during FS1 and FS2, they were marked (Error! Reference source not found.). Each clutch was located by gentle digging into a fresh nest and locating the eggs at the top of the nest. A Hobo temperature logger tethered to a marking post (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 at 30-minute intervals.

Control temperature loggers were also deployed during FS1 to track the sand temperature during the incubation period of marked nests. Control loggers were buried in sand at 500 mm depth, and recorded temperature at 30-minute intervals.

2.2.3.2 Nest Excavation

Marked clutches were excavated by removing and sorting the contents of each egg chamber during FS2 and FS3 (**Table 1**). The timing of FS2 and FS3 ensured that all clutches marked during FS1 were able to hatch prior to excavation. Egg chamber contents were sorted into the following categories:

- Live hatchlings
- Dead hatchlings
- Pipped eggs
- Hatched eggs
- Partially developed embryos (dead)
- Fully developed embryos (dead)
- Undeveloped embryos

In addition to marked clutches, opportunistic clutches were also excavated during FS2 and FS3. Recently emerged nests on routinely monitored islands were identified in the first three days of the field survey and excavated in the final three days of the field survey, to allow sufficient time for the nest to finish hatching. Opportunistic clutches were excavated with caution to avoid disturbance to any remaining live hatchlings within the clutch or to developing embryos that may not yet have hatched. The contents of the egg chamber were sorted into the same categories as the marked clutches.

2.2.4 Hatchling Orientation

A nest fan was recorded if five or more hatchling tracks were sighted from a hatched clutch. Hatchling tracks fan out from a localised depression in the sand which marks the point of emergence. A sighting compass was used at the point of emergence to measure the bearing of the outermost tracks of the nest fan (vectors A and B, **Figure 2**) and the bearing of the most direct route to the ocean (vector X, **Figure 2**). Bearings were measured at the point where the track crossed the high tide line, or five metres from the clutch emergence point (whichever distance was shortest). Any tracks more than 30° outside of the main fan defined by vectors A and B were considered outliers, and the bearing of outlying tracks was recorded separately.

Two metrics were used to track fan spread and offset:

- **Spread angle**: this describes track dispersion from the emergence point, capturing the spread of all hatchling pathways toward the ocean. A larger value indicates greater dispersion or variation in ocean finding bearings and may indicate disruption to natural hatchling sea finding ability.
- **Offset angle:** this describes the degree of deflection of tracks from the most direct route to the ocean. A smaller value indicates a more direct route (i.e., less deviation from the most direct route) and a larger value demonstrates greater deviation from the most direct route, which may indicate disruption to natural hatchling sea finding ability.

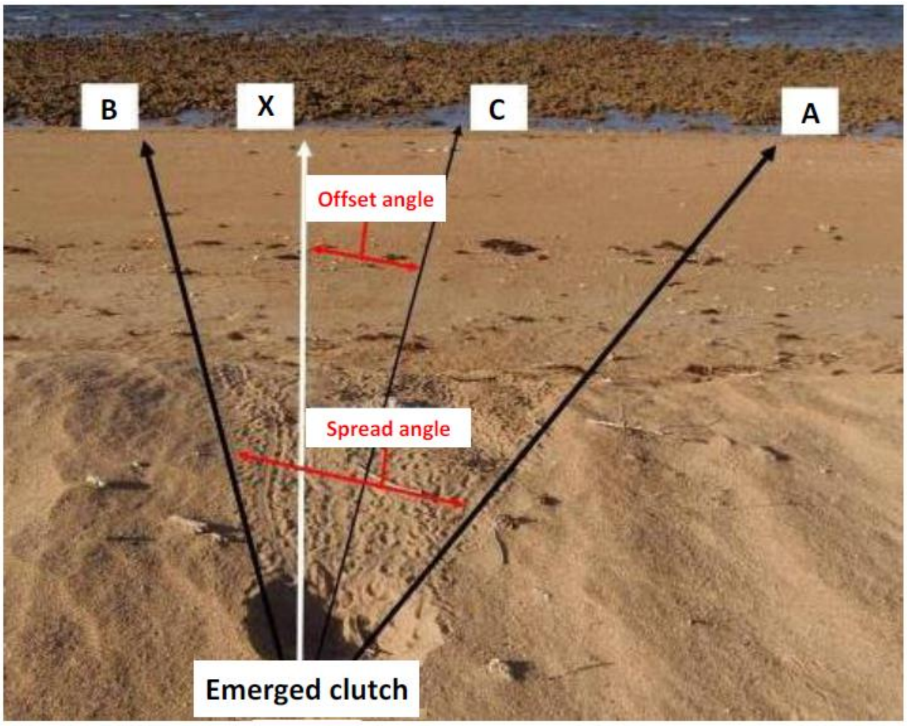

Figure 2: Hatchling orientation indices measured from the emergence point identified as the nest cone. *A* and *B*: the outermost bearings of the main fan, *X*: the bearing of the most direct route to the sea and *C*: offset angle.

2.2.1 Artificial Light Monitoring

Sky42™ (Sky42) light monitoring cameras were deployed on Mainland East, Mainland West, Sholl (East and West), Long and Middle Passage islands during FS2 and FS3 (**Table 1**). Images of night-time light emissions on a 360° horizon were captured automatically by the cameras at 10-minute intervals between sunset and sunrise.

2.3 Data Analysis

2.3.1 Nesting Habitat: Track Census

Descriptive statistics describing abundance (mean ± standard deviation, range and sample size) were generated for the following parameters for each species and each beach across all field surveys:

- overnight nests, and
- overnight tracks (includes false crawls and nesting attempts).

Nesting success, calculated as the number of successful nesting events as a percentage of the total number of overnight tracks, was also determined for census beaches (surveyed daily or tri-weekly) and turtle species. It is important to note that a successful nesting event was not always confirmed by a visual sighting of the eggs, unless the nest was selected for the incubation study. All other nesting events were determined from a visual assessment of the completed nest and was not confirmed by excavation and sighting of the eggs. Consequently, this parameter is an estimate only.

2.3.2 Nesting Habitat: Incubation Success

2.3.2.1 Clutch Fate

Clutch fate was classified as one of four categories:

- Complete: If a clutch was not lost, inundated, disturbed or predated – i.e. it had been left undisturbed for the entire incubation period.
- Lost: If a clutch could not be located by the field team. This could be due to excessive sand deposition, erosion, disturbance from predators or other nesting turtles, or displacement of marking equipment.
- Inundated: If the temperature profile of a clutch showed a sudden substantial drop below the control temperature.
- Disturbed or predated: If the temperature profile of 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 total number of eggs in the clutch. Hatchling emergence success (the percentage of hatchlings successfully leaving the nest) was calculated by subtracting the number of live and dead hatchlings encountered in the egg chamber from the number of hatched eggs, and then dividing by the total number of eggs in the clutch.

2.3.2.3 Incubation Period

The incubation period (IP) is the duration between the date a clutch was marked and the date the clutch hatched. The hatch date of each marked clutch was determined by comparing the clutch temperature profile to the control temperature profile, whereby a drop in temperature in the clutch profile indicated the nest had hatched and emerged.

2.3.2.4 Thermal Environment: Clutch Temperature

Following identification of the hatch date for each clutch, descriptive statistics were generated to describe the incubation environment of each clutch, including:

- mean clutch temperature for the incubation period,
- mean clutch temperature during the Thermosensitive Period (TSP), which represents the middle trimester of development and determines the sex ratio of a clutch (Yntema & Mrosovsky 1980, 1982; Hewavisenthi & Parmenter 2002), and
- the proportion of the incubation period where the mean daily temperature >33°C. This temperature is considered the lower bound of the upper thermal tolerance range (TTR) for marine turtle incubation, above which embryo development is impaired (Ackerman 1997, Van Lohuizen et al. 2016, Tanabe et al. 2020).

2.3.2.5 Thermal Environment: Sand Temperature

Temperature loggers deployed at control sites on each beach section were retrieved during FS2 & FS3. Control logger temperatures were used to calculate the mean daily temperature for the entire incubation period of marked clutches (October to December).

2.3.3 Hatchling Orientation

Offset and spread angles were calculated for bearings measured from each nest fan (**Figure 2**) to determine the spread of hatchling tracks from the point of emergence (angle between vector A and B, **Figure 2**), and the degree to which hatchlings diverged from the most direct route to the ocean (angle between vector X and C, whereby C is the mid-point between vectors A and B, **Figure 2**).

A Kruskal-Wallis H test was performed on the spread and offset angles to determine if there was a significant difference between islands.

To identify significant differences in hatchling orientation behaviours on beaches compared with the baseline dataset, the exceedance values of spread and offset that were considered statistically significant from baseline were set to when they exceed the baseline mean + 2*StDev (Trigger) and the baseline mean + 3*StDev (Threshold) (Mardie Salt Marine Turtle Monitoring Plan, Pendoley Environmental 2023).

2.3.4 Artificial Light Monitoring

2.3.4.1 Identification of Potential Light Sources

Potential sources of artificial light captured by the Sky42 cameras were identified using Google Earth and Visible Infrared Imaging Radiometer Suite (VIIRS) light pollution data (www.lightpollutionmap.info).

2.3.4.2 Data Processing

Sky42 images were batch processed using specialised software (Sky Quality Camera, Euromix Pty Ltd) following the identification and removal of poor-quality images (i.e. those impacted by moonlight, twilight or wind-blown sand). Processing involved converting each image to an isophote (light level) contour map and calculating the mean whole-of-sky brightness value (Vmag/arcsec^2) for all pixels in the map, zenith (60 – 90° field of view directly overhead), and horizon (0 – 30° view). A single isophote map was then selected for each monitoring location (four maps total) to represent the median sky brightness with the least amount of influence from cloud, and converted to equirectangular panoramas. The colour coding in the isophote maps are a representation of light intensity and is not characteristic of the light perceived by human or wildlife receptors. The units of visual magnitudes per arcsecond squared are on an inverse logarithmic scale (higher values correspond to lower levels of light) (**Table 2**).

Table 2: Qualitative description of Sky42 Whole-of-sky (0 – 90°) Vmag/arcsec^2. Use as a guide only.

Whole-of-sky brightness (0 - 90°) (Vmag/arcsec2)	Description
21.5 – 22.0	Ideal natural dark night sky

21.0 – 21.5	Rural night sky
20.0 – 21.0	Semi-rural night sky
19.0 – 20.0	Suburban night sky
18.0 – 19.0	Urban night sky
< 18.0	Urban/Industrial night sky

3 RESULTS

3.1 Nesting Habitat: Characteristics

Islands monitored during the field program predominantly occur in a north-south orientated island chain off the coast of Mardie, and all share similar morphologic features (**Figure 1**). They typically feature a dynamic sand spit on the southern or south-eastern extent, a moderately wide and sloped intertidal zone, a wide supratidal zone, and vegetated dunes adjacent to sandy nesting habitat (**Figure 3**).

Mainland beaches, including those to the east and west of Mardie Creek, are long and low energy beaches with broad and shallow intertidal zones, narrow supratidal zones, and permanently vegetated dunes set back from the beach (**Figure 4**). Sections of the mainland coast are occupied by extensive mangrove forests, such as stretches to the west of Mardie Creek and at creek mouths. Beach sediment is typically dark brown or red in colour, and ranges in composition from stones and gravel to medium-coarse sand.

Figure 3: Example of nesting habitat on Passage Island (top) and Angle Island (bottom).

Figure 4: Example of nesting habitat on the mainland, Mardie, Western Australia.

3.2 Nesting Habitat: Track Census

3.2.1 Abundance and Distribution: Routine Monitoring Island Beaches

3.2.1.1 Field Survey 1

The overnight track census survey at Long, Sholl and the mainland recorded a total of 58 marine turtle tracks. Of these tracks, 40 were flatback turtle tracks (69 %), 2 (3.4 %) were green turtle tracks and the remainder were hawksbill turtle tracks (n = 16, 27.6 %) (**Figure 5**).

Half of these tracks (n=29 out of 58) were associated with nests, with the remaining 29 tracks consisting of unsuccessful nesting attempts or false crawls (i.e., a U-turn with no attempt to dig a nest). Ten nests were hawksbill turtle nests, 1 was a green turtle nest and the remaining 18 nests were from flatback turtles. Of these 29 nests, 15 were marked for excavation during subsequent surveys in the 2023/24 season.

Most tracks were recorded on offshore islands (*n* = 55 tracks) with only limited activity recorded on the mainland (*n* = 3 tracks) (**Appendix C**). The three tracks on the mainland were assigned to flatback turtles and were all unsuccessful nesting attempts.

The track census surveys at Mardie, Fortescue, Solitary, South Passage, Passage, Round, Angle and Middle Passage Islands recorded 21 marine turtle tracks (Error! Reference source not found.). Of these, 19 were flatback tracks, 1 was a hawksbill turtle track and the remaining track was from a green turtle. Most (76 %) of these tracks were recorded on Round (n=7 tracks) and Angle (n=9 tracks) islands.

3.2.1.2 Field Survey 2

The overnight track census survey at Long, Sholl and the mainland recorded a total of 658 marine turtle tracks. Of these tracks, 630 were flatback turtle tracks (95.7 %), 4 (0.6 %) were green turtle tracks, 23 (3.3 %) were hawksbill turtle tracks and there was one unknown track (**Figure 5, Appendix C**).

One hundred and five of these tracks (15.9%) were associated with nests, with the remaining 553 tracks consisting of unsuccessful nesting attempts or false crawls (i.e., a U-turn with no attempt to dig a nest). Three nests (3%) were hawksbill turtle nests, 1 was a green turtle nest (0.9%) and the remaining 101 (96%) nests were from flatback turtles. Of these 105 nests, 4 were marked for excavation during subsequent surveys in the 2023/24 season.

Most tracks were recorded on offshore islands (*n* = 747 tracks) with only limited activity was recorded on the mainland (*n* = 9 tracks) (**Appendix C**). The nine tracks on the mainland were assigned to flatback turtles with one of these being a nest attempt.

The track census surveys at Mardie, Fortescue, South Passage, Passage, Round, Angle and Middle Passage Islands recorded 98 marine turtle tracks (**Figure 5**). Of these, 86 were flatback tracks, 6 were hawksbill turtle tracks and the remaining six tracks could not be identified. Most (74 %) of these tracks were recorded on Angle (n=32 tracks), Round (n=23 tracks) and Middle Passage (n=19) islands.

3.2.1.3 Field Survey 3

The overnight track census survey at Long, Sholl and the mainland recorded a total of 40 marine turtle tracks. Of these tracks, 33 were flatback turtle tracks (82.5 %), two (5 %) were green turtle tracks, one (2.5 %) hawksbill turtle track and four unknown tracks (10 %) (**Figure 5**, **Appendix C**).

Six of these tracks (15 %) were associated with nests, with the remaining 34 tracks consisting of unsuccessful nesting attempts or false crawls (i.e., a U-turn with no attempt to dig a nest). Four nests were flatback nests (66.6 %) and two were green turtle nests (33.3 %).

Most tracks were recorded on offshore islands (*n* = 37 tracks) with only limited activity recorded on the mainland (*n* = 3 tracks) (**Appendix C**). The three tracks on the mainland were assigned to flatback (*n* = 1), green (*n* = 1) and an unknown (*n* = 1). All mainland turtle tracks were classified as false crawls.

The track census surveys at Mardie, Fortescue, South Passage, Passage, Round, Angle and Middle Passage Islands recorded nine marine turtle tracks (**Appendix C**). Of these, four were flatback tracks, two were hawksbill turtle tracks, two were green tracks and one could not be identified. Most (55.6%) of these tracks were recorded on Middle Passage (*n* = 5 tracks), Round (*n* = 2 tracks), Angle (*n* = 1 track) and South Passage (*n* = 1 track) islands.

Two stranded dead adult green turtles were observed washed up on the mainland, neither exhibited any evidence of boat strike or propellor damage. Another dead turtle (unknown species) was also observed at Mardie Island.

Overnight nests recorded at each routinely monitored island across all surveys are displayed in **Figure 6** and **Figure 7**. Survey effort was focussed on the southern and eastern beaches of each island, where the beaches were typically wide and sandy, based on nesting activity during baseline monitoring (Pendoley 2023).

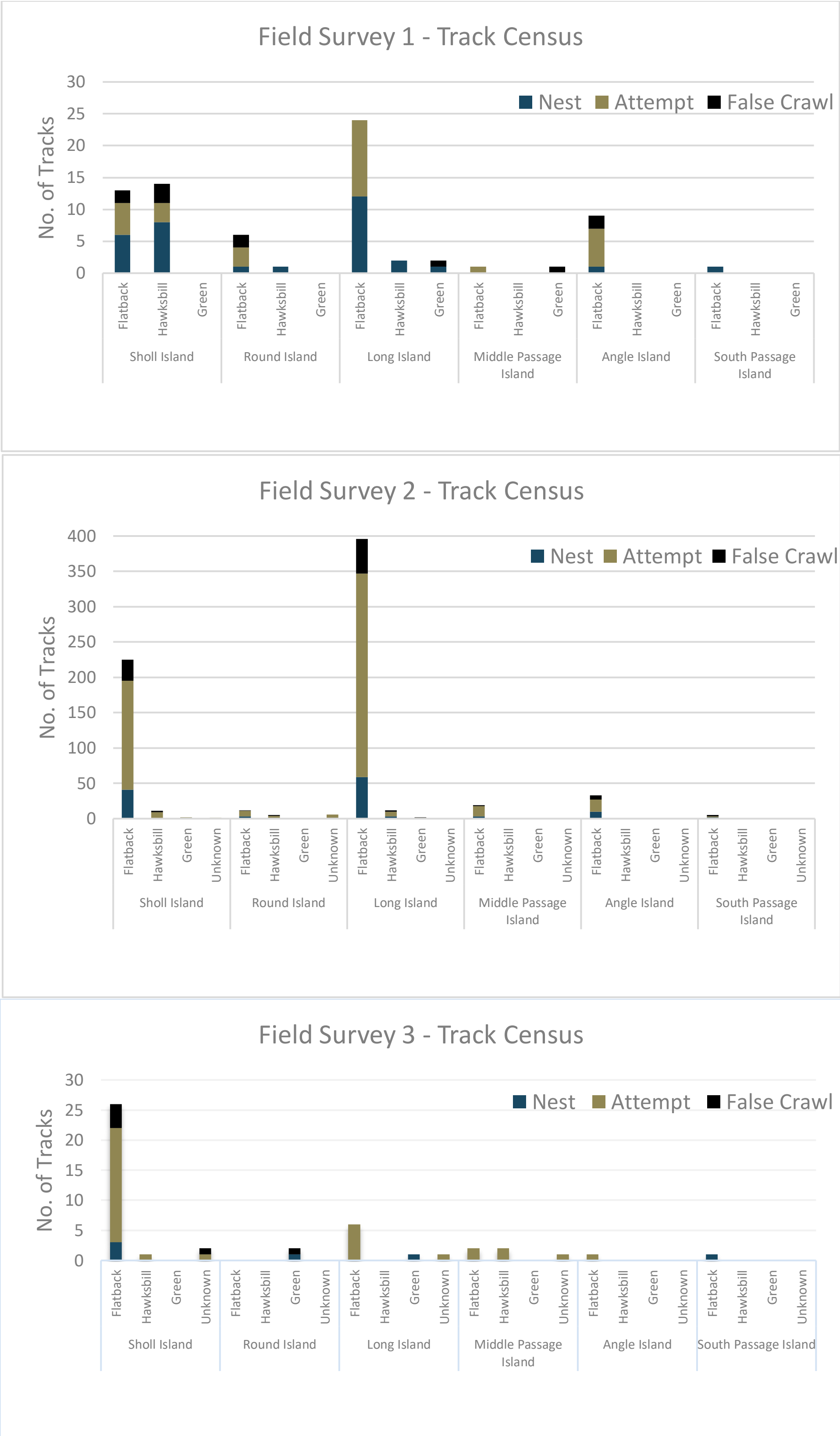

Figure 5: Marine turtle nesting activity during Field Survey 1 (top), Field Survey 2 (middle) and Field Survey 3 (bottom). Note y-axis scales are different.

3.2.2 Nesting Success: Routine Monitoring Island Beaches

Nesting success (proportion of tracks that resulted in a nest) was calculated separately for flatback, hawksbill and green turtles. Records of nesting success at all monitoring locations are tabulated in **Appendix C**. Nesting success was lower for all turtle species at all locations in 2023/24 when compared with baselines data from 2021/22, with the exception of mean nesting success for hawksbill turtles at offshore islands in FS1 (**Appendix C**; Pendoley Environmental 2023).

Mean flatback nesting success at all census monitored islands combined was 36% during FS1, 17% during FS2 and 11% during FS3. When combined for all islands and all surveys (FS1, FS2 and FS3, **Table 3**), the overall nesting success was 18%, and was highest on South Passage Island (57%) and lowest on Middle Passage Island (14%), with a range of 0–33% on the other islands (**Figure 6** and **Figure 7**).

Mean hawksbill nesting success for all census monitored islands was 65% during FS1, 14% during FS2, with very little hawksbill activity (no nests) recorded during FS3. When combined for all islands and all surveys (**Table 3**), the overall nesting success was 30.6%, and was highest on Long Island (35.7%) and lowest on several islands (0%), with a range of 0-33.3% on the other islands (**Figure 6** and **Figure 7**).

Green turtle nesting activity occurred in very low numbers on Sholl, Long, Middle Passage and Round islands across the three field surveys. The small number of tracks recorded resulted in an overall nesting success for these islands of 33.3% during FS1, 25% for FS2, and 67% for FS3. When combined for these islands across all surveys (**Table 3**), the overall nesting success was 40%, was highest on Sholl and Round islands (50%) and lowest on Middle Passage Island (0%), with a range of 0–50% (**Figure 6** and **Figure 7**).

Table 3: Marine turtle nesting success for islands where nesting activity was regularly monitored, across all field surveys.

Field Surveys	Location	Nesting Success %		
		Flatback	Hawksbill	Green
FS1+FS2+FS3 Combined	Sholl Island	18.9	30.8	50
	Round Island	22.2	33.3	50
	Long Island	16.7	35.7	40
	Angle Island	25.8	0	NA
	Middle Passage Island	13.6	0	0
	South Passage Island	57.1	0	NA
	Islands Total	**18**	**30.6**	**40**
	Mardie Creek East	0	NA	NA
	Mardie Creek West	0	NA	NA
	Mainland Total	**7.7**	**NA**	**0**

Figure 6: All marine turtle nests recorded during the monitoring period at Sholl, Round and Long islands.

Figure 7: All marine turtle nests recorded during the monitoring period at Middle Passage, Angle and Passage islands.

3.2.3 Abundance and Distribution: Mainland Beaches

Mainland beaches were accessed via helicopter and surveyed on-foot during each field survey. The helicopter survey covered ~10 km of coastline to the east and west of Mardie Creek, although ~7 km of the surveyed coastline to the west of Mardie Creek was occupied by mangrove forests and vast intertidal flats (i.e. not suitable for turtle nesting)(**Figure 8**). Both east and west transects were surveyed daily during FS1, FS2 and FS3 to record overnight tracks (**Appendix B**).

The total number of tracks recorded at mainland beaches are provided in **Table 4**. A total of 13 flatback tracks (including one nest in FS2) and one green turtle track were recorded at mainland beaches across all surveys.

Table 4: Marine turtle nesting activity on mainland beaches during the monitoring period. MCE = Mardie Creek East, MCW = Mardie Creek West, FS = Field Survey.

Survey	Species	Nesting Activity			Total
		Nest	Attempt	False Crawl	
FS1	Flatback	0	1 (MCE) 2 (MCW)	0	**3**
FS2	Flatback	1 (MCW)	2 (MCE) 5 (MCW)	1 (MCW)	**9**
FS3	Flatback	0	0	1 (MCE)	**1**
	Green	0	0	1 (MCE)	**1**

3.2.4 Nesting Success: Mainland Beaches

Nesting success for flatback and green turtles on mainland beaches was 7.7% and 0%, respectively, for all surveys combined (**Appendix C**). Hawksbill turtles did not use the mainland beaches as nesting habitat during any of the field surveys. Green turtles had not been recorded crawling ashore on the mainland in previous baseline surveys (**Appendix C**).

Figure 8: All marine turtle nesting activity recorded along the mainland coast during the monitoring period.

3.2.5 Abundance and Distribution: Opportunistically Monitored Island Beaches

Fortescue, Stewart, Mardie, Passage and South Passage were all surveyed opportunistically during FS1, FS2 and FS3 (**Table 5**; **Appendix B**), when time allowed. These islands were visited between 1 and 3 times per field survey, with the first visit either providing a "line-in day" if there were subsequent visits to ensure that only new nests were recorded during the monitoring period, or a "snapshot" of activity if only visited once (**Appendix B**). The nesting activity for these islands is presented in **Table 5**, presented with nesting from the 2021/22 season for comparison. Solitary Island was surveyed during FS1 only (**Appendix B**).

Fortescue Island was visited twice in FS1 and FS2, and once in FS3. There was evidence of hawksbill and flatback nesting activity, including one flatback nest (**Table 5**). The nest was located on the north-western side of the island, with other nesting attempts also recorded along the length of the western beach (**Figure 9**).

Stewart Island was visited once in FS1 and twice in FS2 and FS3. Tracks indicated that flatback, hawksbill and green turtles nest on the island, with a total of four flatback nests recorded during a snapshot survey in FS1 and two flatback nests recorded on the first day visit (line-in day) of both FS2 and FS3 (**Table 5**). These nests were predominantly located on the northern section of the island, with nesting activity also occurring on the south-eastern spit (**Figure 9**). No nests were recorded during the monitoring period of FS2 and FS3 (ie. excluding line-in day). Green turtle nesting activity was recorded on line-in day of FS3 only.

Mardie Island was visited three times in FS1 and FS2, and once in FS3. Tracks recorded on the line-in days indicated that flatback and hawksbill turtles nest on the island. However, nesting activity was not recorded during the monitoring period of any of the field surveys (**Figure 9, Table 5**).

Passage Island was surveyed three times in FS1 and twice in FS2 and FS3 (Error! Reference source not found.**Table 5**). There was evidence of flatback nesting activity, including one flatback nest recorded as part of the monitoring period (**Figure 7**). The nest was located on the south-eastern spit, with other nesting attempts by flatback and green turtles also recorded in this location on the "line-in days".

South Passage Island was surveyed three times during FS1 and twice during FS2 and FS3 (**Table 5**). Four flatback nests were recorded and located along the north-eastern side of the island, with one on the south-western spit (**Figure 9**). Nesting activity by flatback and hawksbill turtles was recorded along both sides of the island on "line-in" days of each field survey.

Table 5: Marine turtle nesting activity recorded during opportunistic surveys of Stewart, Fortescue, Mardie, Passage and South Passage islands across all field surveys in 2023/24. Baseline data from 2022/23 has been included for comparison.

Island	Nesting Activity	Marine Turtle Species						Total	
		Flatback		Hawksbill		Unknown			
		21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24
Fortescue	Nests	0	1	1	0	0	0	**1**	**1**
	False crawls	0	0	1	1	0	0	**1**	**1**
	Attempts	0	2	8	1	3	0	**11**	**3**
Stewart	Nests	1	0	3	0	1	0	**5**	**0**
	False crawls	0	3	0	0	0	0	**0**	**3**
	Attempts	0	3	7	0	0	0	**7**	**3**
Mardie	Nests	0	0	1	0	0	0	**1**	**0**
	False crawls	0	0	4	0	0	0	**4**	**0**
	Attempts	0	0	2	0	0	0	**2**	**0**
Passage	Nests	**NA**	1	**NA**	0	**NA**	0	**NA**	**1**
	False crawls	**NA**	0	**NA**	0	**NA**	0	**NA**	**0**
	Attempts	**NA**	9	**NA**	0	**NA**	0	**NA**	**9**
South Passage	Nests	0	4	2	0	0	0	**2**	**4**
	False crawls	0	1	0	0	0	0	**0**	**1**
	Attempts	0	3	1	0	1	0	**2**	**3**

Figure 9: Marine turtle nesting activity recorded opportunistically on Stewart, Fortescue, Mardie and South Passage islands during the monitoring period.

3.3 Nesting Habitat: Incubation Success

Excavations were conducted on marked and opportunistic nests on Sholl and Long islands during FS2 and FS3 to determine incubation success metrics. Clutch size, hatch and emergence success were determined for all viable marked and opportunistic nests, whilst temperature data (used to determined clutch fate and the incubation environment) was only retrieved for marked nests. No clutches were marked on the mainland.

3.3.1 Clutch Fate

A total of 19 clutches were marked during FS1 and FS2 on Sholl (*n* = 11) and Long (*n* = 8) islands (**Figure 10**). No clutches were marked on the mainland. An additional three opportunistic nests were excavated at Sholl (*n* = 2; one flatback, one hawksbill) and Long islands (*n* = 1; hawksbill) in FS2 (**Table 6**).

Of the clutches marked in FS1 and FS2, two could not be located by the field team during FS3 (Error! Reference source not found.). The two clutches were located at the southern end of Long Island in an area of dense nesting activity. Temperature logger data from these lost nests was still able to be retrieved via Bluetooth data downloads.

Five of the marked clutches were inundated during the incubation period, including three at Sholl Island and two at Long Island (**Table 6**). These clutches consisted of three hawksbill and two flatback nests which were all located ≤5 m from the spring high tide line, with their inundation coinciding with spring high tides of >3.5 m. Four of the marked clutches were disturbed during the incubation period, including three on Sholl Island and one on Long Island, most likely due to subsequent turtle nesting activity in the same location.

Of the remaining, complete marked clutches (*n* = 8), six were laid by flatback turtles and two were laid by hawksbill turtles. Following quality control of the data, eleven clutches were used to determine incubation success metrics as the three additional opportunistic nests were also considered complete.

Table 6: Clutch fate of all marked and opportunistic nests on Sholl and Long islands.

Location	Species	Nest number	Distance to spring high tide line (m)	Clutch fate	Logger recovered?	Temperature analysis?
Sholl Island	Flatback	1	9	Complete	Yes	Yes
		2	1	Inundated	Yes	No
		8	11	Disturbed	Yes	No
		9	10	Complete	Yes	Yes
		10	9	Disturbed	Yes	No
		13	5	Complete	Yes	Yes
		Opp 2	16.2	Complete	NA	NA
	Hawksbill	3	1	Disturbed	Yes	No
		4	1	Complete	Yes	Yes
		5	2	Complete	Yes	No
		6	0	Inundated	Yes	No
		7	0	Inundated	Yes	No
		Opp 3	16	Complete	NA	NA
Long Island	Flatback	1	7	Complete	Yes	Yes
		2	1	Complete	Yes	Yes
		3	2	Inundated	Yes	No
		4	1	Disturbed	Yes	No
		6	1	Lost	No	No
		7		Complete	Yes	Yes
		8	5	Lost	Yes	No
	Hawksbill	5	1	Inundated	Yes	No
		Opp 1	8	Complete	NA	NA

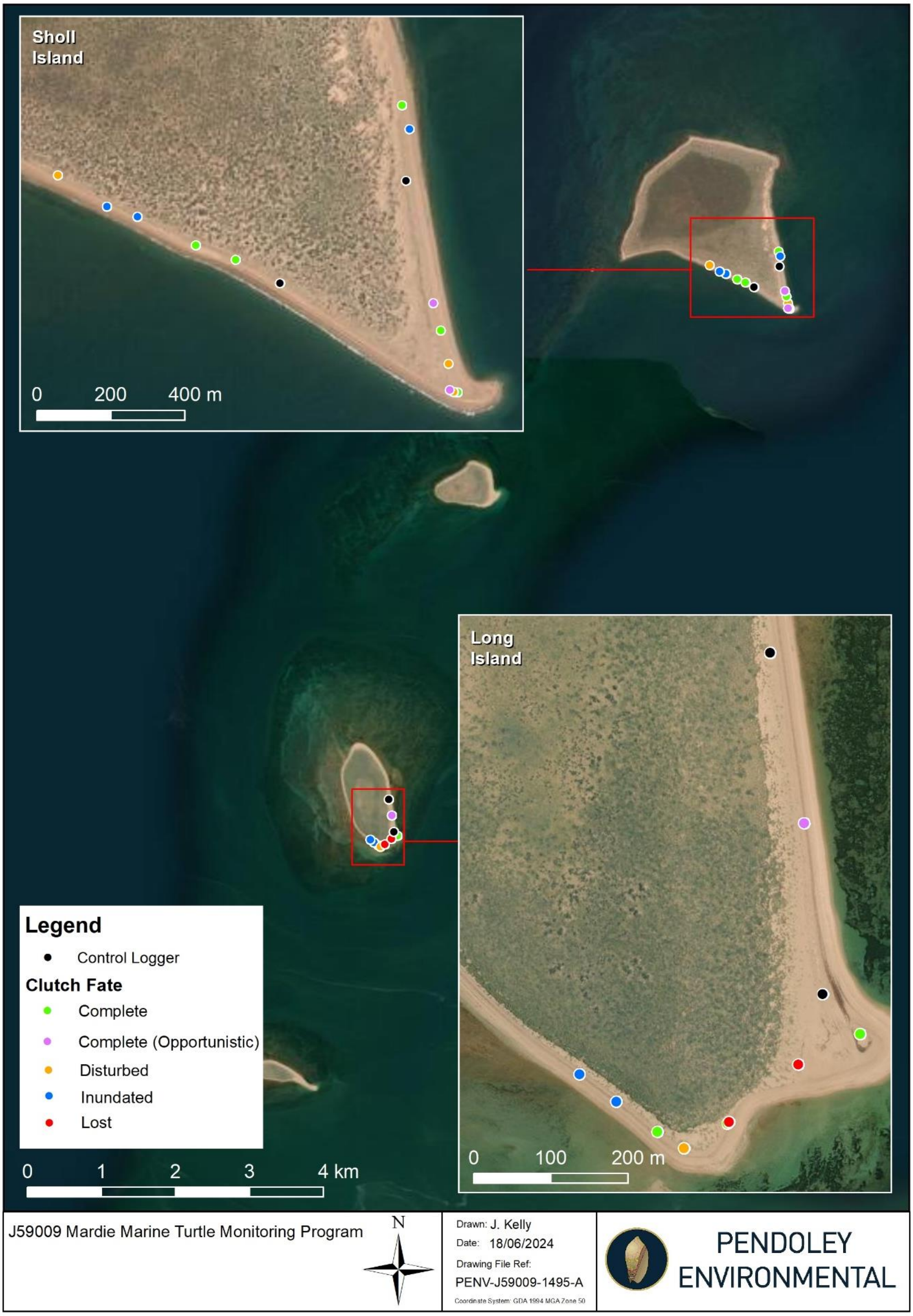

Figure 10: Location and fate of marked clutches at Sholl and Long islands. No clutches were marked on the mainland.

3.3.2 Clutch Size

Mean clutch size for excavated flatback turtle nests (marked and opportunistic) was 50 ± 6 eggs (40-60; *n* = 11) (**Table 7**). For hawksbill nests (marked and opportunistic), mean clutch size was 98 ± 25 eggs (59 – 140; *n* = 9).

3.3.3 Hatch and Emergence Success

Mean hatch success for all flatback turtle nests monitored on Sholl and Long islands was 81.4% ± 22.1 (18.9–95.9%, *n* = 11) and mean emergence success was 80.2% ± 21.9 (18.8 – 95.9%) (**Table 7**). Nests located on Long Island had the greatest mean hatch and emergence success and Sholl Island had the lowest.

The mean hatch and emergence success of hawksbill nests monitored on Sholl and Long islands, that were not inundated (*n* = 6), was 78.7 % ± 13.2 (55.4– 90.7) and 74.6 % ± 16.9 (42.6 – 90.7 %), respectively. The hatch and emergence success of the inundated nests (*n* = 3) was 0% for all nests. The contents of the inundated nests were predominantly undeveloped or partially developed embryos, indicating the inundation events caused close to 100% embryo mortality during the incubation period. When combined, the overall hatch and emergence success for hawksbill nests was 52.4% ± 40.7 (0–90.7%, *n* = 9) and 49.7% ± 39.6 (0 – 90.7 %), respectively (**Table 7**). Nests located Sholl Island had the greatest mean hatch and emergence success and Long Island had the lowest.

Table 7: Hatch and emergence success of excavated flatback and hawksbill turtle clutches (marked and opportunistic). Inundated nests have not been included.

Location	*n*	Statistic	Clutch size	Hatch Success (%)	Emergence Success (%)
Flatback Turtles					
Sholl Island	6	Mean	48	76.8	76.8
		St. Dev	5.5	29.9	29.9
		Min.	40	18.9	18.9
		Max.	56	97.9	97.9
Long Island	5	Mean	51	88.2	85.5
		St. Dev	6.2	6.6	8.55
		Min.	43	76.9	71.2
		Max.	60	93.7	91.7
Total	**11**	**Mean**	**50**	**81.9**	**80.7**
		St. Dev	**5.7**	**22.4**	**22.3**
		Min.	**40**	**18.8**	**18.9**
		Max.	**60**	**97.9**	**97.9**
Hawksbill Turtles					
Sholl Island	6	Mean	99.6	85.9	82.9
		St. Dev	27.3	5.4	6.5
		Min.	74	80	75.7
		Max.	140	90.7	90.7
Long Island	3	Mean	88.2	73.3	69.04
		St. Dev	27.9	18.1	24.8
		Min.	59	55.4	42.6
		Max.	123	91.7	91.7
Total	**9**	**Mean**	**93.9**	**80.5**	**77**
		St. Dev	**26.7**	**13.01**	**16.8**
		Min.	**59**	**55.4**	**42.6**
		Max.	**140**	**91.7**	**91.7**

3.3.4 Thermal Environment

3.3.4.1 Air Temperature and Rainfall

The mean daily maximum air temperature recorded at the Mardie weather station during the overall monitoring period (16th October 2023–19th February 2024) was 36.6 °C (range 29.1–48.2°C), with the highest daily maximum temperature recorded on 19th February 2024 (**Figure 11**). Total rainfall for the period recorded at Mardie Weather Station was 6.2 mm (**Figure 11**; BoM 2024).

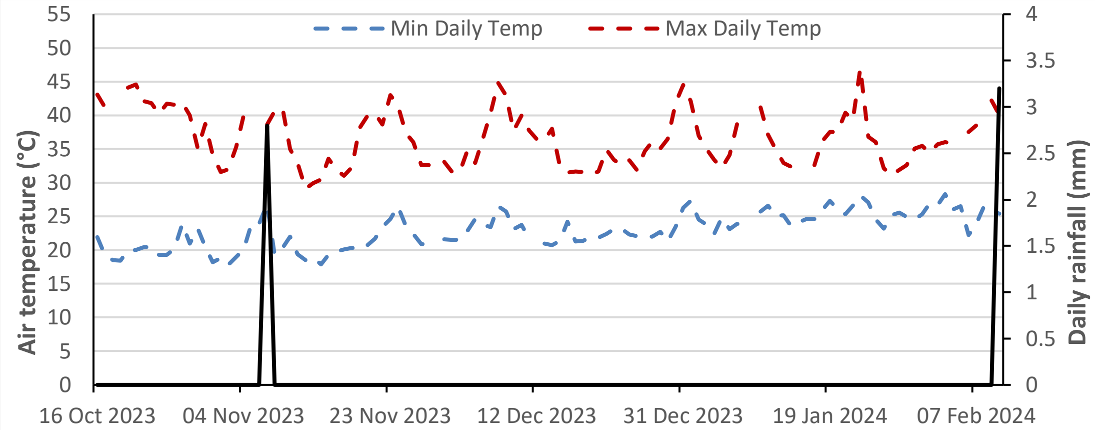

Figure 11: Daily rainfall and air temperature recorded at Mardie, Western Australia, between 16th October 2023 and 19th February 2024. Source: Mardie (station 005008), Bureau of Meteorology.

3.3.4.2 Sand Temperature

Two control temperature loggers were deployed at each location (Long Island, Sholl Island, Mardie Creek West and Mardie Creek East) during FS1. Loggers were in the sand for up to 124 days between 17th October 2023 and 16th February 2024. The deployment duration included the entire incubation period of all marked clutches.

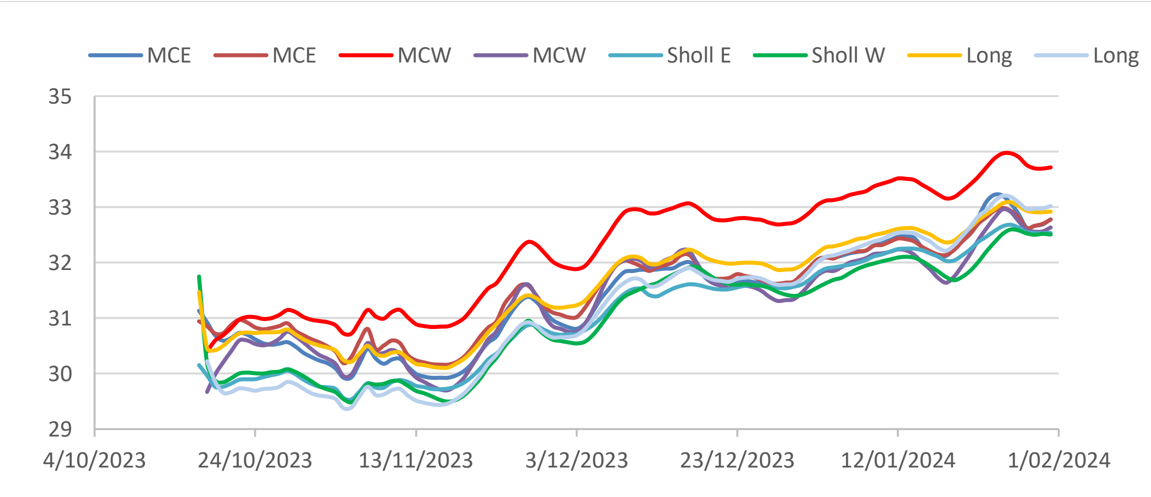

Figure 12: Control logger temperature profiles during the overall incubation period of marked clutches.

Mean daily temperatures recorded by control loggers during the overall incubation period of marked clutches (107 days, 17th October 2023 – 31st January 2024) were 31.6°C at mainland sites and 31.2°C at island sites. Temperature profiles from loggers at Mainland sites recorded consistently warmer temperatures for the incubation period than all the island sites, with Mardie Creek West being the warmest site, and Sholl Island West being the coolest site (**Figure 12**). This was similar to the results of the 2018/19 and 2021/22 turtle monitoring program, which also found the mainland control sites to be warmer than the island control sites over the incubation period (Pendoley Environmental 2019; 2023).

3.3.1 Incubation Environment

Eight temperature profiles from marked clutches were used to determine incubation statistics. This included six temperature profiles from flatback nests, and two from hawksbill nests.

The mean incubation period for flatback clutches was 48 days (range 47–50 days), and clutches had a mean daily temperature of 31.0°C over this period (range 30.0–31.9°C) (**Table 8**). The thermosensitive period (middle trimester of incubation) lasted on average 16 days (range 15–17) and had a mean daily temperature of 30.5°C (range 29.6–31.4°C).

The mean incubation and thermosensitive periods for hawksbill clutches was greater than flatback clutches, at 50 days and 18 days, respectively (**Table 8**). Clutches had a mean daily temperature of 31.5°C over the incubation period, and 30.9°C over the thermosensitive period.

The proportion of the incubation period spent above the thermal tolerance range of 33°C was 23.1% on average for hawksbill nests, and 19.5% for flatback nests. This typically coincided with the third trimester of the incubation period for both turtle species.

Table 8: Incubation period statistics from marked flatback and hawksbill turtle clutches. IP = incubation period, TSP = thermosensitive period.

Location	Flatback					Hawksbill				
	n	Mean IP (days)	Mean IP temp. (°C)	Mean TSP (days)	Mean TSP temp. (°C)	*n*	Mean IP (days)	Mean IP temp. (°C)	Mean TSP (days)	Mean TSP temp. (°C)
Sholl	3	48	31.02	16.7	30.35	2	50	31.5	18	30.9
Long	3	48	31.05	15.3	30.56	-	-	-	-	-
Total	**6**	**48**	**31.0**	**16**	**30.5**	**2**	**50**	**31.5**	**18**	**30.9**

3.4 Hatchling Orientation

A total of 120 individual hatchling fans were recorded during the monitoring period across FS1, FS2 and FS3 (see **Appendix B** for details). Of these, 49 fans were recorded with at least five hatchling tracks and were located within the hatchling orientation monitoring areas outlined in the Mardie Salt Project: Marine Turtle Monitoring Program (Pendoley Environmental 2023). These 49 fans were included in the statistical analysis (40.8 % of the original sample) and are presented below.

Summary statistics for hatchling orientation metrics, including nest fan spread and offset angles are provided in **Table 9** and **Table 10**. **Table 9** shows summary statistics for Sholl Island (East and West), Long Island, Mardie Creek East and Mardie Creek West, which were routinely surveyed (daily) during the monitoring period. No hatchling fans were recorded at Mardie Creek West and Mardie Creek East, across the entire monitoring period. **Table 10** shows summary statistics for the remaining islands, which were surveyed opportunistically across the monitoring period. No hatchling orientation fans were recorded at Middle, Mardie or Fortesque islands across the monitoring period. Nets fans on Sholl and Long islands are displayed in **Figure 13** and **Figure 14,** respectively. Nest fans on remaining islands are not illustrated due to small sample sizes ($n \leq 3$). There were no significant differences in the spread and offset angles across islands in the region (Kruskal-Wallis test, $p>0.05$).

The hatchling orientation data from Sholl and Long islands are compared to benchmark data from the Mardie Salt Project: Marine Turtle Monitoring program (PENV 2023). To identify significant differences in hatchling orientation behaviours on beaches compared with the baseline dataset, the exceedance values of spread and offset angles were considered statistically significant from baseline when they exceed the baseline mean + 2*StDev (Trigger) and the baseline mean + 3*StDev (Threshold) (Mardie Salt Marine Turtle Monitoring Plan 2023). The exceedance criteria for the spread angle and offset angles is presented in **Table 11** and **Table 12**, respectively. Comparison to the baseline data indicates a trigger level spread angle exceedance for Sholl Island (West), while all other locations are below exceedance criteria. Offset angle metrics across all locations are below exceedance criteria. **Table 9** provides a colour guide of indicator criteria exceedances for each location.

Table 9: Summary statistics for routinely surveyed locations. Note: Green indicates no exceedance, orange indicates trigger level exceedance and orange indicates threshold level exceedance.

Statistic		Location					
		Sholl Island (East)	Sholl Island (West)	Long Island	Mardie Creek East	Mardie Creek West	All
n		18	12	12	0	0	42
Spread Angle (°)	Mean	66.5	63.9	69.3	-	-	66.6
	StDev	18.5	29.3	20.4	-	-	22.1
	Min	33	30	39	-	-	30
	Max	101	143	101	-	-	143
Offset Angle (°)	Mean	5.1	6.3	7.4	-	-	6.1
	StDev	3.7	3.4	8.5	-	-	5.4
	Min	1	1	0	-	-	0
	Max	13.5	11.5	21.5	-	-	21.5

Table 10: Summary statistics for opportunistically surveyed locations.

Statistic		Round Island	Middle Passage Island	Angle Island	Mardie Island	South Passage Island	Stewart Island	Fortescue Island	All
		Location							
n		1	0	3	0	1	2	0	7
Spread Angle (°)	Mean	94	-	54.7	-	50	45.0	-	56.9
	St. Dev	-	-	5.8	-	-	18.4	-	18.8
	Min	94	-	48	-	50	32	-	32
	Max	94	-	58	-	50	58	-	94
Offset Angle (°)	Mean	1	-	3.7	-	4	18.0	-	7.4
	St. Dev	-	-	3.5	-	-	12.7	-	9.2
	Min	1	-	0	-	4	9	-	0
	Max	1	-	7	-	4	27	-	27

Table 11: Benchmark hatchling orientation spread angle statistics, trigger and threshold criteria. Benchmark data are from the Mardie Salt Project: Marine Turtle Monitoring Program (Pendoley Environmental 2023). Trigger and threshold criteria are based on baseline mean + 2*StDev and baseline mean + 3*StDev, respectively.

Location	Spread Angle (°)				
	Statistic			Criteria	
	n	Mean	StDev	Trigger	Threshold
Sholl Island (East)	22	60.7	18.0	96.6	102.0
Sholl Island (West)	8	45.0	8.9	62.8	98.9
Long Island	37	52.8	16.7	86.3	91.7
All	67	54.4	17.0	88.5	92.0

Table 12: Benchmark hatchling orientation offset angle statistics, trigger and threshold criteria. Benchmark data are from the Mardie Salt Project: Marine Turtle Monitoring Program (Pendoley Environmental 2023). Trigger and threshold criteria are based on baseline mean + 2*StDev and baseline mean + 3*StDev, respectively.

Location	Offset Angle (°)				
	Statistic			Criteria	
	n	Mean	StDev	Trigger	Threshold
Sholl Island (East)	22	8.8	6.2	21.3	27.5
Sholl Island (West)	8	4.9	5.5	15.9	21.3
Long Island	37	8.7	6.8	22.4	29.2
All	67	8.3	6.5	21.3	27.9

Figure 13: Nest fan spread and offset angles at Sholl Island.

Figure 14: Nest fan spread and offset angles at Long Island.

3.5 Artificial Light Monitoring

Light monitoring cameras were deployed at locations close to the Projects proposed disturbance footprint at Mardie Creek East and Mardie Creek West. They were also deployed on turtle nesting beaches on Long Island, Sholl Island (two locations) and Middle Passage Island during FS2 and FS3. The locations of light camera placement can be seen in **Figure 1.** Nights with the clearest imagery and least amount of cloud cover were selected to generate median whole-of-sky (WOS; 0–90°), zenith (60–90°) and horizon (0–30°) sky brightness values (**Table 13**). For all monitoring locations, this occurred between the 10^{th} and 12^{th} of December 2023 (FS2).

3.5.1 Artificial Light Sources

Several sources of horizon light were visible within the captured imagery at varying levels of brightness and located at different bearings from each monitoring location. Light data is presented as isophote maps (**Appendix D**), and colour coding of the maps is a representation of light intensity (not the colour of light as perceived by a human or turtle eye). The units of sky brightness are presented on an inverted logarithmic scale (i.e. higher values represent lower intensity light and vice versa).

Visible light sources, as detected by VIIRS 2023 Satellite Data (www.lightpollutionmap.info), from the six monitoring locations are presented in **Figure 15** and include:

- Mardie Creek East: Cape Preston, Sino Iron, Barrow Island.
- Mardie Creek West: Sino Iron, Barrow Island.
- Long Island: Cape Preston, Sino Iron, Mardie Village
- Sholl Island (west and east): Cape Preston, Sino Iron, Mardie Village
- Middle Passage Island: Cape Preston, Sino Iron, Mardie Village

Figure 15 provides all visible and infrared light sources for the Optimised Mardie Project Area and the surrounding region detected by the VIIRS satellites, so does not just represent visible light. It has been included to provide an overview of the light sources that may be captured by the light monitoring cameras during the monitoring period.

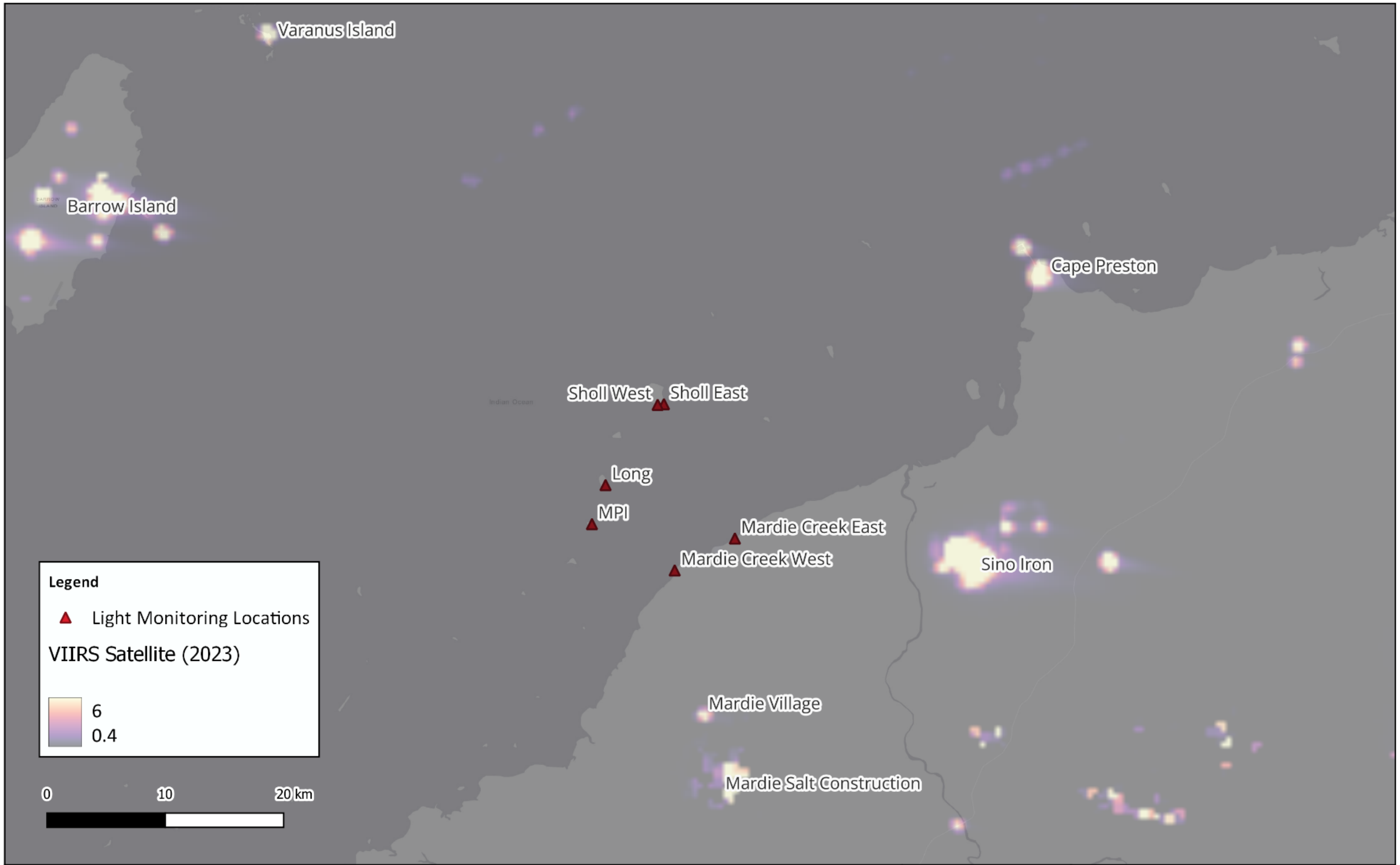

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Figure 15: Artificial light and infra-red sources within the Optimised Mardie Project Area and surrounding region, as detected by satellite. Red triangles indicate light monitoring locations. Source: VIIRS 2023 Satellite Data (www.lightpollutionmap.info).

3.5.2 Night-time Light Emissions

Measured whole-of-sky (WOS) brightness was darkest at Sholl Island West (21.53 Vmag/arcsec^2) followed by Middle Passage Island (21.42 Vmag/arcsec^2) (**Table 13** and **Appendix D**). The brightest WOS sky brightness value was captured at Sholl Island East (21.08 Vmag/arcsec^2) monitoring location. The brightest light source visible from all locations was the Sino Iron development, visible in an easterly to south-easterly direction (**Figures 3-8 in Appendix D**).

Substantial horizon shielding from dunes/vegetation was observed from both Mardie Creek East and Mardie Creek West. Project associated light visible in the processed images included Mardie Village which was observed as a distinct source of light from all monitoring locations except Mardie Creek East, which was shielded by vegetation.

Zenith brightness was dark at all survey locations and followed a similar trend to WOS results with Sholl Island West and Middle Passage Island recording the darkest values (21.83 and 21.92 Vmag/arcsec^2 respectively, **Table 13**), while Mardie Creek West recorded the brightest zenith (21.46 Vmag/arcsec^2).

Table 13: Median sky brightness for whole-of-sky, horizon and zenith captured at light monitoring locations during the 2023-2024 season.

Monitoring location	Sky Brightness (Vmag/arcsec^2)		
	Whole-of-Sky	Horizon	Zenith
Mardie Creek East	21.22	21.18	21.53
Mardie Creek West	21.3	21.39	21.46
Long Island	21.36	21.27	21.71
Sholl Island West	21.53	21.49	21.83
Sholl Island East	21.08	20.94	21.5
Middle Passage Island	21.42	21.24	21.92

3.5.3 Historical Sky Brightness

The Mardie Salt Project: Marine Turtle Monitoring Program (Pendoley 2023) requires that the results from offshore islands (2021/22) and the mainland (2022/23) form a baseline dataset for yearly data to be compared to throughout the monitoring program. **Table 14** shows the change in whole-of-sky brightness observed over the last three years of monitoring, where data is available. It should be noted that the positioning of stars, atmospheric conditions and other natural phenomena may cause variance in sky brightness from year to year, and therefore small changes in sky brightness are expected. The monitoring locations continue to have whole of sky brightness values that are indicative of an ideal night sky (outlined in **Table 2**).

Table 14: Change in whole-of-sky brightness observed from 2021/22 to 2023/24 at the light monitoring locations.

Monitoring location	Whole of Sky Brightness (Vmag/arcsec^2)			Change
	2021/22	2022/23	2023/24	
Mardie Creek East	-	21.24	21.22	↑1.86 %
Mardie Creek West	-	21.34	21.3	↑3.75 %
Long Island	21.19	-	21.36	↓14.49 %
Sholl Island West	-	-	21.53	-
Sholl Island East	21.16	-	21.08	↑7.65 %
Middle Passage Island	-	-	21.42	-

A marginal increase in whole-of-sky brightness was observed at both mainland monitoring locations and from the eastern side of Sholl Island. Long Island recorded a decrease in whole-of-sky brightness of 14.5%. These small changes may be attributed to a slight increase in vegetation height and/or changes in beach and dune profiles.

3.6 Light Sources 2022/23

While it is difficult to quantify changes in specific point sources between seasons, a qualitative analysis of changes in visible light sources from monitored locations has been outlined as shown in **Table 15**.

Table 15: Change in visible light sources observed from 2021/22 to 2023/24 at the light monitoring locations.

Visible Light Source	Visibility	
	February 2022	December 2023
Cape Preston - bearing 65–70°	SIE, LI,	SIE, SIW, LI, ME*
Sino Iron ore mine - bearing 110–125°	SIE, LI	SIE, SIW, LI, ME*, MW*
Mardie Village - bearing 170–175°	SIE, LI	SIE, SIW, LI
Rio Tinto MESA A iron ore mine on the bearing 176–184°	SIE, LI	-
Barrow Island on the bearing 288–294°	SIE	ME*, MW*
Varanus Island on the bearing 318–325°	SIE	-

Table Legend: SIE-Sholl Island East; SIW – Sholl Island West; LI- Long Island; ME – Mardie Creek East (mainland); MW – Mardie Creek West (mainland). * denotes the first season for this location to be monitored.

Light from Rio Tinto Mesa A iron ore mine and Varanus Island was not recorded by the light cameras from any of the monitoring locations in 2023/24. It is important to note that these light sources still exist, however changes in beach and dune topography and vegetation are likely to have shielded the camera locations from these sources.

3.6.1 Night-time Light Emissions and Hatchling Orientation Indices

The comparison of visible light sources recorded in the 2023/24 season with benchmark data from the Mardie Salt Project: Marine Turtle Monitoring program (Pendoley Environmental 2023) reveals that there are no new detectable light sources from any of the locations monitored (**Table 15**). When compared with benchmark data, the hatchling orientation data from Sholl and Long islands in the 2023/24 season had offset angle metrics below exceedance criteria across all locations, however a trigger level spread angle exceedance was identified for Sholl Island West (**Table 12**). The low sample size at this location (n=8) may be a contributing factor for the exceedence, as it is unlikely to be due to an increase in artificial light sources as no new light sources were identified. This was the first season that light has been monitored at Sholl Island West, so it will be useful to continue to monitor light at this location in the next season.

4 DISCUSSION

4.1 Nesting Habitat: Track Census

4.1.1 Nesting Activity Summary

Overall marine turtle nesting activity was greatest on routinely monitored islands during the December survey (FS2), and this was predominately due to flatback turtles. Hawksbill turtle nesting activity was similar during the October (FS1) and December (FS2) surveys. Green turtle activity was greatest in December, although only represented a minor proportion of the total marine turtle nesting activity. Sholl and Long islands were the busiest of all monitoring locations and accounted for 84% of all tracks recorded during the 2023/24 monitoring period.

At the mainland beaches and smaller, opportunistically monitored islands, marine turtle nesting activity was lower than on the routinely monitored islands and not as regionally significant as Sholl or Long islands. Only flatback activity was detected on mainland beaches for FS1 and FS2 in 2023/24, however there was one green turtle false crawl and two dead adult green turtles observed in FS3 at Mardie Creek East. Stranded dead turtles are not uncommon on beaches and as neither exhibited signs of boat strike or propeller damage, the deaths are unlikely to be project related. Green turtle activity also occurred on Sholl, Long, Round and Middle Passage Islands, across all field surveys, although in very small numbers.

Monthly census surveys between August and December 2020 from Rosemary Island suggested that October is the peak nesting period for hawksbill turtles in the Dampier Archipelago (pers com T. Hunt DBCA, 2022). The results of the 2021/22 and 2023/24 surveys did not detect a peak in October, rather it found that nesting activity was roughly equivalent for hawksbill turtles in October and December. This may suggest that the hawksbill nesting for the Mardie offshore islands region either has a different peak, or that the peak is more extended in the region, compared to the Dampier Archipelago. These results could also be a function of the temporal variability in turtle nesting. Longer term monitoring will assess the significance of these results.

Green turtle nesting activity was minor when compared to the nesting contribution of flatback and hawksbill turtles during the monitoring period, which was also the case during the 2018/19 and 2021/22 surveys for the Mardie islands region (Pendoley Environmental 2019; 2023). Green turtles typically favour high energy oceanic beaches with a deep sandy seabed approach (e.g. west coast Barrow Island, north coast Thevenard Island and Serrurier Island) and not the beach types characterised by the mainland and coastal island beaches surveyed here. This species is known to nest over a period of ~4 – 6 months in Western Australia (Limpus 2009), peaking in December and January. This timing is supported by results from systematic green turtle monitoring on North West Cape, where the 2021/22 green nesting season was characterised by high levels of nesting activity peaking in December 2021 (pers com D. Rob DBCA, 2022). The results for the current and baseline surveys of the Mardie offshore islands region are likely to be representative of the spatial and temporal levels of green nesting activity in the area, which are regulated by the El Nino Southern Oscillation (Solow et al. 2002) and not favoured nesting habitat for green turtles. As a result, this area is not considered a regionally significant rookery for green turtles.

4.1.2 Nesting Success

Overall, marine turtle nesting success for all species on routinely monitored islands and the mainland coast was lower for all field surveys than recorded in 2019 and 2021/22. The exception to this was for Hawksbill turtles on offshore islands in FS1. This is likely due to the natural variation in this metric between seasons, which can be influenced by environmental variation in rainfall and temperature affecting the nesting beach sand profile and the ability of turtles to make a nest.

4.2 Nesting Habitat: Incubation Success

Similar to the baseline data (Pendoley Environmental 2023) collected for incubation success, nest marking indicated that a large number of nests could be impacted and lost due to the highly dynamic morphology of offshore islands. Several marked nests were inundated during spring high tides and these resulted in low hatch success rates.

Of the 11 excavated flatback clutches that were not inundated (marked and opportunistic nests), the mean clutch size was 50 eggs, which was comparable to both the 2018/19 and 2021/22 seasons (mean of 52 and 48 eggs, respectively; Pendoley Environmental 2019; 2023), and similar to what has been reported for Barrow Island, Mundabullangana and Cemetery Beach rookeries (mean of 47 eggs at each location; Pendoley et al. 2014). Mean hatch success of flatback clutches was greater in 2023/24 (81%) than in 2021/22 (65%) and 2018/19 (49%), as was emergence success (80% in 2023/24 compared to 56% in 2021/22 and 42% in 2018/19; Pendoley Environmental 2019; 2023).

Of the 6 excavated hawksbill clutches that were not inundated, the mean clutch size was 98 eggs, which was lower than 110 eggs in 2021/22 and 123 eggs in 2018/19 (Pendoley Environmental 2019, 2023). The hatch and emergence success rate for this species was 79% and 75%, respectively, which was similar to the rates recorded in 2021/22 of 79% and 70%, respectively. The sample size of hawksbill clutches is notably small, with data collection hindered by clutches becoming lost to erosion or inundation.

The mean incubation period for six flatback clutches in 2023/24 was 48 days, which was similar to 2021/22 (49 days). The incubation period for both of these seasons was longer than the mean reported for three clutches marked in 2018/19, at 43 days. The mean hawksbill incubation period in 2023/24 was 50 days, which was lower than in 2021/22 at 55 days (no equivalent data available from 2018/19) (Pendoley Environmental 2023).

4.3 Hatchling Orientation

From the 49 hatchling fans analysed in the 2023/24 season, marine turtle hatchlings successfully oriented seaward, regardless of the visibility of light sources. When this data was compared with baseline data from 2021/22, there was one trigger level spread angle exceedance for Sholl Island West, which was not considered to be due to any artificial light impacts as there were no new light sources on the horizon and the hatchling sample size for this location was low (n=8). This result suggests that the trigger limits for this metric are too low. This is likely due to the relatively small benchmark data sample sizes not capturing the variance typically found in biological datasets. All other locations were below exceedance criteria, which was also the case for offset angle metrics analysis.

4.4 Artificial Light Monitoring

Comparison of light data recorded at 6 locations in 2023/24 with the past three seasons of light monitoring (where data was available), revealed a marginal increase in whole-of-sky brightness at Mardie Creek East, Mardie Creek West and from the eastern side of Sholl Island. Long Island recorded a decrease in whole-of-sky brightness of 14.5%. These variations may be attributed to a slight change in vegetation height and changes in beach and dune profiles. It should be noted that the positioning of stars, atmospheric conditions and other natural phenomena may cause variance in sky brightness from year to year, and therefore small changes in sky brightness are expected.

The comparison of visible light sources recorded in the 2023/24 season with benchmark data from the Mardie Salt Project: Marine Turtle Monitoring program (Pendoley Environmental 2023) reveals that there are no new detectable light sources from any of the locations monitored.

The brightest light sources visible continue to include the port at Cape Preston and iron ore mining facilities (Sino Iron). Offshore, sky glow from Barrow Island oil and gas facility is visible from Sholl Island and the two mainland locations, while shielding from a tall primary dune at Long Island prevents these light sources from being detected on the south-eastern side of the island. Skyglow from Varanus Island and Rio Tinto Mesa A iron ore mine was visible from Sholl Island East and Long Island in 2021/22, but was shielded in 2023/24 by changes in dune morphology and vegetation growth at both island monitoring locations. Notably, Mardie Village continues to be visible from Sholl (East and West) and Long islands. VIIRS composite light pollution mapping indicates light emissions from the camp have been increasing since 2020.

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Appendix A: Approval Conditions for marine turtles under Ministerial Statement No. 1175 and 1211; EPBC2018/8236 and EPBC2022/9169 relevant to this scope of work

Approval	Condition No.	Condition
Ministerial Statement No. 1175	10-1	The proponent shall implement the proposal to meet the following environmental outcomes: (1) clearing in the fauna habitat type identified as low-quality turtle nesting habitat (sandy beach habitat) in the *Mardie project – Environmental Review Document* (June 2020) is limited to a width of 50 metres, parallel to the high water mark; (2) no **adverse impact** to marine turtle behaviour on offshore islands as a result of project attributable light;

	10-4	Prior to the commencement of operations the proponent shall submit to the CEO a Marine Turtle Monitoring Program. This plan shall: (2) when implemented, determine whether artificial light emissions are influencing nesting and mis-orientation or disorientation of turtles on the offshore islands (including but not limited to Long and Sholl Islands), and any areas determined to be significant turtle nesting habitat by surveys required by condition 10-3; (3) specify the details of the methodology of monitoring of the nesting turtle population in the proposal area and offshore islands, including nesting adults and hatchlings, during the species-specific reproductive period, which is to include (but not be limited to): (a) identification of the species of turtles nesting on the beaches; (b) identification of the abundance and the distribution of adult tracks on the nesting beaches; (c) collection of data on the health of the nesting habitat; (d) collection of data on hatchling orientation; and (e) measurements on the intensity and extent of light sources visible from nesting beaches. (4) include a commitment to annually compare cumulative results against the baseline assessment (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001); (5) include measures to reduce light to offshore islands to be implemented in the event that **adverse impacts** from the proposal are detected, including a decrease in percentage range and usage of nesting sites (from the baseline study (*Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001*); and (6) provide criteria for when the Illumination Plan required by condition 9-1 will be revised in response to outcomes of the monitoring required by condition 10-6.
	10-6	The proponent shall continue to implement the Marine Turtle Monitoring Program until the CEO has confirmed by notice in writing, on advice from DBCA and DWER, that the outcome of condition 10-1(2) has been, and will continue to be met.

<table>
<tr><td>EPBC2018/8236</td><td>19</td><td>To minimise the impacts to marine turtles, the approval holder must:
a) comply with condition 10 of the WA Approval (MS 1175); and
c) The approval holder must implement the approved Marine Turtle Monitoring Program for the life of the project or until the Minister has confirmed in writing that the Marine Turtle Monitoring Program is no longer required.</td></tr>
<tr><td rowspan="3">Ministerial Statement No. 1211</td><td>B5-1 (2) & (3)</td><td>The proponent shall implement the proposal to achieve the following environmental outcomes:

(2) no change in marine turtle orientation (i.e. misorientation or disorientation) nesting beach utilisation, nesting success or hatchling survivorship as a result of artificial light emissions at both sandy beach habitat adjacent to the development and Long Island, Sholl Island and the Passage Islands (Angle, Middle and Round); and

(3) significant marine fauna are not prevented/deterred from undertaking critical behaviours in biologically important areas.</td></tr>
<tr><td>B5-3 (2)</td><td>The proponent must in consultation with DWER:

(2) implement the Marine Turtle Monitoring Program (rev 3, submitted, May 2023) environmental management plan that satisfy the requirements of condition C4 and demonstrates how achievement of the significant marine fauna outcomes in B5-1(2-3) will be monitored and substantiated, and submit it to the CEO.</td></tr>
<tr><td>C4-1</td><td>Environmental Management Plans: Conditions Relating to Monitoring and Adaptive Management for Outcomes Based Conditions and conditions (1) – (8) therein;

(1) threshold criteria that provide a limit beyond which the environmental outcomes are not achieved;
(2) trigger criteria that will provide an early warning that the environmental outcomes are not likely to be met;
(3) monitoring parameters, sites, control/reference sites, methodology, timing and frequencies which will be used to measure threshold criteria and trigger criteria. Include methodology for determining alternative monitoring sites as a contingency if proposed sites are not suitable in the future;
(4) baseline data;
(5) data collection and analysis methodologies;
(6) adaptive management methodology;
(7) contingency measures which will be implemented if threshold criteria or trigger criteria are met; and
(8) reporting requirements.</td></tr>
</table>

	C4 (2)	The environmental management plan required under condition B5-3 is also required to: (1) be updated to include management actions, management targets and contingency measures that will establish whether the proposal is having a detectable difference on marine turtle orientation (i.e. misorientation or disorientation), and nesting beach utilisation as described in condition B5-1(2). (2) include a commitment to annually compare cumulative results against the baseline assessment (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001); (3) Include a monitoring plan that is in accordance with the recommendations published in the National Light Pollution Guidelines (2020); (4) provide criteria for when the Mardie Illumination Plan required by condition B6-5 will be revised in response to outcomes of the monitoring required by condition B5-3; and (5) Continue to be implemented until the CEO has confirmed by notice in writing, on advice from DBCA and DWER, that the outcome of condition B5-1(1-3) has been, and will continue to be met.

Appendix B: Field Survey Schedule

Table B 1: Field survey schedule. MC = Mardie Creek, x = survey day, **X** = line-in day.

Date	Survey Location												
	Sholl	Round	Long	Middle Passage	Angle	Passage	South Passage	Stewart	Fortescue	Mardie	MC East	MC West	Solitary
Field Survey 1													
16/10/2024	Transit												
17/10/2024	**X**		**X**								**X**	**X**	
18/10/2024	x	**X**	x		**X**						x	x	
19/10/2024	x	x	x	**X**	x	**X**	**X**	snapshot			x	x	**X**
20/10/2024	x	x	x						**X**	**X**	x	x	
21/10/2024	x	x	x	x	x	x	x				x	x	
22/10/2024	x	x	x	x	x						x	x	
23/10/2024	x		x								x	x	
24/10/2024	x		x	x		x	x				x	x	x
25/10/2024	x		x	x	x				x		x	x	
26/10/2024	x	x	x	x	x					x	x	x	
27/10/2024	x		x								x	x	
28/10/2024	x	x	x	x	x						x	x	x
29/10/2024	x		x								x	x	x
30/10/2024	x		x							x	x	x	
Field Survey 2													
4/12/2023	Transit												
5/12/2023	**X**		**X**								**X**	**X**	-
6/12/2023	x	**X**	x	**X**	**X**						x	x	-
7/12/2023	x	x	x					**X**		**X**	x	x	-
8/12/2023	x		x			**X**	**X**		**X**		x	x	-
9/12/2023	x	x	x	x	x						x	x	-
10/12/2023	x	x	x	x						x	x	x	-
11/12/2023	x	x	x	x							x	x	-

12/12/2023	x		x		x						x	x	-
13/12/2023	x		x								x	x	-
14/12/2023	x		x					x	x	x	x	x	-
15/12/2023	x	x	x	x	x						x	x	-
16/12/2023	x		x			x	x				x	x	-
17/12/2023	x		x								x	x	-
Field Survey 3													
5/02/2024	Transit												
6/02/2024	**X**		**X**								**X**	**X**	-
7/02/2024	x	**X**	x	**X**	**X**								-
8/02/2024	x		x										-
9/02/2024	x		x						**X**	**X**			-
10/02/2024	x	x	x	x	x			**X**					-
11/02/2024	x		x			**X**	**X**						-
13/02/2024	x		x										-
14/02/2024	x	x	x	x	x						x	x	-
15/02/2024	x		x										-
16/02/2024	x		x					x			x	x	-
17/02/2024	x	x	x	x	x								-
18/02/2024	x		x			x	x						-
19/02/2024	x		x								x	x	-

Appendix C: Track Census

Table C 1: Track census results and nesting success for flatback turtles from all monitoring field surveys in 2021/22 (baseline) and in 2023/24. NA = Not applicable. 'Unknown' turtle tracks are not included. Stewart Island was only surveyed once in FS1 as a snapshot.

Field Survey	Location	Nest		False Crawl		Attempt		Total		Nesting Success (%)	
		21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24
FS1	Fortescue Island	NA	0	NA	0	NA	1	NA	1	NA	0
	Stewart Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sholl Island	5	6	1	2	2	5	8	13	63	46
	Round Island	0	1	0	2	1	3	1	6	0	17
	Long Island	15	12	2	0	6	12	23	24	65	50
	Middle Passage Island	2	0	0	0	1	1	3	1	67	0
	Angle Island	0	1	0	2	0	6	0	9	NA	11
	Passage Island	0	NA	0	NA	0	NA	0	NA	NA	NA
	South Passage Island	NA	1	NA	0	NA	0	NA	1	NA	100
	Islands Total	**22**	**20**	**3**	**6**	**10**	**28**	**35**	**55**	**63**	**37**
	Mardie Creek East	1	0	0	0	0	1	1	1	100	0
	Mardie Creek West	1	0	0	0	0	2	1	2	100	0
	Mainland Total	**2**	**0**	**0**	**0**	**0**	**0**	**2**	**3**	**100**	**0**
FS2	Fortescue Island	NA	1	NA	0	NA	1	NA	2	NA	50
	Stewart Island	NA	0	NA	3	NA	3	NA	6	NA	0
	Sholl Island	34	41	13	30	36	154	83	225	41	18.2
	Round Island	2	3	1	1	4	8	7	12	29	25
	Long Island	23	59	4	49	37	288	64	396	36	15
	Middle Passage Island	4	3	2	1	4	15	10	19	40	16
	South Passage Island	NA	2	NA	1	NA	2	NA	5	NA	40
	Angle Island	4	10	0	6	1	17	5	33	80	30
	Passage Island	5	1	0	0	3	9	8	10	63	10
	Islands Total	**72**	**120**	**20**	**91**	**85**	**497**	**177**	**708**	**41**	**17**
	Mardie Creek East	1	0	0	0	0	2	1	2	100	0
	Mardie Creek West	0	1	0	1	1	5	1	7	0	14
	Mainland Total	**1**	**1**	**0**	**1**	**1**	**7**	**2**	**9**	**50**	**11**

FS3	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	0	0	0	0	0	0	0	0	0	0
	Sholl Island	1	3	1	4	9	19	11	26	9	12
	Round Island	0	0	0	0	0	0	0	0	NA	NA
	Long Island	0	0	0	0	0	6	0	6	NA	0
	Middle Passage Island	0	0	0	0	0	2	0	2	NA	0
	South Passage Island	NA	1	NA	0	NA	0	NA	1	NA	100
	Angle Island	0	0	0	0	0	1	0	1	NA	0
	Passage Island	1	0	1	0	0	0	2	0	50	NA
	Islands Total	**2**	**4**	**2**	**4**	**9**	**28**	**13**	**36**	**15**	**11**
	Mardie Creek East	2	0	0	1	5	0	7	1	29	0
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**2**	**0**	**0**	**1**	**5**	**0**	**7**	**1**	**29**	**0**

Table C 2: Track census results and nesting success for hawksbill turtles from all monitoring field surveys in 2021/22 (baseline) and in 2023/24. NA = Not applicable. 'Unknown' turtle tracks are not included.

Field Survey	Location	Nest		False Crawl		Attempt		Total		Nesting Success (%)	
		21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24
FS1	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	8	8	0	3	10	3	18	14	44	57
	Round Island	10	1	0	0	8	0	18	1	56	100
	Long Island	0	2	0	0	4	0	4	2	0	100
	Middle Passage Island	7	0	1	0	3	0	11	0	64	NA
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Angle Island	1	0	2	0	2	0	5	0	20	NA
	Passage Island	3	0	0	0	1	0	4	0	75	NA
	Islands Total	**29**	**11**	**3**	**3**	**28**	**3**	**60**	**17**	**48**	**65**
	Mardie Creek East	0	0	0	0	0	0	0	0	NA	NA
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**NA**
FS2	Fortescue Island	NA	0	NA	0	NA	1	NA	1	NA	0
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	4	0	0	2	5	9	9	11	44	0
	Round Island	6	1	4	1	6	3	16	5	38	20
	Long Island	14	3	0	2	14	7	28	12	50	25
	Middle Passage Island	1	0	0	0	4	0	5	0	20	NA
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Angle Island	1	0	0	0	1	0	2	0	50	NA
	Passage Island	2	0	0	0	2	0	4	0	50	NA
	Islands Total	**28**	**4**	**4**	**5**	**32**	**20**	**64**	**29**	**44**	**14**
	Mardie Creek East	0	0	0	0	0	0	0	0	NA	NA
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**NA**

FS3	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	**0**	0	0	0	**0**	1	0	1	NA	0
	Round Island	**0**	0	0	0	**0**	0	**0**	0	NA	NA
	Long Island	**0**	0	0	0	**0**	0	**0**	0	NA	NA
	Middle Passage Island	0	0	0	0	**0**	2	**0**	2	NA	0
	Angle Island	0	0	0	0	**0**	0	**0**	0	NA	NA
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Passage Island	1	0	1	0	1	0	3	0	33	NA
	Islands Total	**3**	**0**	**1**	**0**	**13**	**3**	**17**	**3**	**18**	**0**
	Mardie Creek East	0	0	0	0	0	0	0	0	NA	NA
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**NA**

Table C 3: Track census results and nesting success for green turtles from all monitoring field surveys in 2021/22 (baseline) and in 2023/24. No green turtle nesting activity was recorded in Field Survey 3. NA = Not applicable. 'Unknown' turtle tracks are not included.

Field Survey	Location	Nest		False Crawl		Attempt		Total		Nesting Success (%)	
		21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24	21/22	23/24
FS1	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	0	0	0	0	0	0	0	0	NA	NA
	Round Island	0	0	0	0	0	0	0	0	NA	NA
	Long Island	0	1	0	1	0	0	0	2	NA	50
	Middle Passage Island	0	0	0	1	0	0	0	1	NA	0
	Angle Island	0	0	0	0	0	0	0	0	NA	NA
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Passage Island	1	0	0	0	1	0	2	0	50	NA
	Islands Total	**1**	**1**	**0**	**2**	**1**	**0**	**2**	**3**	**50**	**33.3**
	Mardie Creek East	0	0	0	0	0	0	0	0	NA	NA
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**NA**
FS2	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	1	1	0	0	6	1	7	2	14	50
	Round Island	0	0	0	0	1	0	1	0	0	NA
	Long Island	1	0	0	1	5	1	6	2	17	0
	Middle Passage Island	0	0	0	0	0	0	0	0	NA	NA
	Angle Island	0	0	0	0	0	0	0	0	NA	NA
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Passage Island	1	0	1	0	1	0	3	0	33	NA
	Islands Total	**3**	**1**	**1**	**1**	**13**	**2**	**17**	**4**	**18**	**25**
	Mardie Creek East	0	0	0	0	0	0	0	0	NA	NA
	Mardie Creek West	0	0	0	0	0	0	0	0	NA	NA
	Mainland Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**NA**

FS3	Fortescue Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Stewart Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Sholl Island	**0**	**0**	0	**0**	**0**	**0**	0	**0**	**NA**	**NA**
	Round Island	**0**	**1**	0	**0**	**0**	**1**	**0**	**2**	**NA**	**50**
	Long Island	**0**	**1**	0	**0**	**0**	**0**	**0**	**1**	**NA**	**100**
	Middle Passage Island	0	**0**	0	**0**	**0**	**0**	**0**	**0**	NA	**NA**
	Angle Island	0	**0**	0	**0**	**0**	**0**	**0**	**0**	NA	**NA**
	South Passage Island	NA	0	NA	0	NA	0	NA	0	NA	NA
	Passage Island	1	**0**	1	**0**	1	**0**	3	**0**	33	**NA**
	Islands Total	**3**	**2**	**1**	**0**	**13**	**1**	**17**	**3**	**18**	**67**
	Mardie Creek East	0	**0**	0	**1**	0	**0**	0	**1**	NA	**0**
	Mardie Creek West	0	**0**	0	**0**	0	**0**	0	**0**	NA	**NA**
	Mainland Total	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**NA**	**0**

Appendix D: Artificial Light Monitoring Report 2023/24

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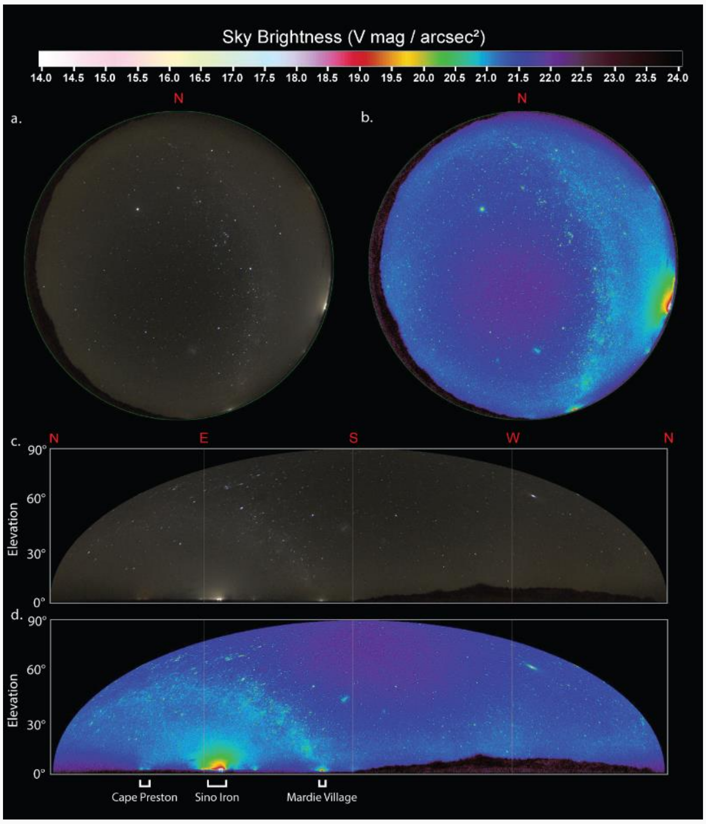
MARDIE SALT PROJECT: ARTIFICIAL LIGHT MONITORING REPORT 2023/24



Prepared by

Pendoley Environmental Pty Ltd

For

BCI MINERALS LIMITED

26 July 2024

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DOCUMENT CONTROL INFORMATION

TITLE: MARDIE SALT PROJECT: ARTIFICIAL LIGHT MONITORING REPORT 2023/24

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Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		25/06/2024	F. Mathews
Rev IB	Technical Review	25/06/2024	05/07/2024	Dr L. Nicholson, Dr K. Pendoley
Rev A	Client review	05/07/2024		S. Snyman
Rev 0	Final report issued	16/07/2024	26/07/2024	S. Snyman

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Project manager:	Dr K. Pendoley/Dr P. Wilson
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Name of project:	Mardie Project Marine Turtle Monitoring APPENDIX D
Client	BCI MINERALS LIMITED
Client representative:	S. Van Straaten
Report number:	J59009 – APPENDIX D
Cover photo:	Mardie Creek East Night Sky Light Image captured by Sky42 camera

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1 Appendix D: Artificial Light Monitoring Report – 2023/24

This Artificial Light Monitoring Report appends to *Mardie Salt Project: Marine Turtle Monitoring Program 2023/24* (APPENDIX D, Pendoley Environmental 2024). Light monitoring cameras were deployed at locations close to the Projects proposed disturbance footprint at Mardie Creek East and Mardie Creek West. They were also deployed on turtle nesting beaches on Long Island, Sholl Island (two locations) and Middle Passage Island during Field Survey 2 (FS2) and Field Survey 3 (FS3) (**Figure 1**). Nights with the clearest imagery and least amount of cloud cover were selected to generate median whole-of-sky (WOS; 0–90°), zenith (60–90°) and horizon (0–30°) sky brightness values (**Table 1**). For all monitoring locations, this occurred between the 10^{th} and 12^{th} of December 2023 (FS2).

1.1 Artificial Light Sources

Visible light sources, as detected by VIIRS 2023 Satellite Data (www.lightpollutionmap.info), from the six monitoring locations are presented in **Figure 2** and include:

Mardie East: Cape Preston, Sino Iron, Barrow Island.

Mardie West: Sino Iron, Barrow Island.

Long Island: Cape Preston, Sino Iron, Mardie Village

Sholl Island (west and east): Cape Preston, Sino Iron, Mardie Village

Middle Passage Island: Cape Preston, Sino Iron, Mardie Village

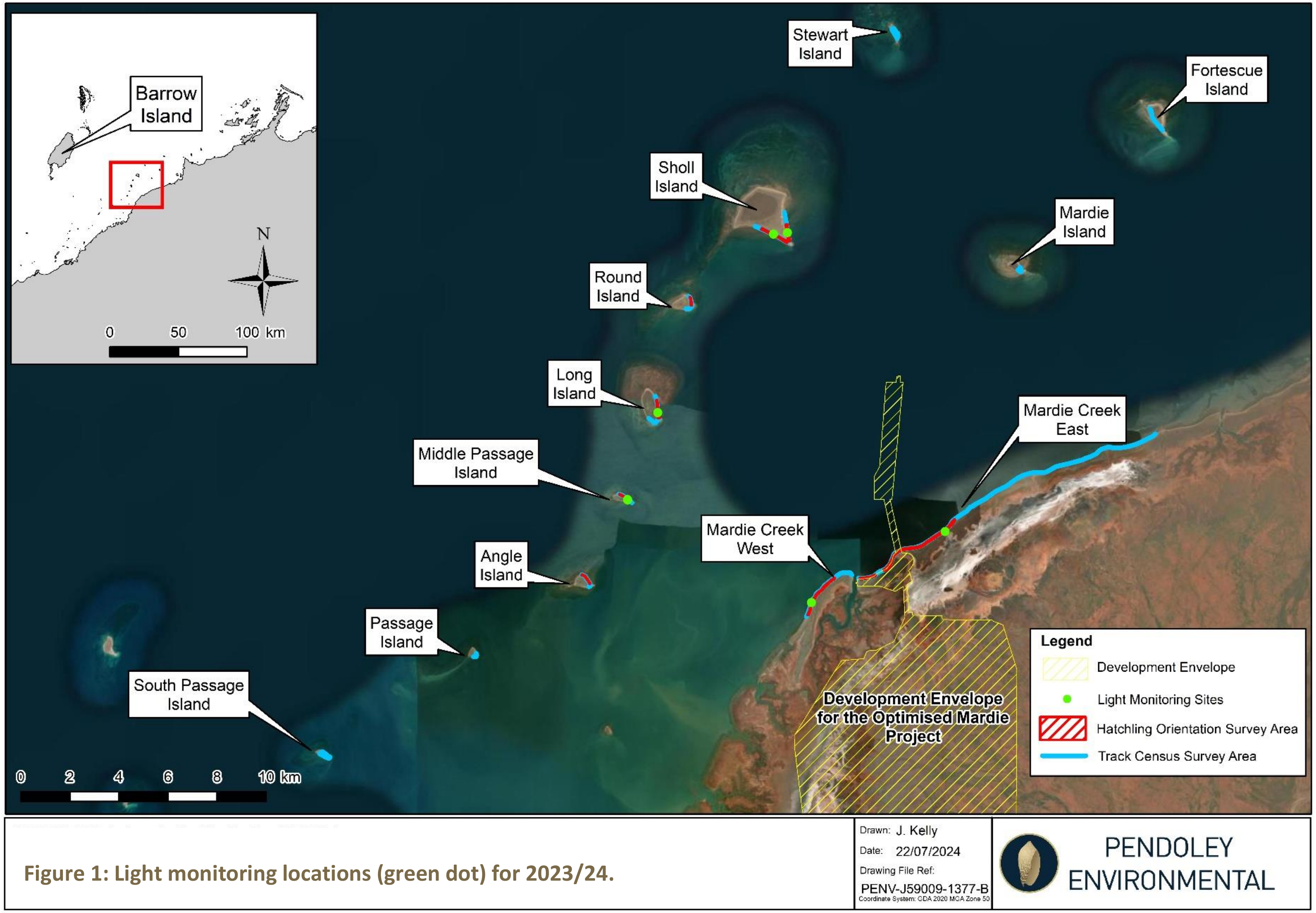

Figure 1: Light monitoring locations (green dot) for 2023/24.

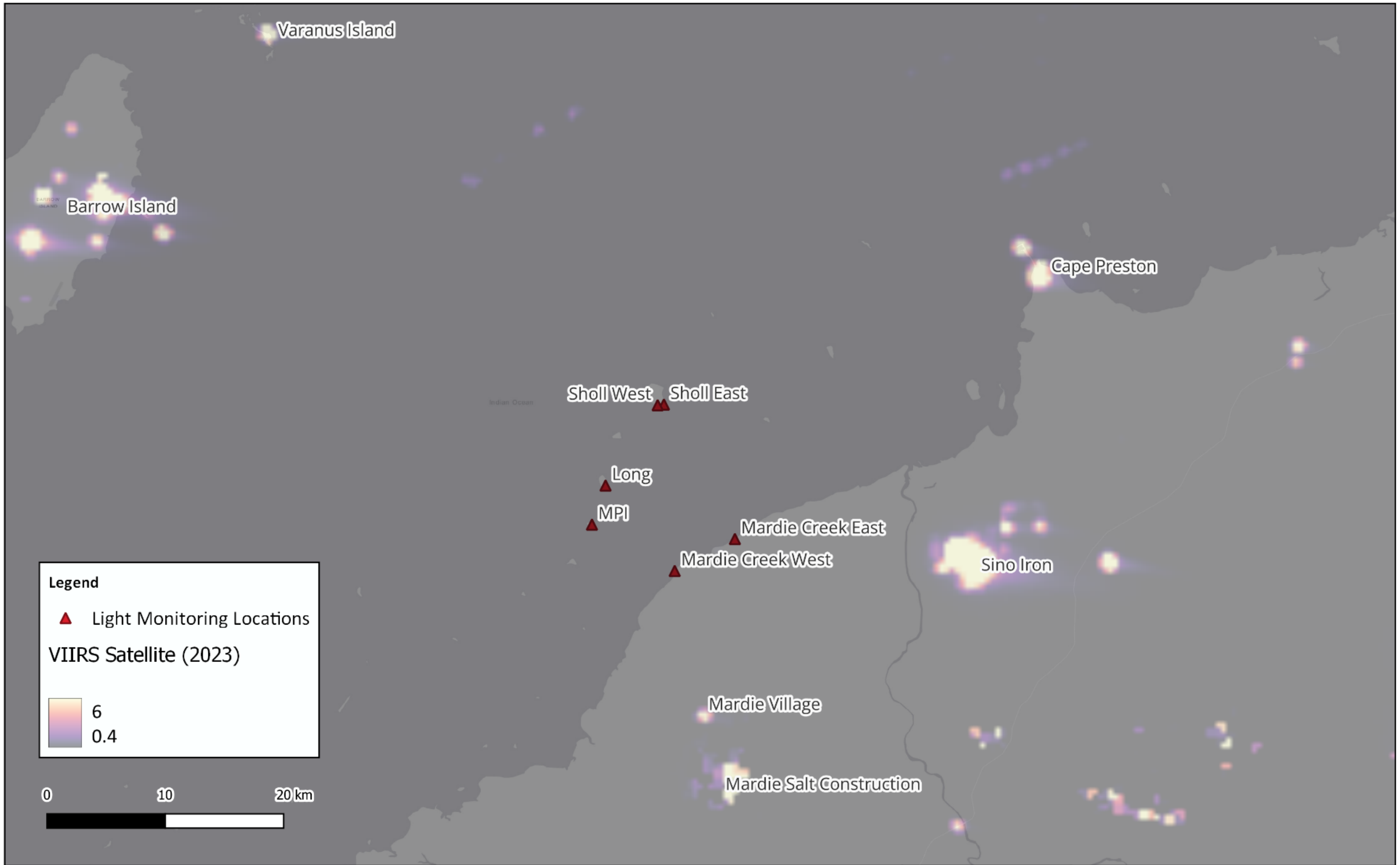

Figure 2: Artificial light and infra-red sources within the Optimised Mardie Project Area and surrounding region, as detected by satellite. Red triangles indicate light monitoring locations. Source: VIIRS 2023 Satellite Data (www.lightpollutionmap.info).

Drawn: F. Matthews
Date: 05/06/2024
Drawing File Ref:
PENV-J59009-1484-A
Coordinate System: EPSG:4326 - WGS 84

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1.2 Night-time Light Emissions

Several sources of horizon light were visible within the captured imagery at varying levels of brightness and located at different bearings from each monitoring location. Light data is presented as isophote maps (Figures 3-8), and colour coding of the maps is a representation of light intensity (not the colour of light as perceived by a human or turtle eye). The units of sky brightness are presented on an inverted logarithmic scale (i.e. higher values represent lower intensity light and vice versa).

Measured whole-of-sky (WOS) brightness was darkest at Sholl Island West (21.53 Vmag/arcsec^2) followed by Middle Passage Island (21.42 Vmag/arcsec^2) (**Table 1**). The brightest WOS sky brightness value was captured at Sholl Island East (21.08 Vmag/arcsec^2) monitoring location. The brightest light source visible from all locations was the Sino Iron development visible in an easterly to south-easterly direction (**Figure 3 - Figure 8).**

Substantial horizon shielding from dunes/vegetation was observed from both Mardie Creek East and Mardie Creek West. Project associated light visible in the processed images included Mardie Village which was observed as a distinct source of light from all monitoring locations except Mardie Creek East, which was shielded by vegetation.

Zenith brightness followed a similar trend with Sholl Island West and Middle Passage Island recording the darkest values (21.83 and 21.92 Vmag/arcsec^2 respectively, **Table 1**)

Table 1: Median sky brightness for whole-of-sky, horizon and zenith captured at light monitoring locations during the 2023-2024 season.

Monitoring location	Sky Brightness (Vmag/arcsec^2)		
	Whole-of-Sky	Horizon	Zenith
Mardie Creek East	21.22	21.18	21.53
Mardie Creek West	21.3	21.39	21.46
Long Island	21.36	21.27	21.71
Sholl Island West	21.53	21.49	21.83
Sholl Island East	21.08	20.94	21.5
Middle Passage Island	21.42	21.24	21.92

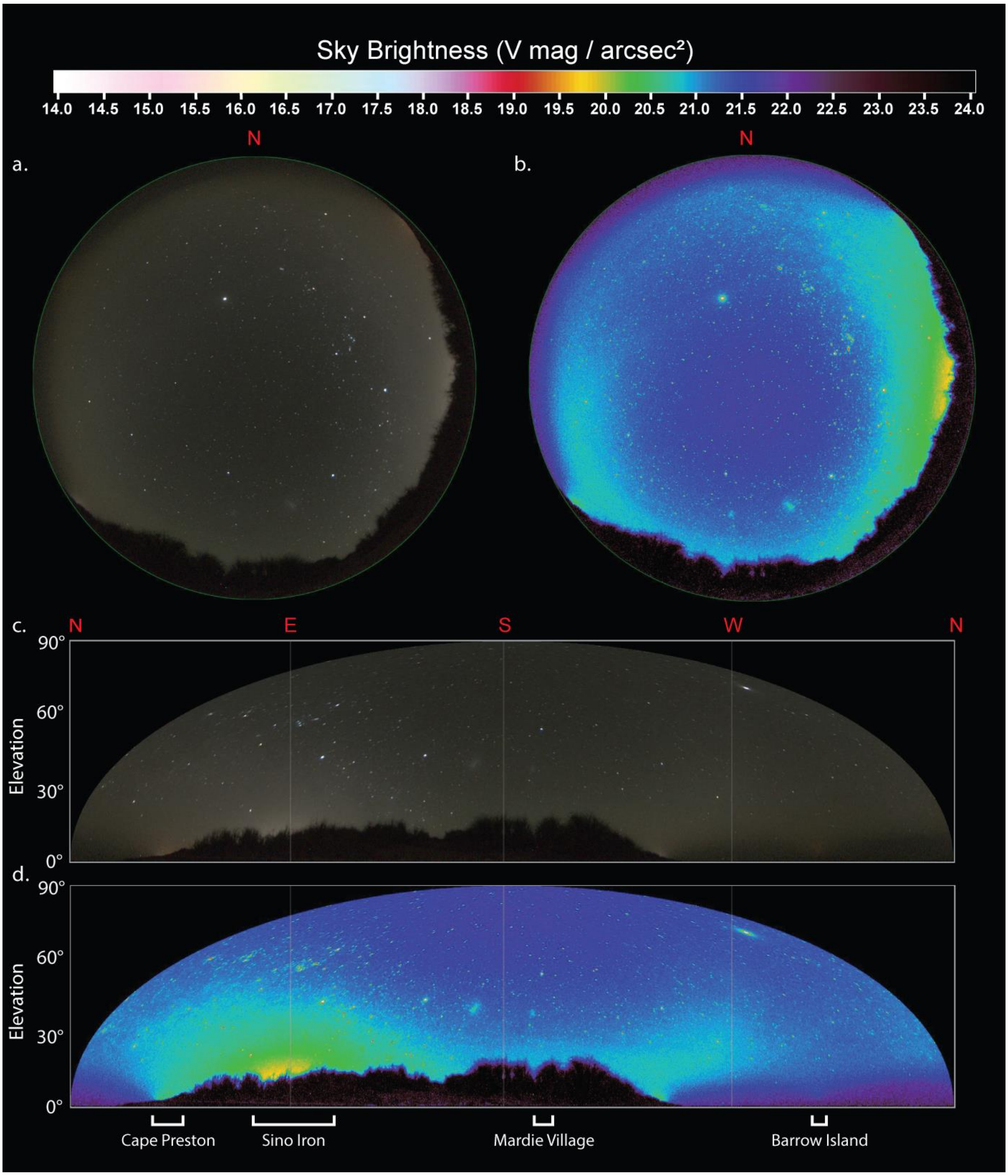

Figure 3: Artificial light monitoring results at Mardie Creek East on 10th December 2023. a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

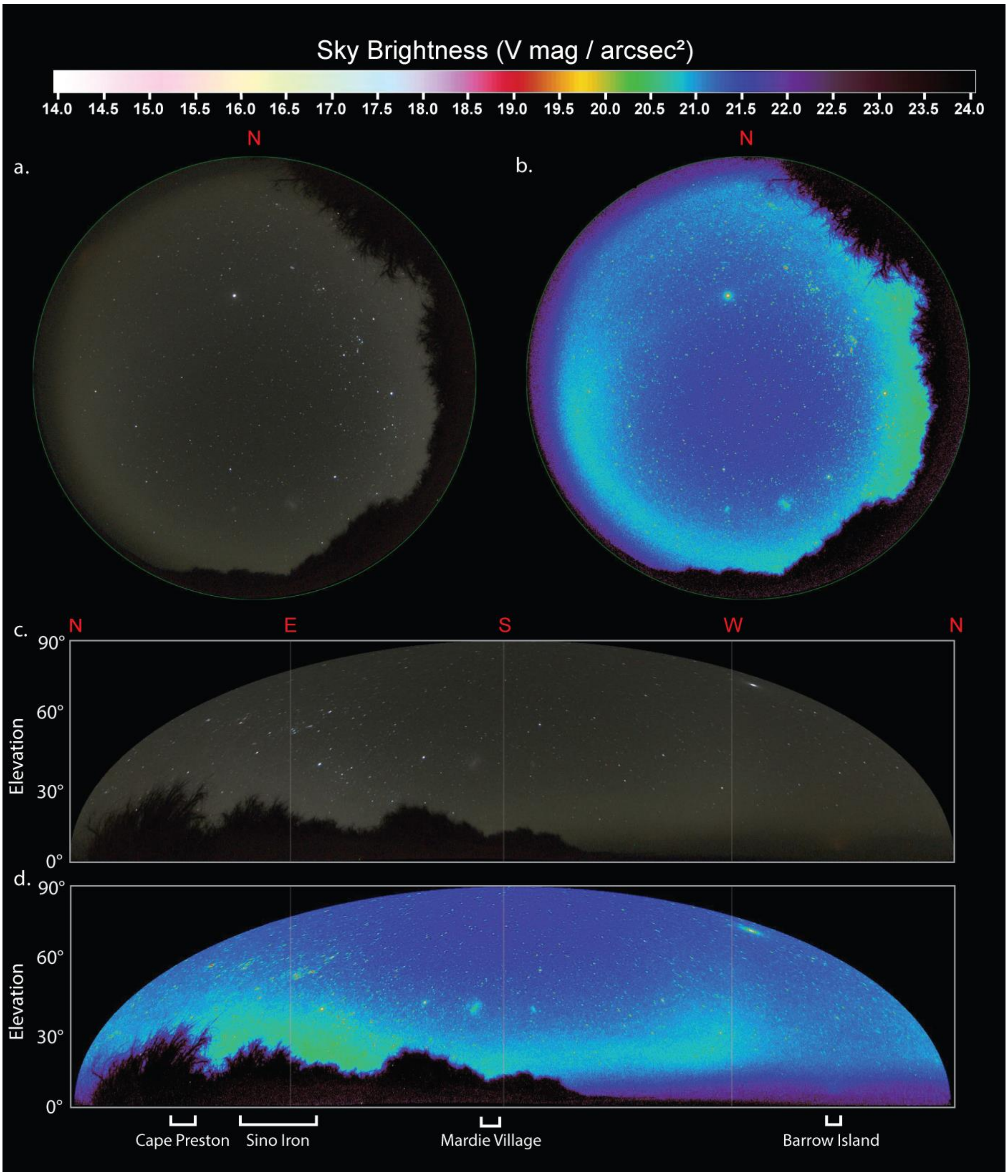

Figure 4: **Artificial light monitoring results at Mardie Creek West on 10th December 2023.** a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

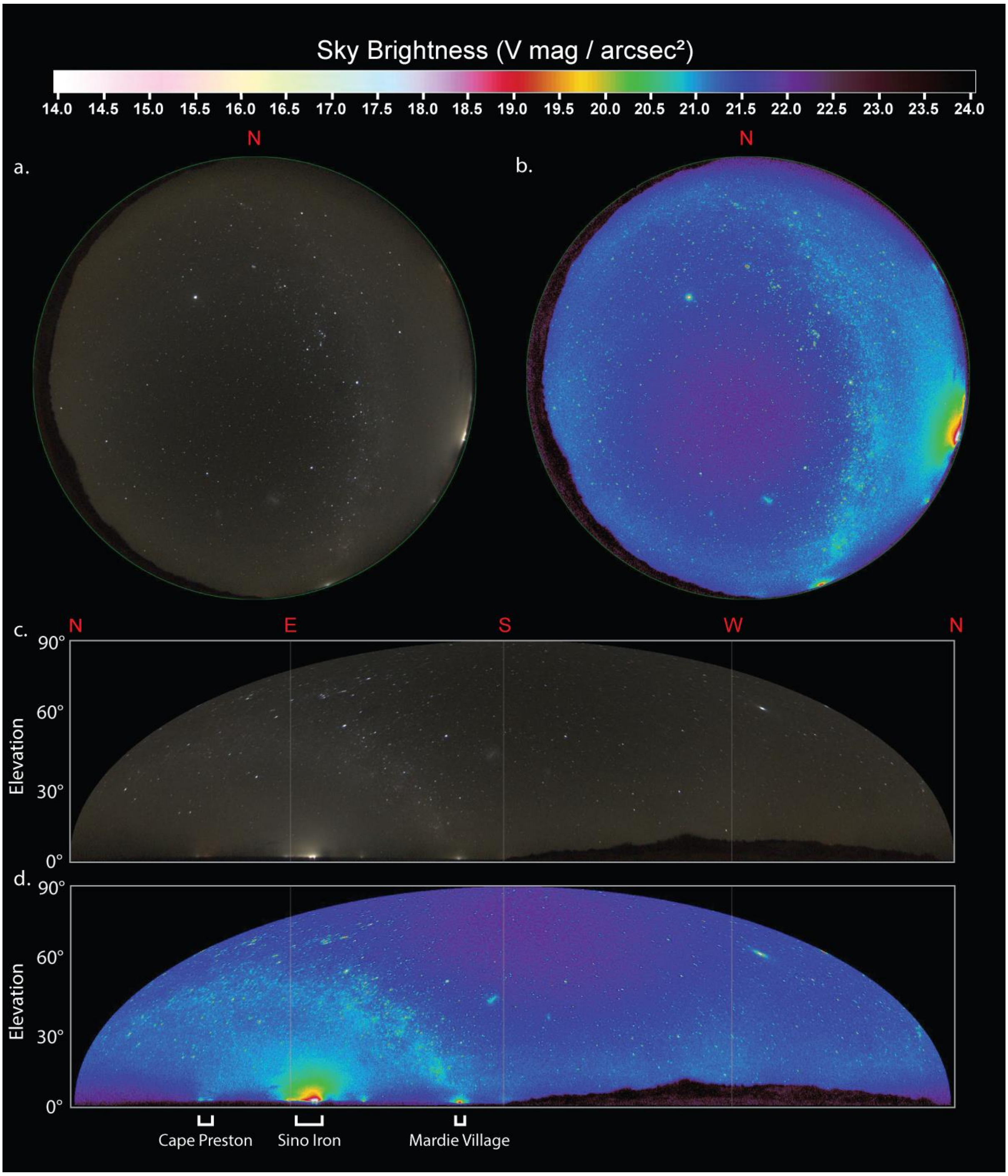

Figure 5: Artificial light monitoring results at Long Island on 12th December 2023. a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

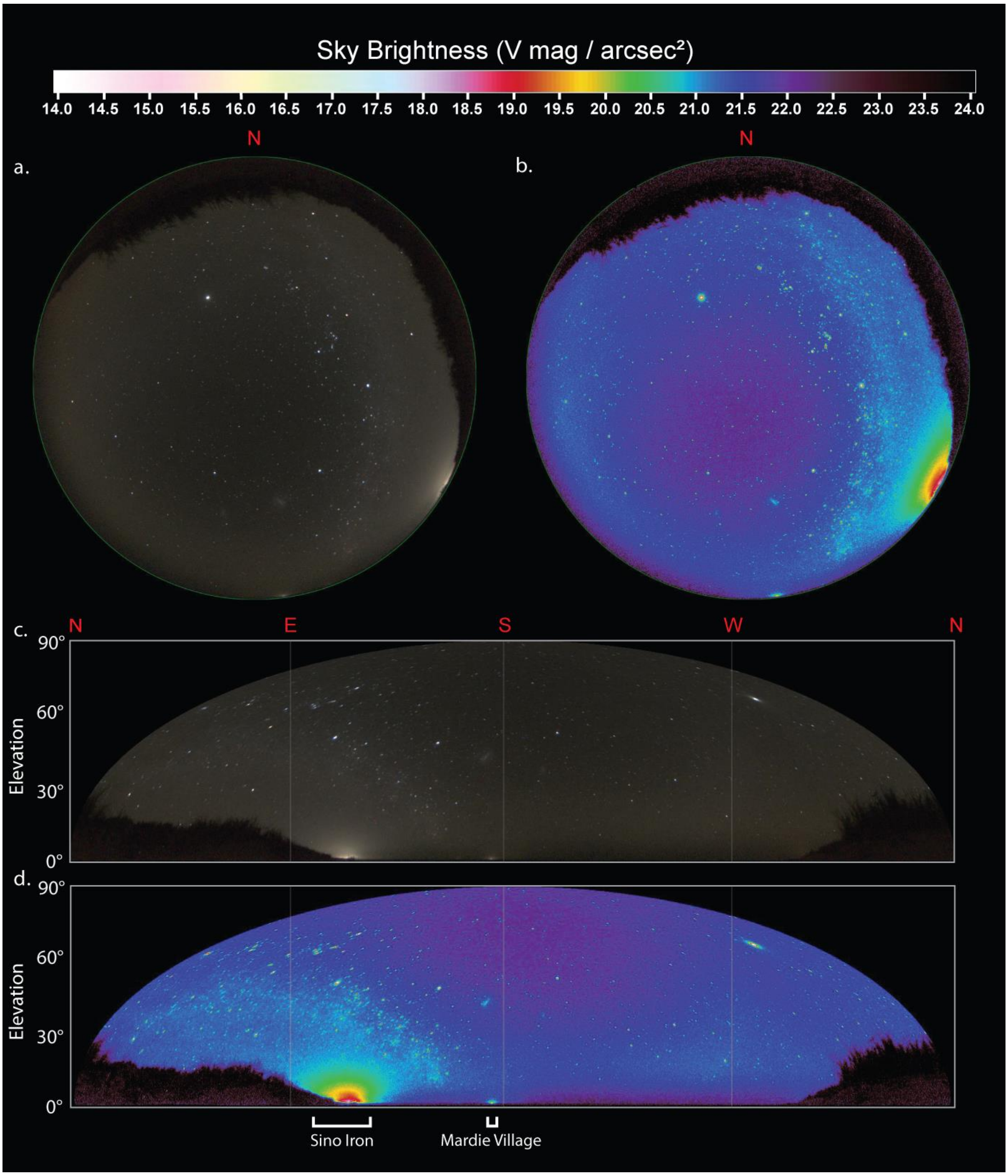

Figure 6: **Artificial light monitoring results at Sholl Island West on 12th December 2023.** a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

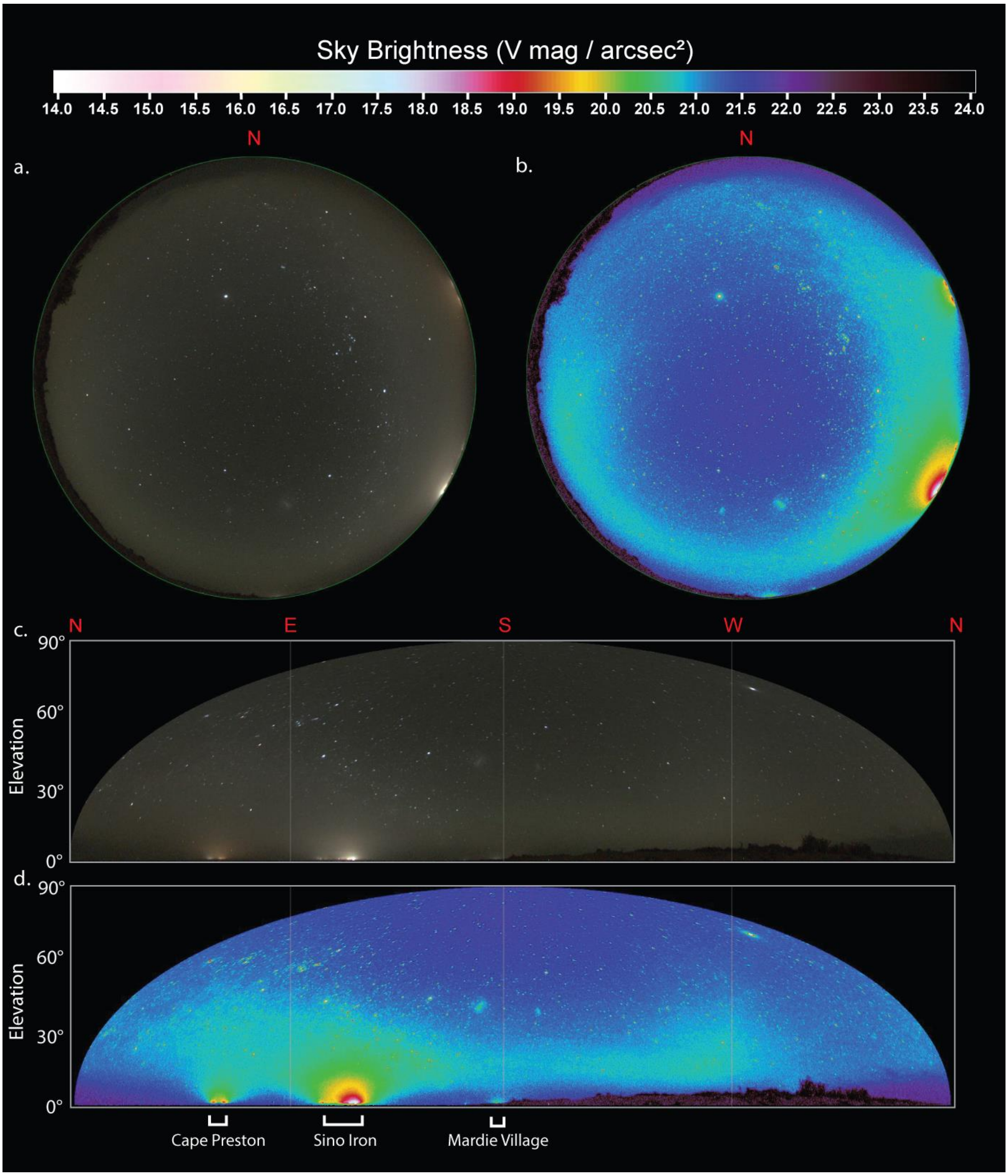

Figure 7: Artificial light monitoring results at Sholl Island East on 10th December 2023. a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

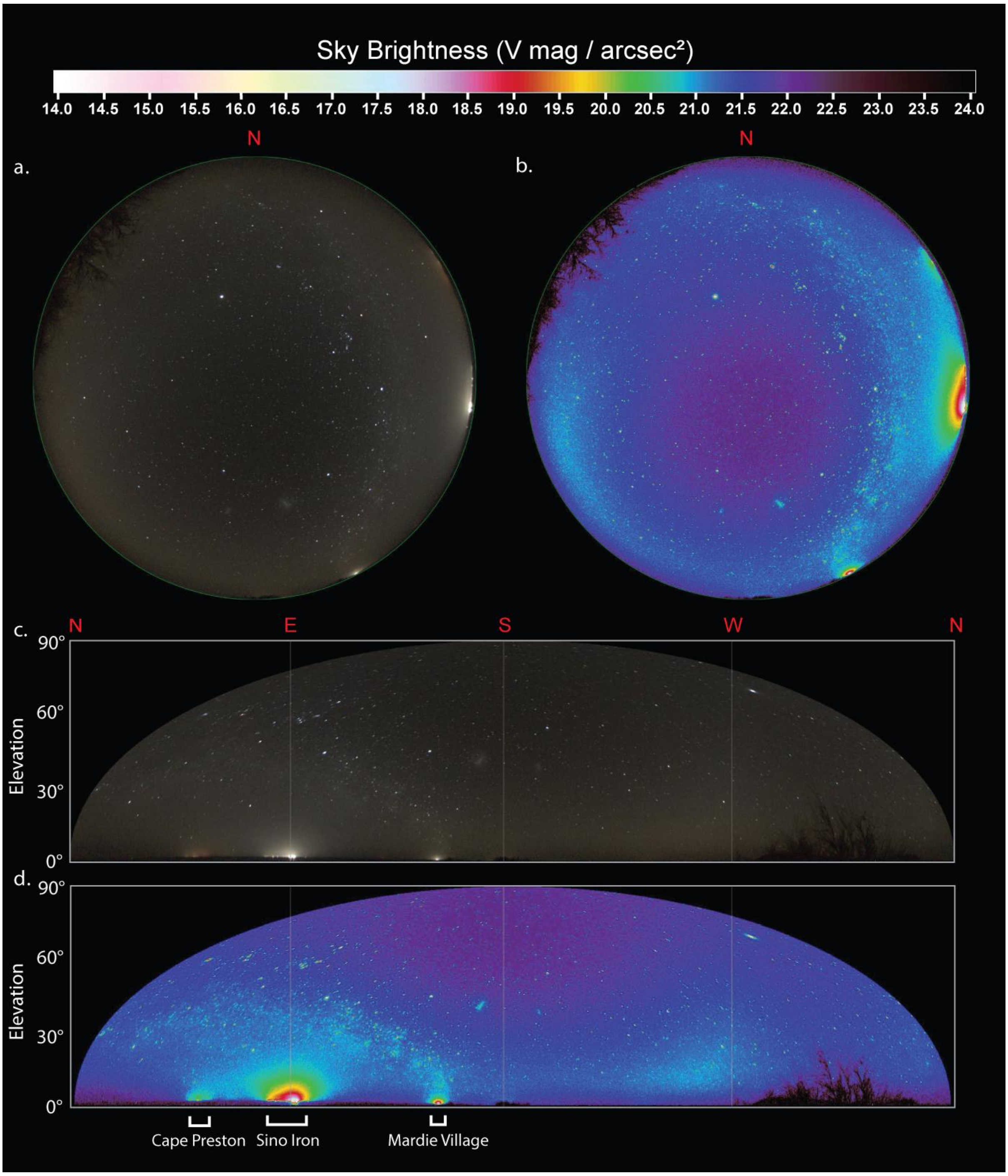

Figure 8: Artificial light monitoring results at Middle Passage Island on 11th December 2023. a. Clearest raw circular image; b. Processed circular image; c. Raw hammer-aitoff image; d. Processed hammer-aitoff image.

1.3 Historical Sky Brightness

The updated management program (Pendoley 2023) states that the results from offshore islands (2021/22) and the mainland (2022/23) will form a baseline dataset for yearly data to be compared to throughout the monitoring program. **Table 2** shows the change in whole-of-sky brightness observed over the last three years of monitoring, where data is available. It should be noted that the positioning of stars, atmospheric conditions, changes in dune profile, vegetation height and other natural phenomena may cause variance in sky brightness from year to year, and therefore small changes in sky brightness are expected.

Table 2: Change in whole-of-sky brightness observed from 2021/22 to 2023/24 at the light monitoring locations.

Monitoring location	Whole of Sky Brightness (Vmag/arcsec^2)			Change
	2021/22	2022/23	2023/24	
Mardie Creek East	-	21.24	21.22	↑1.86 %
Mardie Creek West	-	21.34	21.3	↑3.75 %
Long Island	21.19	-	21.36	↓14.49 %
Sholl Island West	-	-	21.53	-
Sholl Island East	21.16	-	21.08	↑7.65 %
Middle Passage Island	-	-	21.42	-

A marginal increase in whole-of-sky brightness was observed at both mainland monitoring locations and from the eastern side of Sholl Island. Long Island recorded a decrease in whole-of-sky brightness of 14.5%, which may be attributed to a slight increase in vegetation height and changes in dune profile.

1.4 Light Sources 2022/23

While it is difficult to quantify changes in specific point sources between seasons, a qualitative analysis of changes in visible light sources from monitored locations has been outlined as shown in **Table 3**.

Table 3: Change in visible light sources observed from 2021/22 to 2023/24 at the light monitoring locations. * denotes the first season for this location to be monitored.

Visible Light Source	Visibility	
	February 2022	December 2023
Cape Preston - bearing 65–70°	**SIE, LI,**	**SIE, SIW, LI, ME***
Sino Iron ore mine - bearing 110–125°	**SIE, LI**	**SIE, SIW, LI, ME*, MW***
Mardie Village - bearing 170–175°	**SIE, LI**	**SIE, SIW, LI**
Rio Tinto MESA A iron ore mine on the bearing 176–184°	**SIE, LI**	**-**
Barrow Island on the bearing 288–294°	**SIE**	**ME*, MW***
Varanus Island on the bearing 318–325°	**SIE**	**-**

Light from Rio Tinto Mesa A iron ore mine and Varanus Island was not recorded by the light cameras from any of the monitoring locations in 2023/24. It is important to note that these light sources still exist, however changes in dune topography and vegetation have shielded the camera locations from these sources.