LEICHHARDT SALT PTY LTD

ERAMURRA SOLAR SALT PROJECT: MARINE TURTLE MONITORING 2023/24

Prepared by

Pendoley Environmental Pty Ltd

For

Leichhardt Salt Pty Ltd

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PENDOLEY ENVIRONMENTAL

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EXECUTIVE SUMMARY

Leichhardt Salt Pty Ltd (LEIC) is the Proponent for the Eramurra Solar Salt Project, a proposed solar salt operation in the Pilbara region of Western Australia (WA). The Project is targeting average production of 5.2 million tonnes per annum of high-grade salt from seawater using a series of evaporation and crystallisation ponds. The development envelope for the Project occurs adjacent to Citic Pacific's Sino Iron export facility at Cape Preston, WA.

In response to comments received from the Environmental Protection Authority, LEIC engaged Pendoley Environmental (PENV) to undertake a second consecutive season of benchmark marine turtle nesting surveys in the vicinity of the Project, to determine the species and abundance of marine turtles nesting and hatching on nearby (within 20 km of the Project) beaches. This includes beaches on the mainland coast and islands offshore from the Project. Data from the surveys conducted this season was then used to update and consolidate the light spill risk assessment conducted in 2022/23, which considered the potential for Project lighting to impact hatchling behaviour, and the Project's contribution to the cumulative impact of lighting on the turtle population of the North West Shelf.

Three field surveys were undertaken at suitable nesting habitat on mainland and island beaches in October 2023 (Field Survey 1; FS1), January 2024 (Field Survey 2; FS2), and February 2024 (Field Survey 3; 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*). All field surveys were a minimum of 14 days in duration, as per the recommendations of the National Light Pollution Guidelines for Wildlife (NLPGW). For those surveys undertaken in October and January, the 14-day period represents the mean inter-nesting period for turtles in the North West Shelf Region, and nesting results can be used to estimate the relative annual index of marine turtle nester abundance for each species.

The field surveys focused on four routine monitoring locations and two opportunistic monitoring locations. The routine monitoring locations included North East (NE) Regnard Island, South West (SW) Regnard Island, Steamboat Island, and Cape Preston East (CPE) beach. The opportunistic monitoring locations included Cape Preston West and Forty Mile Beach. A total of 45 survey days were undertaken for the 2023/24 nesting season.

Hawksbill nesting activity accounted for the greatest number of tracks in the overall monitoring period. The highest density of nesting activity occurred on the south-east side of Steamboat Island. Overall nesting success (the number of successful nests as a percentage of the total number of overnight tracks) was high for hawksbill turtles in FS1 at 36.2 %, meaning the majority of hawksbill tracks represented unsuccessful nesting attempts (47 %) or false crawls (17 %). Flatback and green turtle nesting was found to be present but marginal when combined for all routine monitoring beaches.

Nest fan data was reflective of the nester abundance for each beach, with nest fans rarely encountered on the routine beaches, except for Steamboat Island. A total of 10 nest fans were recorded over the January and February surveys, with 5 (50 %) occurring on Steamboat Island. The remaining fans occurred on SW Regnard Island (*n* = 2), NE Regnard Island (*n* = 1), and CPE (*n* = 2). Hatchling species included hawksbill (*n* = 4), flatback (*n* = 1), and unknown (*n* = 5). Positive identification of hatchling species was determined from track characteristics and the presence of dead

hatchlings at the surface of the nest cone. Where this was not possible, the emergence was determined to be of unknown species.

Nest fans indicated marine turtle hatchlings successfully oriented seaward after emergence at SW Regnard Island, NE Regnard Island, and CPE. At Steamboat Island, several nest fans occurred on a sand spit, and as a result had much larger spread and offset angles. Emergence patterns on island spits are typically irregular, due to the presence of the ocean across multiple bearings to the nest cone, and the position of the nest further back on the beach. Despite this, the nest fans at Steamboat Island also indicated that hatchlings oriented seaward.

A risk assessment was undertaken using a standard risk assessment matrix, with modified definitions for consequence and likelihood ratings relevant to hatchling turtles, the regional nesting population, and the nesting success of breeding activities. The risk assessment applied to SW Regnard Island, NE Regnard Island, Steamboat Island, CPE, and FMB. The process assessed the potential for artificial light to cause mis- or disorientation of hatchling sea turtles of all species occurring in the vicinity of the Project, leading to a reduced fitness or mortality, when compared to 'benchmark' (Pre-construction) light conditions. The risk assessment used light modelling at nearly all locations to determine the predicted change in light attributable to the Project and proposed Cape Preston East Export Facility (CPEEF), including its intensity, visibility, and directionality at nesting habitat. The modelling represents the unmitigated ('worst-case') visibility of light associated with the Project and CPEEF under clear-sky conditions during a new moon period.

The risk assessment found the risk at NE Regnard Island, SW Regnard Island, Steamboat Island, and FMB to be 'Low'. At CPE, the risk was assessed as 'Medium', due to the proximity of nesting habitat to the proposed CPEEF, deemed likely to have potential to change hatchling behaviour in its modelled state. However, due to the small size of the overall nesting population in proximity to the Project, any impact is not expected to have a detectable effect on the respective genetic stocks of each species.

It is recommended that the Project consider the ways in which the lighting design can be revised to meet the Best Practice Lighting Design Principles outlined in the NLPGW. Principles such as reducing the Correlated Colour Temperature of outdoor lighting, reducing the number of lights, considering smart lighting controls, and applying shielding or recessing to lights will reduce the visibility of light at turtle nesting beaches, and also reduce the impact on other species of wildlife and social surroundings, including dark sky conservation values.

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ACRONYMS

BoM	Bureau of Meteorology
CPE	Cape Preston East
CPEEF	Cape Preston East Export Facility
CPW	Cape Preston West
EPA	Environmental Protection Authority
FMB	Forty Mile Beach
F-Pil	Pilbara stock, Flatback turtles
FS	Field Survey
G-NWS	North West Shelf stock, Green turtles
H-WA	Western Australia stock, Hawksbill turtles
LEIC	Leichhardt Salt Pty Ltd
NE	North East
NLPGW	National Light Pollution Guidelines for Wildlife
OGV	Ocean-going vessel
PENV	Pendoley Environmental
SW	South West
TSV	Trans-shipment vessel
UAV	Unmanned Aerial Vehicle
WA	Western Australia

1 INTRODUCTION

1.1 Project Description

Leichhardt Salt Pty Ltd (LEIC) is the Proponent for the Eramurra Solar Salt Project (hereafter, 'the Project'), a proposed solar salt operation in the Pilbara region of Western Australia (WA). The Project is targeting an average production rate of 5.2 million tonnes per annum of high-grade salt from seawater, with up to 6.8 Mt of salt deposited in a low rainfall year. The Project will be located to the east of Citic Pacific's Sino Iron Project at Cape Preston, WA.

The Project will require development of concentrator and crystallisation ponds and construction of a processing plant and other supporting infrastructure. Nearshore, dredging of a shipping channel will provide access to a trestle jetty at the Cape Preston East Export Facility (CPEEF), which was referred and approved separately to the Project. However, construction of the CPEEF may occur in conjunction with the Project construction.

1.2 Scope Context

LEIC engaged Pendoley Environmental (PENV) to undertake benchmark artificial light monitoring at turtle nesting habitat in the vicinity of the project in June 2022, in response to comments received from the Environmental Protection Authority (EPA) on their draft Environmental Scoping Document (14^{th} March 2022):

"Undertake a baseline light survey to identify the current light environment and undertake a light spill study to consider the direction and intensity of the expected light sources to determine whether the Proposal will attract turtle hatchlings or otherwise alter their behaviour. The light spill study will consider cumulative lighting impacts on the turtle population of the North West Shelf."

The outcome of the artificial light study identified that there was insufficient information available on the nesting population of turtles at Cape Preston and surrounding beaches to conduct an artificial light impact assessment. Further marine turtle surveys were recommended, designed in line with the recommendations of the National Light Pollution Guidelines for Wildlife (NLPGW, Commonwealth of Australia 2023), to understand the species abundance and distribution of nesting marine turtles and hatchling turtle behaviour across two breeding seasons.

PENV therefore undertook monitoring surveys at known turtle nesting habitat in the vicinity of the Project during the 2022/23 breeding season (PENV 2023). The outcomes determined the species abundance and distribution of adult turtles during their respective peak nesting period for the region, including for hawksbill (*Eretmochelys imbricata*; October to November), flatback (*Natator depressus*; December to January), and green (*Chelonia mydas*; December to January) turtles (Commonwealth of Australia 2017). Furthermore, surveys were conducted during new moon conditions to capture data on the behaviour of hatchling turtles when orienting on the beach.

1.3 Scope of Work and Objectives

This report details the outcomes of benchmark marine turtle monitoring undertaken to estimate the abundance and distribution of marine turtles nesting within the vicinity of the Project, and record hatchling behaviour for a second consecutive breeding season. Marine turtle surveys were undertaken over the 2023/24 austral summer, and were designed to record information on hawksbill, flatback (*Natator depressus*), and green (*Chelonia mydas*) turtles in line with the monitoring recommendations of the NLPGW (Commonwealth of Australia 2023).

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; and
- Record benchmark data on hatchling orientation.

Where possible, monitoring data recorded this season (2023/24) will be presented in context with the results of the 2022/23 season.

2 METHODS

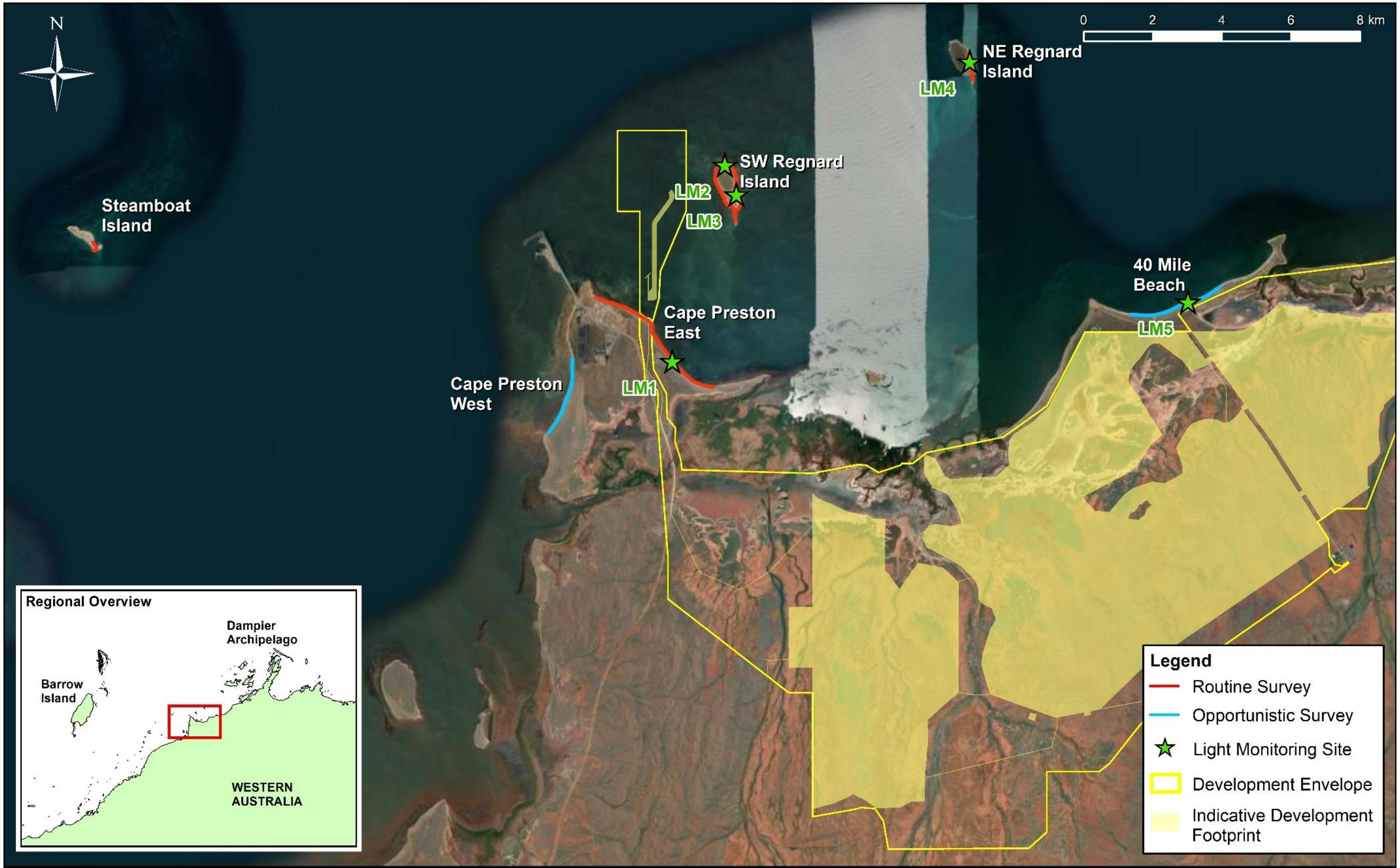
2.1 Survey Location and Schedule

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; 14th – 27th October 2023):** Targeted the peak of the hawksbill turtle nesting season over one 14-day inter-nesting period (**Section 2.3**).
- **Field Survey 2 (FS2; 4th – 19th January 2024):** Targeted the peak of the green and flatback turtle nesting season over one 14-day inter-nesting period and peak hawksbill hatching season (**Section 2.4**).
- **Field Survey 3 (FS3; 5th – 19th February 2024):** Targeted the peak of green and flatback hatching season over one 14-day period (**Section 2.5**).

Peak nesting and hatching periods were determined for the relevant genetic stock for each species, as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017). This includes the North West Shelf stock of green turtles (G-NWS), the Pilbara stock of flatback turtles (F-Pil), and the Western Australia stock of hawksbill turtles (H-WA).

Suitable sandy beach habitat was surveyed to determine the presence and abundance of nesting activities, and hatchling orientation. The work program and survey methods were tailored based on the objectives of each survey, with the potential impact beaches prioritised according to the rationale provided in **Table 1**.



J106003 Eramurra Marine Turtle Monitoring

Figure 1: Field survey locations for the Eramurra Solar Salt Project, Western Australia.

Drawn: P. Whittock
Date: 23/05/2024
Drawing File Ref: PENV-J106003-1449-A
Coordinate System: GDA 1994 MGA Zone 50

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Table 1: Survey site selection rationale.

Location	Rationale
South West (SW) Regnard Island	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). 1.3 km from proposed shipping channel (closest point), 3.5 km from trestle jetty (closest point) and 4.0 km from proposed port infrastructure and salt stockpile.
North East (NE) Regnard Island	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). 11 km from proposed pump station flood lighting (closest point).
Cape Preston East (CPE) Beaches (north and south)	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). Adjacent to proposed CPE port infrastructure and stockpile.
Steamboat Island	Routine monitoring location (all surveys). Data deficient for marine turtle nesting activity and hatchling orientation (all species). 15 km from proposed port infrastructure and salt stockpile.
Cape Preston West (CPW) Beach	Opportunistic monitoring location (FS1 and FS2). Data deficient for marine turtle nesting activity. Surveyed opportunistically due to its position on the west side of existing Cape Preston infrastructure and Port – Project will be shielded by Cape Preston. Difficult to access on foot.
Forty Mile Beach (FMB; Gnoorea)	Opportunistic monitoring location (FS1 and FS2). Data deficient for marine turtle nesting activity and hatchling orientation (all species). 2.5 km from pump station flood lighting. Open to off-road vehicles and campers.

2.2 Work Program

An overview of the work scopes conducted for each field survey is provided in **Table 2**, with methodology detailed in the following sections. A daily location schedule for each field survey is provided in **Appendix A.**

Table 2: Field survey work program. Locations marked with '*' were only monitored via opportunistic ('snapshot') survey for the period indicated. NE = North East; SW = South West; CPE = Cape Preston East; FMB = Forty Mile Beach; CPW = Cape Preston West.

Location	Track Census			Hatchling Orientation		
	FS1	FS2	FS3	FS1	FS2	FS3
NE Regnard Island	✓	✓	✓	-	✓	✓
SW Regnard Island	✓	✓	✓	-	✓	✓
Steamboat Island	✓	✓	✓	-	✓	✓
CPE (North and South)	✓	✓	✓	-	✓	✓
FMB	✓*	✓*	-	-	-	-
CPW	✓*	✓*	-	-	-	-

2.3 Field Survey 1

Field Survey 1 (FS1) was conducted between 14th and 27th October 2023, with the objective of completing a track census of adult nesting activity during the peak hawksbill turtle nesting period for the Pilbara (nominally October and November; Commonwealth of Australia 2017), over a 14-day inter-nesting period. The survey was completed by one PENV field member, supported by a vessel master and deckhand from Bhagwan Marine.

2.3.1 Track Census

2.3.1.1 Data Capture

The October track census was completed using an unmanned aerial vehicle (UAV) launched and landed by a qualified remote pilot from the survey vessel. Aerial imagery was captured at routine monitoring beaches using a DJI Phantom 4 Pro UAV. The UAV flew along pre-programmed flight paths over suitable nesting habitat on NE Regnard Island, SW Regnard Island, Steamboat Island, and CPE for each day of FS1 (**Appendix A**). In addition, other beaches in the vicinity of the Project were monitored with the UAV on an opportunistic basis, which involved conducting one-off, 'snapshot' flights over CPW and FMB.

The UAV was flown at a ground speed of 4.5 – 4.8 ms^{-1}, 30 m above ground level, and captured images at two-second intervals. Each image was georeferenced with the UAV's position at time of capture. At this speed, altitude, and capture frequency, the UAV recorded images at a high ground sampling distance of 0.8 cm^2 per pixel and 75 % overlap, which is necessary for the generation of a high resolution orthomosaic.

2.3.1.2 Data Processing

Aerial imagery was stitched into a single georeferenced orthomosaic for each survey day using Pix4D Mapper Pro software (v4.7.5). Each orthomosaic was visually screened in QGIS (v3.28.2) for overnight nesting activity. New activity was identified by comparing imagery from each new survey day with imagery from the previous day. Turtle species, location, and type of nesting activity ('false crawl', 'attempt', 'nest', or 'unknown'; **Table 3**) were identified for each track by a qualified marine turtle biologist using track and nest characteristics, including track width, shape and orientation of flipper marks, tail drag marks, and displaced sand.

Table 3: Definitions of turtle nesting activity.

Activity	Definition
Nest	A female turtle successfully laid a clutch of eggs, covered, and camouflaged the nest before returning to the sea.
Attempt	A female turtle attempted to lay a clutch of eggs, by digging a nest, or part thereof, but not actually depositing her eggs before returning to the sea.
False Crawl	A female turtle crawled on the beach and made no digging attempt before returning to the sea without laying.
Unknown	The nesting activity could not be determined from the track characteristics.

2.4 Field Survey 2

Field Survey 2 (FS2) was conducted between the 4th and 19th January 2024, with the objective of completing a track census of adult nesting activity during the peak green (December to February, inclusive) and flatback (November to January, inclusive) nesting period for the Pilbara region (Commonwealth of Australia 2017), over a 14-day inter-nesting period. In addition, a hatchling orientation survey was conducted on beaches where hawksbill nesting activity was observed in FS1, to collect nest fan data from recently emerged hawksbill hatchlings during the peak hatching period (December to February, inclusive; Commonwealth of Australia 2017). The survey was scheduled over a new moon period as recommended by the NLPGW (new moon: 11th January 2024; Commonwealth of Australia 2023).

2.4.1 Track Census

The January track census was largely completed on-foot by two PENV field personnel at routine monitoring beaches to increase the detectability of hatchling tracks surveyed concurrently (**Section 2.4.2**). Species information, nesting activity (**Table 3**), and a GPS location were recorded on a field tablet for each adult turtle track encountered during the daily beach walks.

Due to the size of the survey area and logistical constraints of reaching and walking all beaches on every day of the program, beaches were instead monitored on every second day of the program, alternating between mainland beaches (CPE) and island beaches (NE Regnard, SW Regnard, and Steamboat islands). The survey was therefore conducted over a 16-day period, to ensure each beach was visited for a total of at least 14 days (refer to **Appendix A** for full survey schedule).

The results of the October survey indicated that adult tracks above the high tide mark remained visible for multiple days, including preservation of key features that allow for species and activity identification. An example of the preservation of adult tracks on CPE is provided in **Appendix B**. There was high confidence that for the January survey, routine monitoring beaches could be surveyed every second day of the program and still derive an accurate abundance estimate, provided weather conditions were not adverse (i.e. gale-force winds, rainfall, or cyclone). Each survey day therefore captured nesting activity from the previous two nights.

Opportunistic monitoring beaches (CPW and FMB) were surveyed by UAV in a single snapshot survey at each location. This is because no hawksbill nesting activity was detected at these beaches during the October survey (**Section 3.3**) or in 2022/23 (PENV 2023), and there is no historical data available indicating hawksbills use these beaches for nesting (PENV 2009; O2 Marine 2022). Therefore, it was considered unlikely that hawksbill hatchling fans would be encountered on this beach in January. All UAV imagery collected during the January survey was processed and analysed as per the methods in **Section 2.3.1.1** and **2.3.1.2**.

2.4.2 Hatchling Orientation

2.4.2.1 Data Collection

Hatchling fans were surveyed concurrently with the on-foot track census. Whilst it is acknowledged that hatchling fans are more susceptible to being erased by wind when surveyed on alternate days (when compared to adult tracks), this approach was adopted due to the following rationale:

- The size and remoteness of survey beaches made it logistically difficult for the survey team to patrol all beaches on foot every day of the field program, taking into account weather, vessel transit times, tidal movements, health and safety considerations, and the terrain governing access to beaches. In addition, it was not desirable to survey hatchling fans in the late afternoon due to the heat, and reduced detectability of hatchling fans as a result of a high sun angle.

- Hatchlings may take multiple nights to emerge from a nest, having the potential to create more than one fan over successive nights. Therefore, there may be multiple opportunities to record some of the emergence event (i.e. one fan), provided the weather is conducive to detecting hatchling fans (i.e. absence of rain or high winds).

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 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 from the point where the track crossed the high tide line. Single hatchling tracks that were more than 30˚ from the outermost track of the main fan were recorded as outliers.

Positive species identification was made based on hatchling track characteristics (size and number of tracks), and from the presence of alive and/or dead hatchlings at the surface of the nest cone. In general, flatback hatchling tracks are easily identifiable from hawksbill and green tracks based on their size. In contrast, hawksbill and green tracks are difficult to tell apart, and identification of species at this level only occurred where there was a hatchling present at the surface.

2.4.2.2 Data Analysis

Offset and spread angles were calculated for bearings measured from each nest fan to determine the spread of hatchling tracks from the point of emergence, and the degree to which hatchlings diverged from the most direct route to the ocean.

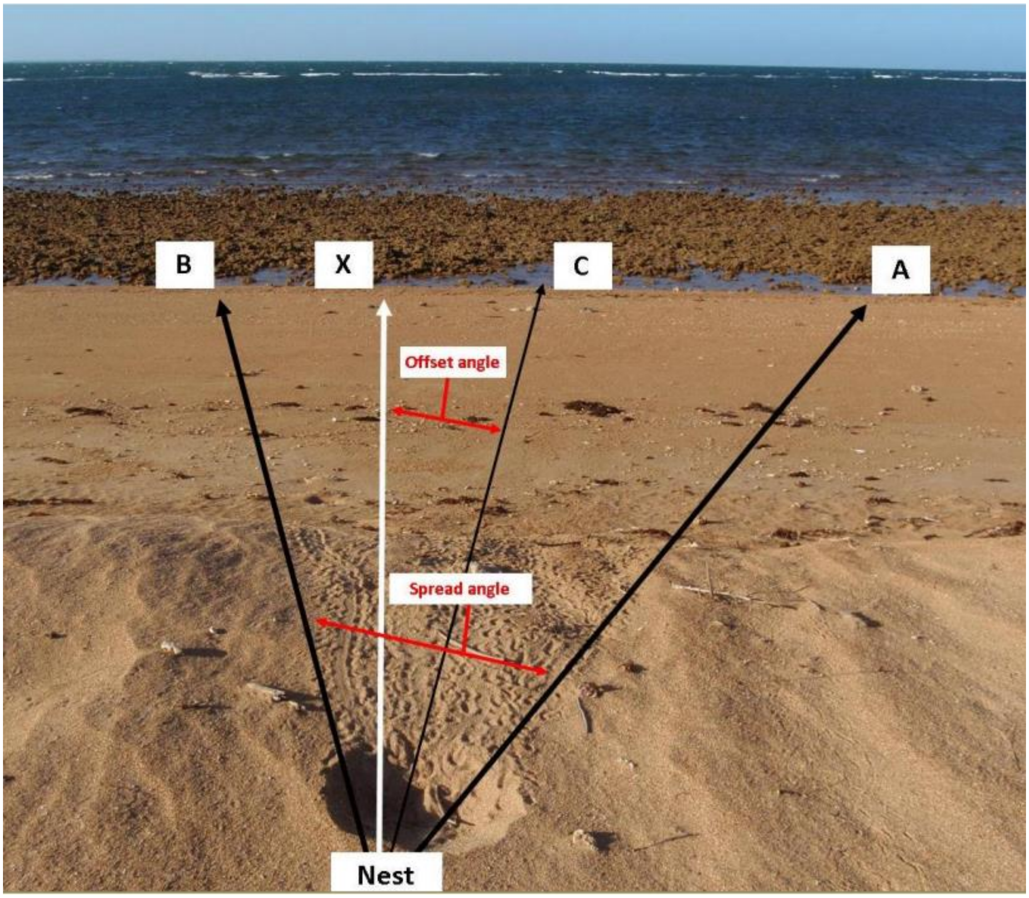


Figure 2: Hatchling orientation measurements describing hatchling spread and offset.

2.5 Field Survey 3

Field Survey 3 (FS3) was conducted between the 5th and 19th February 2024, with the objective of recording hatchling fans during the peak flatback and green turtle hatching period (both February – March, inclusive; Commonwealth of Australia 2017). The survey was scheduled over a new moon period as recommended by the NLPGW (new moon: 10th February 2024; Commonwealth of Australia 2023). Information on adult nesting activity was also captured during this period, however the results do not form part of an adult nester abundance estimate as they were recorded outside of the reported peak nesting period for all species.

2.5.1 Hatchling Orientation

Hatchling fans were surveyed on-foot at four survey locations, including NE Regnard Island, SW Regnard Island, Steamboat Island, and CPE. As per FS2, the island locations were surveyed on alternate days to the mainland beaches (**Appendix A**) for the reasons outlined in **Section 2.4.2**. Hatchling fan data from FS3 was analysed as per **Section 2.4.2.2.**

2.5.2 Track Census

Information on adult tracks, including the species, nesting activity and GPS location, were recorded concurrently with the hatchling orientation surveys at routinely monitored locations. No opportunistic surveys were undertaken during FS3 in February as it was outside the reported peak nesting period for all species i.e. CPW and FMB were not monitored.

3 RESULTS

3.1 Field Conditions

All three field surveys were completed as planned over the scheduled dates (**Section 2.1** and **Appendix A**).

With the exception of some days in FS2, field conditions were generally suitable for the majority of the field season, which encompassed a total of 45 survey days. Weather data from the Bureau of Meteorology (BoM) at nearby Mardie Station (40 – 60 km from survey locations) is displayed for all survey periods in **Figure 3**. Maximum daily temperatures for the period ranged from 29.1 – 48.2 °C. There was very low rainfall recorded across the period, with two events recording a total rainfall of 6.2 mm.

FS2 was impacted by strong winds which limited the vessel use on certain days. This included the 15th January 2024 when only NE Regnard and SW Regnard were accessed (wind speed was 17 km/hr gusting to 50 km/hr), and on 17th January 2024 when wind gusts exceeded 50 km/hr and no islands were accessed (NE Regnard, SW Regnard, or Steamboat) (**Appendix A**). All other survey days, including those conducted at the mainland, were executed as planned.

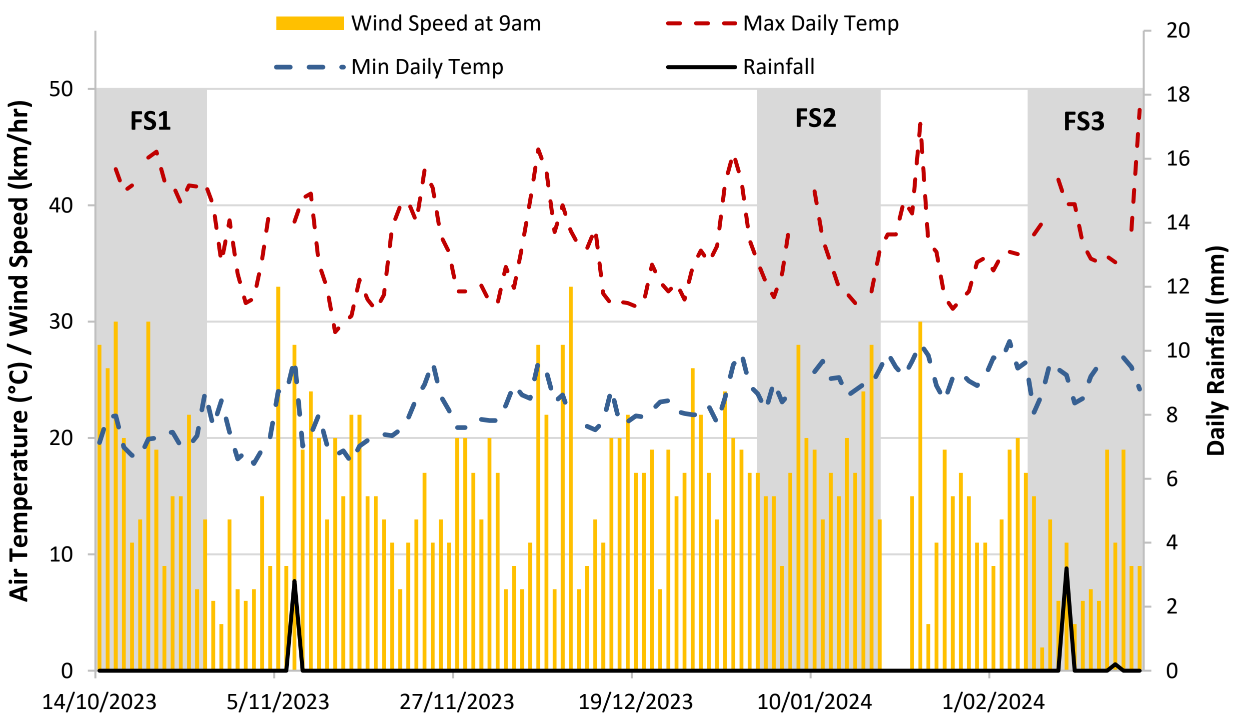


Figure 3: Daily rainfall, air temperature, and wind speed recorded at Mardie, Western Australia, between 14th October 2023 and 19th February 2024. Source: Mardie Station (station 005008), BoM. Grey shading indicates period of each field survey. Wind speed is taken as the measurement recorded at 9:00 am.

3.2 Nesting Habitat

3.2.1 Cape Preston East

The beach along the east of Cape Preston features ~4 km of suitable nesting habitat for marine turtles. The southern beach (~2.5 km) has a shallow slope and sandy approach, wide beach face and low primary dune that is densely vegetated (**Figure 4a**). It is bounded at either end by intertidal rock platforms. The northern beach (~1.5 km) has a shallower nearshore approach, a rocky intertidal platform and a tall, steeply sloping primary dune that is also densely vegetated (**Figure 4b**).

The conditions at CPE were excellent for adult track preservation, with tracks persisting for weeks to months on this beach.

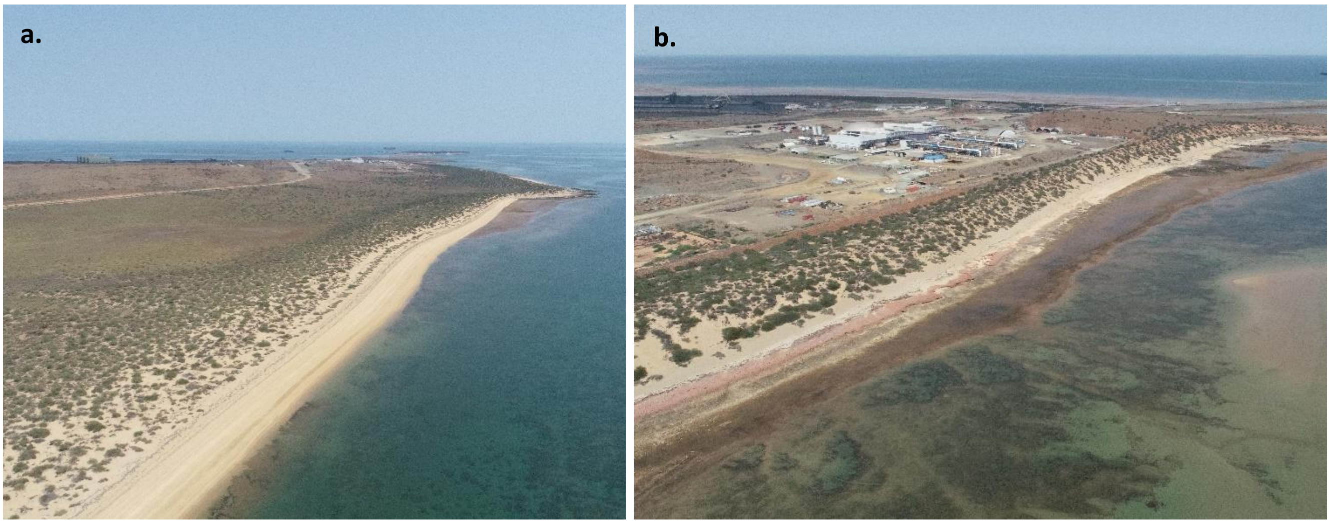


Figure 4: Cape Preston East Beaches: a. South; b. North

3.2.2 South West Regnard Island

SW Regnard Island is located ~4 km offshore to the northeast of Cape Preston. The island is predominantly bounded by intertidal rock platforms and reef, and features a long and thin sand spit extending from the south of the island that becomes fully submerged on a high spring tide. Viable nesting habitat is fragmented around the island, typically consisting of a thin sandy area between the top of the high tide line and the base of the tall primary dune. The total length of beach supporting nesting is estimated to be 1.1 km.

Track preservation at SW Regnard Island was moderate, with adult tracks persisting for multiple days to weeks. No evidence of predation of any nests was recorded during FS2 in January or FS3 in February. On 13th January 2024, eggs that had been discharged by a hawksbill turtle on the surface of the sand were observed at the northern end of the island (**Figure 5**). The eggs were situated along the returning 'down' track of the adult turtle and were below the recent high tide line. This occurrence may be due to repeat failed nesting attempts and unsuitable nesting conditions for the construction of an egg chamber in the sand, potentially caused by presence of large rocks and/or shallow bedrock in this area.

Figure 5: Hawksbill turtle eggs discharged on the surface of the beach at the northern end of South West Regnard Island.

3.2.3 North East Regnard Island

NE Regnard Island is located ~12 km northeast from Cape Preston, and ~7.5 km north of FMB (**Figure 1**). The island is predominantly bounded by intertidal rock and reef, with a long and thin sand spit extending from the south of the island that becomes fully submerged during a high spring tide. Suitable nesting habitat occurs along a ~500 m stretch of beach, extending north from the sand spit, along the eastern shoreline.

Track preservation on NE Regnard was moderate, with adult tracks lasting for days to weeks. There were a number of old and deep body pits. No evidence of predation of turtle eggs or hatchlings was recorded on the island.

3.2.4 Steamboat Island

Steamboat Island is located ~15 km offshore from Cape Preston in a north-westerly direction. The island is predominantly bounded by intertidal rock and reef, with only a short length of beach present on either side of sand spit at the southern end of the island (**Figure 6**). The primary dune behind the beach is low and moderately vegetated, and the total length of beach supporting nesting is estimated at 280 m. Recreational use of the island was observed during FS2 and FS3.

Track preservation on Steamboat Island was poor and highly dependent on wind direction. This is because the island is not shielded from south-westerly winds by the mainland (i.e. as Cape Preston provides some wind-sheltering for SW and NE Regnard) and does not have a tall hind-dune. Track preservation was therefore variable, with fresh adult tracks lasting less than one week. Due to excessive wind conditions in FS2, there was a period of four days where the field team was unable to access the island and any tracks were erased prior to detection, as confirmed by field observations (i.e. tracks recorded four days prior were no longer visible) (see **Appendix A**).

Figure 6: Nesting beach at Steamboat Island.

3.2.5 Forty Mile Beach (Gnoorea)

FMB is a southwest-northeast oriented beach to the east of Cape Preston, approximately 5.5 km in length (**Figure 1**). Similar to CPE, the length of the beach above the high tide line consists of habitat that would be suitable for turtle nesting, however the beach is open for public recreational use, including the use of off-road vehicles along the length of it (**Figure 7**). There is a campsite (Gnoorea) at the western end of the beach and a small boat ramp. The dune behind the beach is tall and densely vegetated, and the nearshore approach is shallow, with a reef platform extending ~1 km offshore from the beach.

Figure 7: Forty Mile Beach.

3.2.6 Cape Preston West

The beach along the west of Cape Preston features ~3 km of potentially suitable nesting habitat for marine turtles. The beach is oriented in a north-south direction, and has a shallow nearshore approach, with a reef platform extending up to 1 km from shore. The primary dune is low but densely vegetated, and some taller hills exist behind the dunes creating a natural topographic barrier between the eastern and western sides of the cape.

3.3 Track Census

3.3.1 Routine Survey

FS1 recorded 47 overnight hawksbill tracks, including 8 false crawls, 22 attempts, and 17 nests (**Table 4**). The nesting success rate (the number of successful nests as a percentage of the total number of overnight tracks) for this species during the peak of the nesting season was therefore 36.2 % which was higher compared to 2022/23 (14.7 %). One track (false crawl) from an unknown species was also recorded during the October survey on NE Regnard. No tracks from other marine turtle species were recorded.

FS2 recorded 11 overnight hawksbill tracks, including eight attempts and three false crawls, resulting in a 0 % nesting success rate which was lower compared to 2022/23 (0 %) (**Table 4**). Flatback tracks totalled six, including three nests, one attempt, and two false crawls, resulting in a nesting success rate of 16.7 % which was lower compared to 2022/23 (28.5 %). Three green tracks were also recorded, consisting of two nests and one false crawl, making nesting success 66.7 % for this species.

FS3 recorded 12 overnight hawksbill tracks, including one nest, eight attempts, and three false crawls, resulting in a nesting success rate of 8.3 %. One flatback turtle nest was also recorded, with no other tracks, making nesting success 100 % for this species (**Table 4**).

The species and nesting activity distributions at routine monitoring beaches (including Steamboat Island) are displayed in **Figures 8** – **11** for FS1 and FS2. No data is displayed for FMB as no adult tracks were detected there during any survey.

Table 4: Track census results for routinely surveyed locations for the 2023/24 nesting season. N = Nest; A = Attempt; FC = False Crawl. Numbers in red are from tracks recorded on the line-in day where the age of the track could not be determined.

Location	Hawksbill			Flatback			Green			Unknown		
	N	A	FC	N	A	FC	N	A	FC	N	A	FC
Field Survey 1												
SW Regnard	5 (0)	8 (8)	1 (1)	-	-	-	-	-	-	- (1)	- (1)	- (1)
NE Regnard	- (2)	- (1)	-	-	-	-	-	-	-	-	- (1)	1 (-)
Steamboat	11 (9)	13 (10)	7 (3)	-	-	-	-	-	-	-	-	-
CPE	1 (1)	1 (0)	-	-	-	-	-	-	-	- (3)	-	-
Total	**17 (12)**	**22 (19)**	**8 (4)**	**-**	**-**	**-**	**-**	**-**	**-**	**0 (4)**	**0 (2)**	**1 (1)**
Field Survey 2												
SW Regnard	- (1)	5 (17)	1 (2)	- (1)	- (1)	- (1)	-	-	-	-	- (1)	- (1)
NE Regnard	- (1)	- (1)	-	-	-	-	-	-	-	- (1)	-	-
Steamboat	- (2)	3 (3)	2 (-)	2 (-)	1 (-)	2 (-)	2 (1)	- (1)	1 (-)	-	- (1)	- (1)
CPE	- (1)	- (2)	-	1 (-)	-	-	- (1)	-	-	- (1)	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	**- (5)**	**8 (23)**	**3 (2)**	**3 (1)**	**1 (1)**	**2 (1)**	**2 (2)**	**- (1)**	**1 (-)**	**- (2)**	**- (2)**	**- (2)**
Field Survey 3												
SW Regnard	1 (-)	- (1)	-	-	-	-	-	-	-	-	-	-
NE Regnard	-	-	-	-	-	-	-	-	-	-	-	-
Steamboat	-	8 (3)	3 (1)	1 (3)	- (3)	-	-	-	-	-	- (1)	-
CPE	-	- (1)	-	-	-	-	-	-	-	-	-	-
FMB	-	-	-	-	-	-	-	-	-	-	-	-
Total	**1 (-)**	**8 (12)**	**3 (1)**	**1 (3)**	**- (3)**	**-**	**-**	**-**	**-**	**-**	**- (1)**	**-**

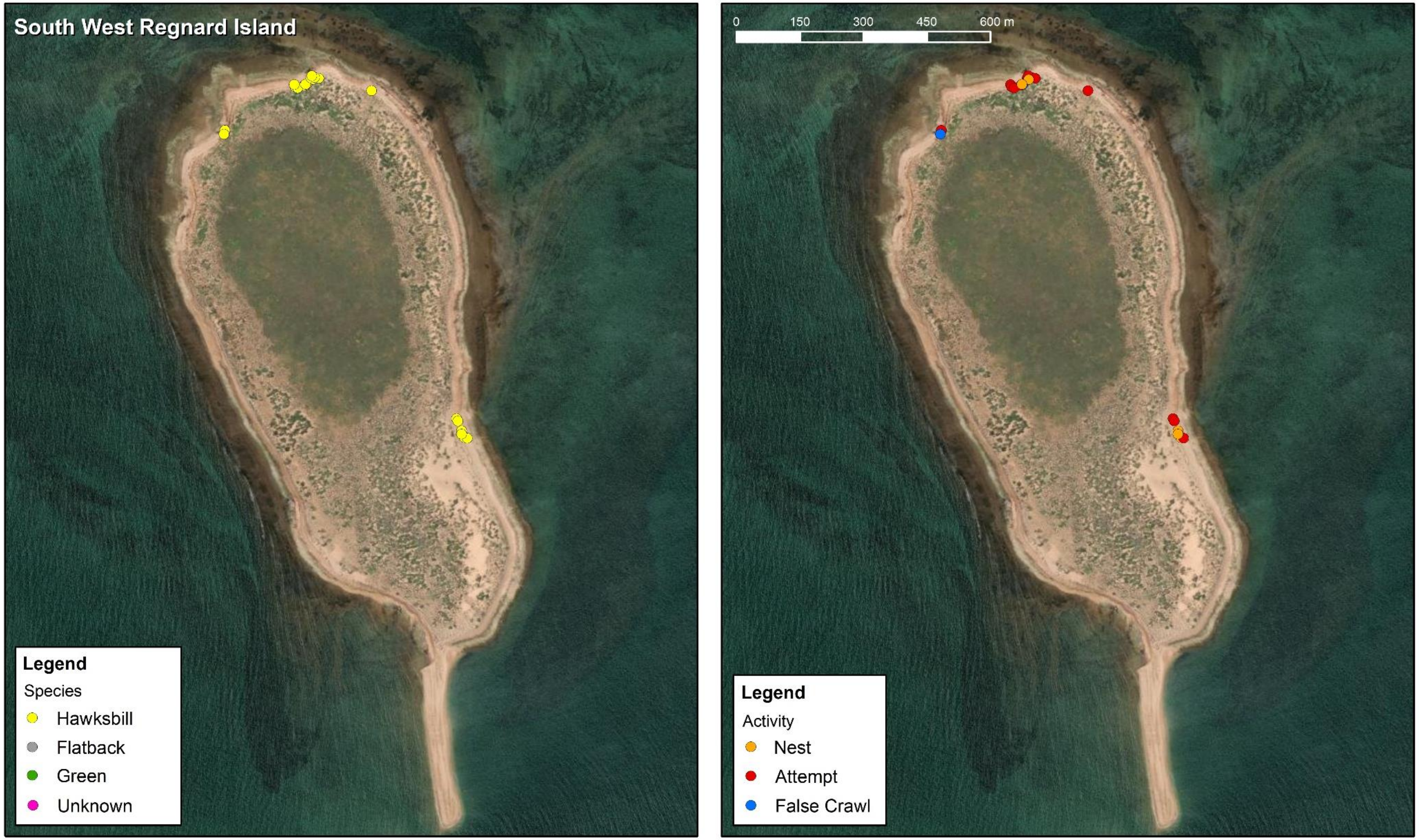
3.3.1.1 Comparison with 2022/23

At SW Regnard Island, overnight nesting activity was primarily distributed across the island's northern side and in an area on the eastern side (**Figure 8**). Recorded species was entirely hawksbill turtles. This distribution and species use was consistent with 2022/23, which also recorded activity in these same areas from predominantly hawksbill turtles.

At NE Regnard Island, the limited overnight nesting activity was distributed on the north-west side of the island which was consistent with 2022/23 (**Figure 9**). Due to the low level of nesting activity, no comparison of recorded species is provided.

At CPE, all overnight nesting activity was recorded on the northern beach at CPE which was consistent with 2022/23 (**Figure 10**). Recorded species was a mixture of hawkbill (n = 2 tracks) and flatback (n = 1 track) turtles. This distribution and recorded species were largely consistent with 2022/23, with the exception of no overnight flatback nesting activity recorded in 2022/23.

At Steamboat Island, all overnight nesting activity was recorded on the island's south-east side, with some activity at the end of the sand spit (**Figure 11**). Recorded species was predominantly hawksbill turtle (n = 33 tracks), with some flatback (n = 5 tracks) and green (n = 3 tracks) turtles. This distribution and species use was consistent with 2022/23, which also recorded activity in these same areas from predominantly hawksbill turtles.



J10603 Eramurra Marine Turtle Monitoring

Figure 8: South West Regnard Island combined track census results for FS1 (14 days, October 2023) and FS2 (15 days, January 2024).

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Figure 9: North East Regnard Island combined track census results for FS1 (14 days, October 2023) and FS2 (15 days, January 2024).

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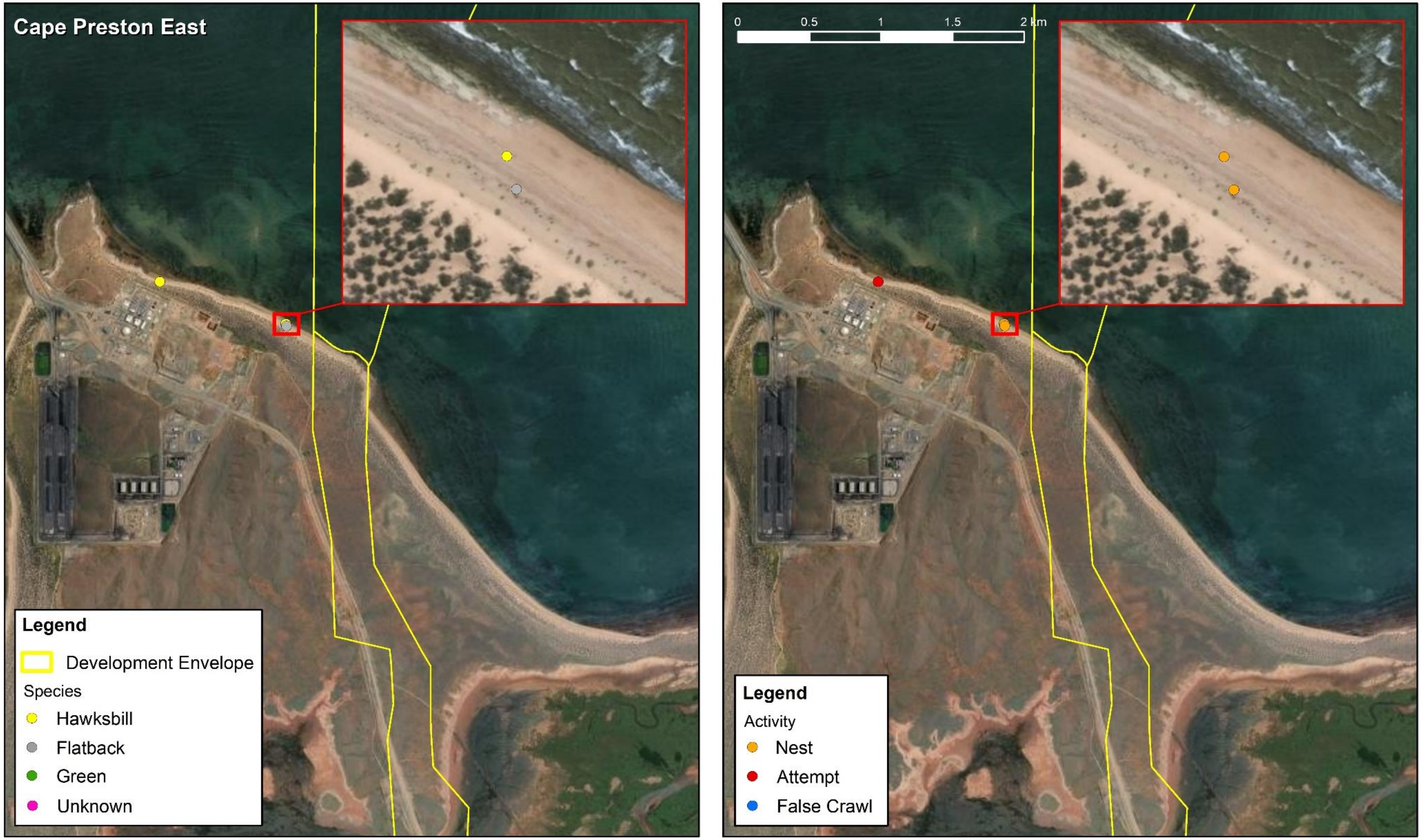

J10603 Eramurra Marine Turtle Monitoring

Figure 10: Cape Preston East combined track census results for FS1 (14 days, October 2023) and FS2 (15 days, January 2024).

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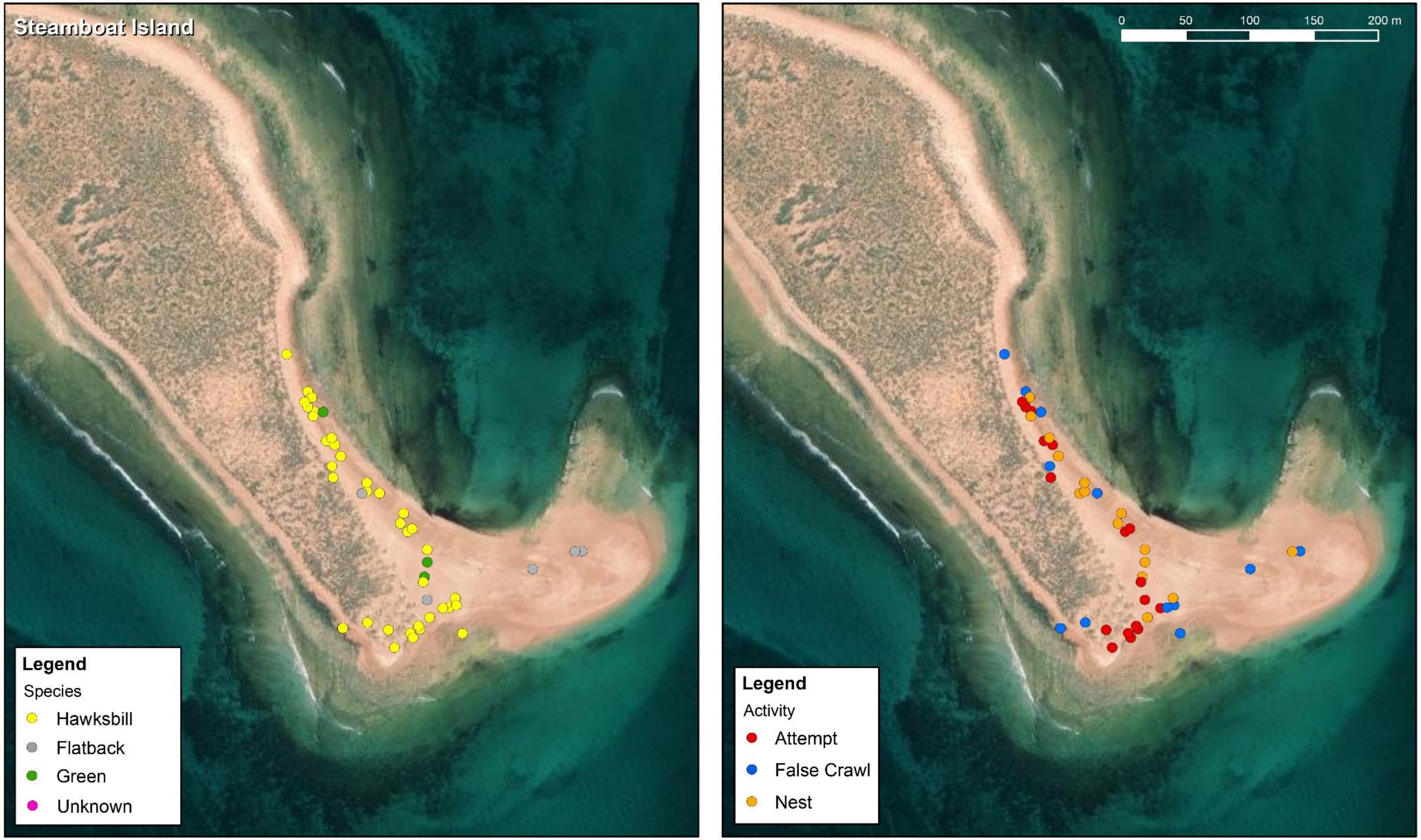

J10603 Eramurra Marine Turtle Monitoring

Figure 11: Steamboat Island combined track census results for FS1 (14 days, October 2023) and FS2 (15 days, January 2024).

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3.3.1.2 Nester Abundance

Estimates of nester abundance typically assume that 70 – 80 % of turtles of each species would be available for nesting during the mean 14-day inter-nesting period at the respective peak of the nesting season (Whittock et al. 2014). An overall nester abundance has been estimated for each species by combining the track census data for all routine monitoring locations. For example, the nester abundance estimate for hawksbill turtles is determined from all nesting data at SW Regnard Island, NE Regnard Island, Steamboat Island, and CPE beach from FS1, with the same applied for flatback and green turtles from nesting data in FS2. Where the nester abundance is estimated to be zero for a species based on track census results (i.e. no nests detected), observations from outside the survey period are considered to ensure nesting activity is adequately represented.

Nester abundance estimates are used in the risk assessment to determine the nesting habitat contribution to the respective regional genetic stocks (**Section 4.1.1**).

Hawksbill Turtles

Based on successful nest counts for the 14-day survey in October 2023, the overall annual nester abundance estimate for hawksbills during the October peak is 21 – 24 individual turtles, with Steamboat Island experiencing the heaviest use. Note that this estimate is higher compared to 2022/23 due to the inclusion of Steamboat Island as a routine monitoring site this season. If data captured from Steamboat Island is excluded from this season, the estimate is 8 – 9 individual turtles which is comparable to 2022/23 (6 – 7 turtles).

Flatback Turtles

Based on successful nest counts for the 14-day survey in January 2024, the overall nester abundance estimate for flatbacks is 3 – 4 individual turtles. This estimate is comparable to what was reported in 2022/23 (2 – 3 turtles).

Green Turtles

Based on successful nest counts for the 14-day survey in January 2024, the overall nester abundance estimate for individual green turtles is 2 – 3, with no other green nesting activity detected outside of the survey period at routine monitoring locations. This estimate is comparable to what was reported in 2022/23 (2 – 4 individual turtles).

3.3.2 Opportunistic Survey

At FMB, one track was identified as an attempt during FS1 in October. The track could not be accurately assigned to a species as it was old and wind-blown, erasing many of the identifying features required to make a classification. At CPW, one flatback turtle track was identified as a false crawl during FS2 in January.

3.4 Hatchling Orientation

A total of 10 hatchling nest fans were recorded during FS2 in January (*n* = 7) and FS3 in February (*n* = 3) (**Table 5**). The seven nest fans recorded during FS2 occurred on CPE (*n* = 2), Steamboat (*n* = 2), SW Regnard (*n* = 2), and NE Regnard (*n* = 1) islands. All three nest fans recorded during FS3 occurred on Steamboat Island. From a species perspective, one fan was from a flatback nest, four from hawksbill nests, and five where the species was not identified.

Table 5: Summary statistics for nest fans. Where a mean could not be calculated (i.e. where *n* = 1), the individual spread and offset angle is given. Standard deviation was not calculated for sample size ≤ 3.

Location	Spread Angle (°)				Offset Angle (°)			
	2023/24		2022/23 & 2023/24		2023/24		2022/23 & 2023/24	
	n	Mean ± StDev	*n*	Mean ± StDev	*n*	Mean ± StDev	*n*	Mean ± StDev
SW Regnard	2	58.5 ± NA	4	52.3 ± 14.0	2	5.8 ± NA	4	5.4 ± 1.1
NE Regnard	1	75.0 ± NA	2	56.0 ± NA	1	25.5 ± NA	2	22.0 ± NA
Steamboat	5	77.8 ± 38.4	22	61.7 ± 32.0	5	36.3 ± 31.5	22	27.6 ± 21.6
CPE	2	48.5 ± NA	5	64.2 ± 15.2	2	4.8 ± NA	5	5.6 ± 2.1

Summary statistics for all hatchling orientation metrics this season (pooled for both surveys) and when combined with the previous season (2022/23), including nest fan spread and offset angles, are provided in **Table 5**. All nest fans recorded this season are displayed in **Figure 12** – **Figure 14**. Nest fans on SW Regnard Island, NE Regnard Island, and CPE showed no signs of mis- or dis-orientation, with all fans having small spread and offset angles, indicating dispersal along the most direct route to the ocean. There were also no outliers recorded for these nest fans.

Three nest fans situated on the centre of the sand spit on Steamboat Island had larger spread and/or offset angles (**Figure 14**). Two of these recorded a spread angle of >90° and offset angle of >60°, indicating severe mis- and dis-orientation.

These nest fans may have exhibited larger spread and/or offset angles due to their location on the sand spit and the access to the ocean on either side of the nest. When ocean finding, hatchlings use natural cues to orient themselves, including moving towards the brightest horizon over the ocean and away from tall dark silhouettes, such as those formed by dunes behind the beach (Lohmann & Lohmann 1996; Salmon et al. 1992; Limpus & Kamrowski 2013). These cues may be obscured for hatchlings emerging on spits due to:

- the shortest distance to the ocean occurring on multiple and opposite bearings from the emergence point; or
- a low dune profile behind the sand spit, reducing the scale and influence of a tall dark horizon behind the nests.

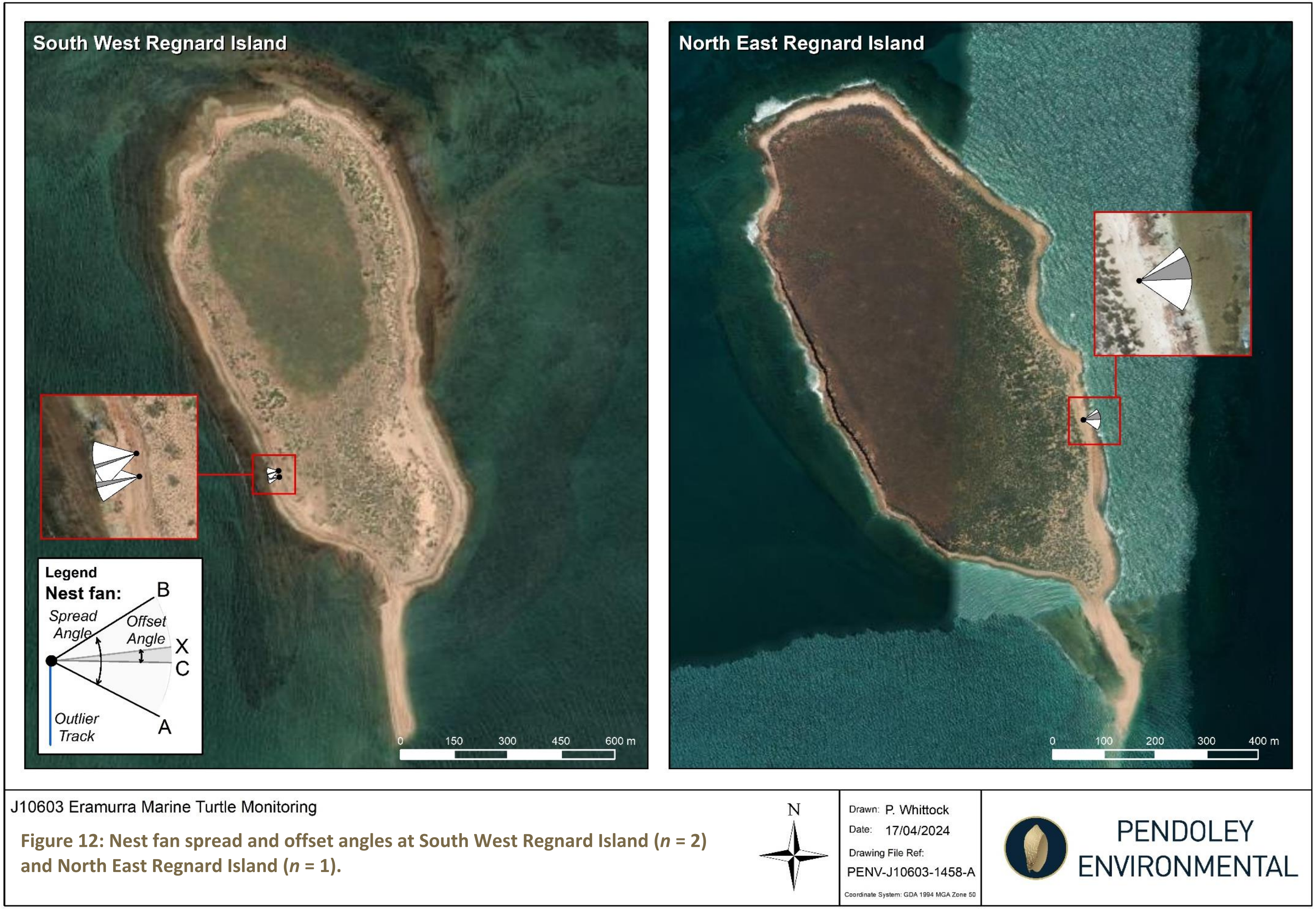

Figure 12: Nest fan spread and offset angles at South West Regnard Island (*n* = 2) and North East Regnard Island (*n* = 1).

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Figure 13: Nest fan spread and offset angles at Cape Preston East (*n* = 2).

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Figure 14: Nest fan spread and offset angles at Steamboat Island (*n* = 5).

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4 RISK ASSESSMENT

The findings of the 2023/24 monitoring program, as detailed in this report, have been used to update and consolidate the light spill risk assessment conducted in the previous season (2022/23; PENV 2023). The incorporation of monitoring data from two breeding seasons at SW Regnard, NE Regnard, and CPE to assess the importance of the marine turtle population(s) and help inform the risk assessment, aligns with the recommendations of the NLPGW (Commonwealth of Australia 2023).

In 2022/23, Steamboat Island was not monitored routinely for the entirety of the monitoring program and therefore the importance of the marine turtle population that used the island could not be assessed in that season. Consequently, the island was not included within the 2022/23 risk assessment. However, this season, routine monitoring has been implemented, making Steamboat Island eligible for inclusion in this risk assessment.

4.1 Approach

The potential for artificial light to impact on the sea-finding behaviour of hatchling turtles in the vicinity of the Project was assessed using a risk assessment matrix (**Table 6**), modified from the Great Barrier Reef Marine Park Authority Environmental Assessment and Management Risk Management Framework (GBRMPA 2017). The matrix applies a score to the ‘Likelihood’ of an impact occurring, and the potential ‘Consequence’ of the impact occurring and combines these scores to determine an overall risk rating.

This process assessed the potential for artificial light to cause mis- or dis-orientation of hatchling sea turtles of all species occurring in the vicinity of the Project (hawksbill, flatback, and green), leading to a reduced fitness or mortality, when compared to ‘benchmark’ (Project pre-construction) light conditions. The Project lighting environment, and that of the Cape Preston East Export Facility (CPEEF) has been modelled using a preliminary lighting inventory provided to PENV (see PENV 2022). The modelling represents the unmitigated (‘worst-case’) visibility of light associated with the Project and CPEEF under clear-sky conditions during a new moon period.

The risk assessment considered light sources both individually (i.e. directionality, intensity, and visibility of light from each source), and cumulatively (i.e. the cumulative contribution to visible direct light and sky glow from existing and proposed sources, as informed by light modelling), to determine an overall risk rating to hatchlings emerging at each routine monitoring location: CPE, SW Regnard Island, NE Regnard Island, Steamboat Island, and FMB. A description of each Consequence criteria is provided in **Section 4.1.1**, and each Likelihood criteria is provided in **Section 4.1.2**.

Table 6: Risk Assessment Matrix.

Likelihood (see Table 10 for definition)	**Consequence (see Table 9 for definition)**				
	Insignificant 1	*Minor* 2	*Moderate* 3	*Major* 4	*Catastrophic* 5
Almost certain 5	**Medium** 5	**High** 10	**High** 15	**Extreme** 20	**Extreme** 25
Likely 4	**Medium** 4	**Medium** 8	**High** 12	**High** 16	**Extreme** 20
Possible 3	**Low** 3	**Medium** 6	**Medium** 9	**High** 12	**High** 15
Unlikely 2	**Low** 2	**Low** 4	**Medium** 6	**Medium** 8	**High** 10
Rare 1	**Low** 1	**Low** 2	**Low** 3	**Medium** 4	**Medium** 5

4.1.1 Description of Consequence Criteria

When determining the consequence of the impact, two factors were considered:

1. The significance of the nesting population at impact sites, based on the relative contribution of breeding individuals to the overall genetic stock (**Section 4.1.1.1**); and

2. The length of time over which turtle hatchlings may be exposed to the impact (**Section 0**).

4.1.1.1 Importance of Nesting Population

Approach

As per the NLPGW (Commonwealth of Australia 2023), when determining the consequence score of a development's risk assessment, it is necessary to consider the importance of potential impact sites to marine turtle nesting, relative to the overall genetic stock of the nesting species. Benchmark marine turtle monitoring undertaken during the 2022/23 and 2023/24 breeding seasons successfully recorded nesting activity data during the peak breeding period of each known marine turtle species across one inter-nesting cycle in each season, allowing for an estimate of the annual abundance of adult nesters for each species at routine monitoring locations (see **Section 3.3.1.2**).

To compare the estimated annual abundance of adult nesters within the vicinity of the Project to the overall genetic stock, it was also necessary to estimate the overall annual nester abundance for each stock. For the purpose of this impact assessment, nester abundance estimates for each regional genetic stock (H-WA, F-Pil and G-NWS), were informed using the following resources:

- IUCN Red List Assessments (https://www.iucnredlist.org/): These assessments are available for each marine turtle species at a scale of the overall population within Australia and, for some species, each genetic stock/subpopulation. The assessments include estimates of the population abundance for some nesting sites and for the overall stock/subpopulation.

- Queensland Government Department of Environment and Science Turtle Nesting Distribution Abundance and Migration Atlas Project: Provides an estimated range of annual nesters at areas of nesting habitat (Queensland Government 2021). Note that only those areas with an estimated range of 101 – 500 nesting females per year or above were considered within the population estimate.

The upper estimate for the annual abundance of adult nesters within the vicinity of the project presented in this report was then divided by the total annual abundance of adult nesters for each genetic stock to determine the percentage contribution to the overall stock for each species. One limitation within the NLPGW is that it does not include a threshold for when the percentage contribution of marine turtle nesting to the genetic stock is considered important. Therefore, this assessment used the Queensland Government's definition for matters of state environmental significance specific to marine turtle nesting areas (Queensland Government 2022) to determine the threshold of significance, including:

- Highly important = >40 % of the species or genetic stock rely on the nesting area
- Important = >1 % of the species or genetic stock rely on the nesting area
- Present but unimportant = <1 % of the species or genetic stock rely on the nesting area

One limitation is that this approach only considers the size of the population when assessing the importance of marine turtle nesting. To overcome this and provide additional context and supporting information, we also considered the nesting success of all species during their respective peak nesting periods across the project area. Note that other factors that could contribute to the overall importance of a nesting area, such as the species' conservation status or recovery potential, location within its range of nesting, cumulative exposure to existing threats, cultural significance to Aboriginal communities, or its economic/scientific/ recreational/educational value, were excluded.

Outcome

The combined nester abundance for each stock at the routinely monitored locations in each season (2022/23: NE Regnard Island, SW Regnard Island, CPE and FMB; 2023/24: NE Regnard Island, SW Regnard Island, CPE and Steamboat Island), are provided in **Table 7**, alongside the estimated nester abundance for each relevant genetic stock. A level of importance was assigned according to the 'Contribution to Genetic Stock' estimate.

Table 7: Relative importance of each species of marine turtle nesting in the vicinity of the Project in relation to its contribution to the overall genetic stock. *2022/23 routine beaches include NE Regnard Island, SW Regnard Island, CPE, and FMB; **2023/24 routine beaches includes NE Regnard Island, SW Regnard Island, CPE, and Steamboat Island.

Species	Genetic Stock	Project: Annual Nester Abundance		Genetic Stock: Annual Nester Abundance	Contribution to Genetic Stock (%)		Level of Importance
		2022/23*	2023/24**		2022/23	2023/24	
Hawksbill	**H-WA**	6 – 7	21 – 24	4,000	0.18*	0.60	Unimportant
Flatback	**F-Pil**	2 – 3	3 – 4	8,000	0.04	0.05	Unimportant
Green	**G-NWS**	1 – 2	2 – 3	25,000	0.01	0.01	Unimportant
Cumulative Total		9 – 12	26 – 31	37,000	0.03	0.08	Unimportant

The combined nesting success for hawksbill and flatback turtles at all monitored nesting sites during the two monitoring seasons has been low (hawksbill: 2022:/23: 14.7 %, 2023/24: 36.2 %; and flatback: 2022/23: 28.5 %, 2023/24: 16.7 %) (see **Section 3.3.1**). This indicates that the nesting habitat does not support a high rate of successful nesting and its importance is low. Note that for green turtles, the very low total number of overnight tracks (2 in 2022/23; and 3 in 2023/24) prevents any meaningful insights into the importance of the species' nesting success.

4.1.1.2 Duration of Impact

The duration of impact describes the time over which a species is exposed to an impact, which in the case of the Project describes the time over which artificial light emissions (from construction and operational phases of the Project and CPEEF) are visible from nesting habitat. For the purpose of this assessment, impact durations have been categorized as short-term, medium-term, or long-term (**Table 8**).

The generation time of a species is used by the IUCN when assessing the potential impact of threats and estimating the risk of their extinction. Using a generational scale for the relevant species is considered to be more appropriate than a year scale (O'Grady et al. 2008). In this assessment, the generation time of marine turtles is defined as the age of their sexual maturation and commencement of breeding, which is estimated at 30 – 35 years for Indo-Pacific hawksbill turtles (Mortimer & Donnelly 2008), 12 – 23 years for flatback turtles (Tomaszewicz et al. 2022; IUCN data deficient) and 30 – 40 years for green turtles (Seminoff 2004).

Table 8: Description of impact duration.

Description	Duration
Short term	A period that is less than five years.
Medium term	A period longer than five years and shorter than the generation time of the local marine turtle species.
Long term	A period longer than the generation time of the local marine turtle species.

4.1.1.3 Consequence Criteria

Consequence criteria derived from the above rationale are provided in **Table 9**.

Table 9: Definition of consequence descriptions.

Description	Definition
Insignificant	The population is unimportant relative to the size of the genetic stock (<1 %).
Minor	The population is important and artificial light will be visible from their habitat short-term. There will be no detectable effect at a population level.
Moderate	The population is important and artificial light will be visible from their habitat medium-term. There may be a negative effect on the population before recovering.
Major	The population is important and artificial light will be visible from their habitat long-term. There may be a detectable decline in the population that may recover over a prolonged period.

Description	Definition
	The population is very important and artificial light will be visible from their habitat medium-term. There may be a detectable decline in the population that may recover over a prolonged period.
Catastrophic	The population is very important and artificial light will be visible from their habitat long-term. The population may become extinct and will not recover.

4.1.2 Description of Likelihood Criteria

Hatchling sea turtles typically emerge from their nest on the beach at night (Mrosovsky & Shettleworth 1968) and must crawl rapidly to reach the ocean to avoid predation (Salmon 2003). They find the ocean using a combination of topographic and brightness cues, orienting towards the lower, brighter oceanic horizon, and away from elevated darkened silhouettes of dunes and/or vegetation behind the point of their emergence on the beach (Pendoley & Kamrowski 2015; Lohmann et al. 1997; Limpus & Kamrowski 2013; Salmon et al. 1992). Artificial light can interfere with these cues, influencing their sea-finding behaviour (Withington & Martin 2003; Pendoley & Kamrowski 2015; Kamrowski et al. 2014). As a result, hatchlings may become disorientated - where they crawl in circuitous paths; or misorientated - where they move in the wrong direction, resulting in an increased mortality rate due to exhaustion, dehydration, or increased exposure to predation (Withington & Martin 2003; Lohmann et al. 1997; Salmon 2003).The NLPGW recommends that when assessing the likelihood of the effect of a development's light on hatchling turtles, the risk assessment should consider how they will perceive visible light from their habitat and whether it could influence their sea-finding behaviour described above (Commonwealth of Australia 2023). The likelihood assessment was undertaken by a PENV Subject Matter Expert, who considered the modelled light emissions for the Project alongside numerous physical and biological variables to determine the likelihood of sources impacting hatchling behaviour (see PENV 2022). Major factors considered include:

- Presence/absence of a tall, dark silhouette behind the habitat;
- Natural shielding of light from vegetation or topographic features;
- Orientation of light sources and distance from the nesting habitat;
- Wavelength and intensity of modelled light; and
- Hatchling turtle perception of light.

Likelihood criteria were then applied to each routine monitoring location, as per the definitions in **Table 10**.

Table 10: Definition of likelihood descriptions.

Description	Definition
Rare	Hatchling turtles could be dis- and misoriented but will reach the ocean. May occur during new moon conditions but only when light is amplified by atmospheric conditions such as the presence of cloud.
Unlikely	Hatchling turtles could be dis- and misoriented but will reach the ocean. May occur during new and full moon conditions but only when light is amplified by atmospheric conditions such as the presence of cloud.
Possible	Hatchling turtles could be dis- and misoriented meaning some hatchlings may not reach the ocean. May occur during new moon conditions under all atmospheric conditions.
Likely	Hatchling turtles could be dis- and misoriented meaning some hatchlings may not reach the ocean. May occur during new and full moon conditions under all atmospheric conditions.
Almost certain	Hatchling turtles could be severely dis- and misoriented meaning most will not reach the ocean. May occur throughout the hatching season during all moon phases and atmospheric conditions.

4.1.3 Limitations

The following limitations apply to this risk assessment:

- The risk assessment only considers light as it is visible to hatchlings emerging on a beach and makes no assumptions about the visibility of light or its influence on the dispersal patterns of hatchlings once they reach the water. There are many additional directional cues thought to impact hatchlings in the water, such as wave, light and current cues (Lohmann & Lohmann 1996; Pilcher et al 2000; Wilson et al 2018), and these factors cannot be accounted for with the information presently available for the Project site.
- The Project lighting inventory is in the preliminary stages of planning and proposed mitigation measures consistent with the Best Practice Lighting Design Principles (outlined in the NLPGW) are not available at the time of assessment. Therefore, no assessment of the residual risk to hatchling turtles (i.e. the reduced risk that Project lighting poses after mitigation measures have been applied) has been undertaken.

4.2 Risk Assessment

Due to the low nester abundance of all three species recorded during the 2022/23 and 2023/24 monitoring seasons (**Table 7**), the cumulative contribution of nesting females to the genetic stock of each species was <1 %. Furthermore, the nesting success of hawksbill and flatback turtles in both seasons was low (nesting success for green turtles was not considered due to the very low number of overnight nesting activity). Each monitoring location therefore meets the **Insignificant** consequence criteria under the risk assessment matrix, as the contribution for each location is even less than the cumulative estimate. This means, that due to the low level of nesting observed in the vicinity of the Project, any impacts caused by light are not expected to have implications on the respective genetic stocks.

Likelihood criteria are discussed for each location in the following sections, and an overall risk rating assigned taking into account the universal consequence rating of **Insignificant**.

4.2.1 Cape Preston East

CPE beach (LM1; see **Figure 1**) was predicted to be the brightest location from light modelling due to development of the CPEEF. Although approved separately to the Project, this site is subject to assessment from a cumulative perspective, as it will contribute to the cumulative artificial light footprint with Cape Preston (Citic Pacific) and the Eramurra Solar Salt Project (Leichhardt). At Cape Preston East beach, light from the CPEEF will be directly visible from nesting habitat as the topography at this location provides minimal natural shielding of direct light and sky glow from the proposed port lighting. Other Project facilities and the ocean-going vessel (OGV) anchorages will also be visible as sources of sky glow on the horizon.

Due to construction of the CPEEF occurring through potential nesting habitat, and the intensity of lighting proposed for the facility, there is a **Likely** likelihood that there will be an impact on the emergence behaviour of hatchling turtles. Hatchlings may crawl up the beach towards port infrastructure or become entrained in light on the beach and crawl in circuitous patterns in proximity to it. This may result in some hatchlings not making it to the ocean due to exhaustion or increased exposure to predation.

The likelihood and consequence rankings consider the inherent risk to be **Medium** at CPE (**Table 11**).

4.2.2 South West Regnard Island

Project lighting visibility was assessed from two locations on South West Regnard Island in June 2022, informed by the limited information available on nesting distribution (prior to the 2022/23 monitoring season). Results showed that nesting habitat at the northern end of the island (LM2; see **Figure 1**), will largely be shielded from Project lighting and CPEEF by a tall dune. New light sources will contribute to the cumulative glow visible above the elevated dune horizon on the same bearing as the existing Sino Iron facilities at Cape Preston. The greatest change in horizon brightness will result from the addition of the OGV anchorages, which are visible as direct and unshielded sources of light directly offshore from the beach.

On the eastern beach of SW Regnard Island (LM3; see **Figure 1**), the increase in horizon brightness is predicted to be higher than the northern beach, as the dune is lower at this location. The increase will primarily be caused by the contribution to sky glow from the CPEEF on the same bearing as Cape Preston (Sino Iron), however some glow from the Project facilities and OGV Anchorages will also be visible.

The results of the 2022/23 and 2023/24 monitoring seasons indicated that SW Regnard Island supports more hawksbill turtle nesting than the adjacent mainland at CPE and nearby NE Regnard Island. The distribution of activity in both seasons (see **Section 3.3.1.1**) matched that reported in a 2008 survey (PENV 2009), where the highest density of nesting occurred at the northern end of the island, and is therefore shielded from most of the current and future light sources proposed for the mainland. However, the proposed trans-shipment vessel (TSV) route runs along the length of the western shoreline of the island, within ~1 km at the closest point, and transient light from TSVs may be directly visible to hatchlings as vessels approach the OGV anchorages to the north of the island.

As nesting occurs on fragmented lengths of beach around the northern side of the island, the visibility of light from nesting habitat is variable. There is a **Possible** likelihood of impact on the sea-finding behaviour of hatchling turtles, either from the cumulative sky glow on the mainland, which is bright at the east and southern ends of the island but some distance away, or from the vessels, which are transient light sources but much closer to the nesting habitat.

The likelihood and consequence rankings consider the inherent risk to be **Low** at SW Regnard Island (**Table 11**).

4.3 North East Regnard Island

The nesting beach on NE Regnard Island (LM4; see **Figure 1**) will experience a small increase in glow on the horizon associated with the Project facilities and CPEEF. The nesting beach is largely shielded from the mainland by a tall primary dune, and as a result the glow is only predicted to be visible above the elevated dune horizon. The brightest sources of light visible at NE Regnard Island are the Burrup Peninsula and Karratha townsites, and these are located offshore from the beach, and up to 50 km away.

The cumulative glow from the Project facilities, CPEEF and Cape Preston (Sino Iron) is **Unlikely** to impact on the orientation of hatchlings at NE Regnard Island due to the distance of light sources from the island, and the moderating influence of the dunes, which creates a tall, dark horizon for hatchlings to orient away from. Sky glow from the Project and CPEEF may be amplified by atmospheric conditions (i.e. cloud and aerosols) on some nights, and it is under these circumstances that the accumulation of sky glow from Cape Preston could cause a change in hatchling behaviour.

The likelihood and consequence rankings consider the inherent risk to be **Low** at NE Regnard Island (**Table 11.**

4.4 Steamboat Island

The nesting beach at Steamboat Island supports the highest level of marine turtle nesting activity out of all routinely monitored locations, with the majority of activity recorded from hawksbill turtles nesting on the beach situated on the island’s south-east side.

The nesting beach is situated ~15 km from the Project Facilities on the mainland and ~19 km from the OGV anchorages. As a result of this distance, any visible Project-related artificial light is likely to be of low intensity sky glow. Furthermore, the closer Project-related light on the mainland will be shielded by the Cape Preston (Sino Iron) causeway and offloading facility, further reducing the visibility of any light spill (see **Figure 1**).

The cumulative glow from the Project facilities, CPEEF, and Cape Preston (Sino Iron) is **Unlikely** to impact on the orientation of hatchlings at Steamboat Island due to the distance of light sources from the island. When the cumulative glow of all facilities is amplified by cloud, the light may be bright enough to cause mis- or disorientation in some hatchlings.

The likelihood and consequence rankings consider the inherent risk to be **Low** at Steamboat Island (**Table 11**).

4.5 Forty Mile Beach

The nesting beach at FMB is very marginal, with no nesting by any species detected during the 2022/23 monitoring season and only one hawksbill turtle track in 2023/24. Historical reports have recorded nominal flatback nesting activity on the beach (i.e. one track per survey), and it is noted that the beach has moderate 4WD use, which may deter adults nesters from laying here.

Modelling predicts FMB (LM5 ; see **Figure 1**) is to experience only small changes in horizon brightness from the benchmark state as a result of new Project development and the CPEEF. The CPEEF will occur on the same bearing as Cape Preston (Sino Iron), and will contribute to cumulative sky glow, increasing the overall visibility of light to the west of the beach. The visibility of Project lighting at FMB will be different according to a hatchlings position on the beach, and generally be visible as glow above the elevated dune horizon, if visible at all.

The cumulative light from the Project and CPEEF is **Unlikely** to impact on hatchling behaviour at FMB due to the tall hind dune creating a natural, dark barrier between the beach and Project lighting. When the cumulative glow of all facilities is amplified by cloud, the light may be bright enough to cause mis- or disorientation in some hatchlings. The likelihood and consequence rankings consider the inherent risk to be **Low** at FMB (**Table 11**).

Table 11: Risk assessment outcome.

Location	Consequence	Likelihood	Ranking
Cape Preston East	Insignificant	Likely	Medium
South West Regnard	Insignificant	Possible	Low
North East Regnard	Insignificant	Unlikely	Low
Steamboat	Insignificant	Unlikely	Low
Forty Mile Beach	Insignificant	Unlikely	Low

4.6 Recommendations

Despite the consequence of light impacts from the Project being described as **Insignificant** for each genetic stock, the potential for light causing a change in the behaviour of individual hatchlings is considered **Possible** at SW Regnard Island and **Likely** at CPE. Considering the Precautionary Principle, it is therefore recommended that the Project consider the ways in which the lighting design can be revised to better meet the Best Practice Lighting Design Principles (Commonwealth of Australia 2023). In addition, the best practice lighting design will further reduce the likelihood of any potential impact in the event of long-term climate change induced shifts in spatial and temporal nesting effort by the three species within the region.

5 CONCLUSION

Marine turtle monitoring was undertaken over the 2023/24 summer to investigate the distribution and abundance of species nesting on beaches in the vicinity of the Eramurra Solar Salt Project. Three routine surveys, each spanning a minimum of 14 days, identified three species of turtles nesting:

hawksbill, flatback, and green. Nesting activity was spread across accessible nesting habitat at SW Regnard and Steamboat Islands, with lower levels of activity recorded at NE Regnard Island and CPE. Of the three species, hawksbill turtles were the most abundant, with the highest activity recorded on Steamboat Island during the October two-week monitoring period.

In addition to adult nesting activity, hatchling fans were recorded during the second two surveys to establish a benchmark of two seasons of hatchling behaviour (2022/23 and 2023/24). Fans were recorded on SW Regnard Island, NE Regnard Island, CPE, and Steamboat Island. There was no evidence of mis- or disorientation in the fans recorded, with the exception of some fans on Steamboat Island that were mis- and/or disorientated (i.e. wide spread angles) due to their position on the island spit.

A risk assessment was undertaken to evaluate the potential for artificial light occurring in the vicinity of the Project to cause mis- or disorientation of hatchling sea turtles. The assessment was informed by a light modelling report prepared separately for LEIC (PENV 2022) and considered other physical and biological factors that influence hatchling sea-finding behaviour, as well as the relative importance of nesting females and the success of their breeding activities to the relevant genetic stocks. Due to the low nester abundance of all three species recorded during the 2022/23 and 2023/24 monitoring seasons, the cumulative contribution of nesting females to the genetic stock of each species was <1 % which was considered unimportant. Furthermore, the nesting success of hawksbill and flatback turtles in both seasons was low, indicating that the nesting habitat is unlikely to support breeding activities that provide an important contribution to the genetic stock.

The risk assessment determined the inherent (unmitigated) risk to be **Low** at NE Regnard Island, SW Regnard Island, FMB, and Steamboat, and **Medium** at CPE. Despite the low-risk outcomes of the assessment, it is recommended that the Project review and apply mitigation measures to external lighting to reduce the likelihood of impact on individual hatchlings, according to the Best Practice Lighting Design Principles outlined in the NLPGW. Furthermore, these mitigation measures and best practice measures will reduce the likelihood of impact to other light-sensitive species that may be present, including terrestrial mammals, bats, and migratory shorebirds/seabirds.

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Appendix A: Field Survey Schedule

Table A1: Field Survey Schedule. X = survey day.

Date	Survey Location					
	SW Regnard Is.	NE Regnard Is.	Cape Preston East	Steamboat Is.	40 Mile Beach	Cape Preston West
Field Survey 1						
13/10/2023	Transit					
14/10/2023	X	X	X	X		
15/10/2023	X	X	X	X	X	
16/10/2023	X	X	X	X		
17/10/2023	X	X	X	X		
18/10/2023	X	X	X	X		
19/10/2023	X	X	X	X		
20/10/2023	X	X	X	X		
21/10/2023	X	X	X	X		
22/10/2023	X	X	X	X		
23/10/2023	X	X	X	X		
24/10/2023	X	X	X	X		
25/10/2023	X	X	X	X		
26/10/2023	X	X	X	X		X
27/10/2023	X	X	X	X		
Field Survey 2						
04/01/2024			X			
05/01/2024	X	X		X		
06/01/2024			X			
07/01/2024	X	X		X		
08/01/2024			X		X	
09/01/2024	X	X		X		X
10/01/2024			X			
11/01/2024	X	X		X		
12/01/2024			X		X	
13/01/2024	X	X		X		
14/01/2024			X			
15/01/2024	X	X		**Weather Standby**		
16/01/2024			X			
17/01/2024	**Weather Standby**			**Weather Standby**		
18/01/2024			X		X	
19/01/2024	X	X		X		X
Field Survey 3						
05/02/2024			X			
06/02/2024	X	X		X		
07/02/2024			X			
08/02/2024	X	X		X		
09/02/2024			X			

Date	Survey Location					
	SW Regnard Is.	NE Regnard Is.	Cape Preston East	Steamboat Is.	40 Mile Beach	Cape Preston West
10/02/2024	X	X		X		
11/02/2024			X			
12/02/2024	X	X		X		
13/02/2024			X			
14/02/2024	X	X		X		
15/02/2024			X			
16/02/2024	X	X		X		
17/02/2024			X			
18/02/2024	X	X		X		
19/02/2024			X			

Appendix B: Track Preservation

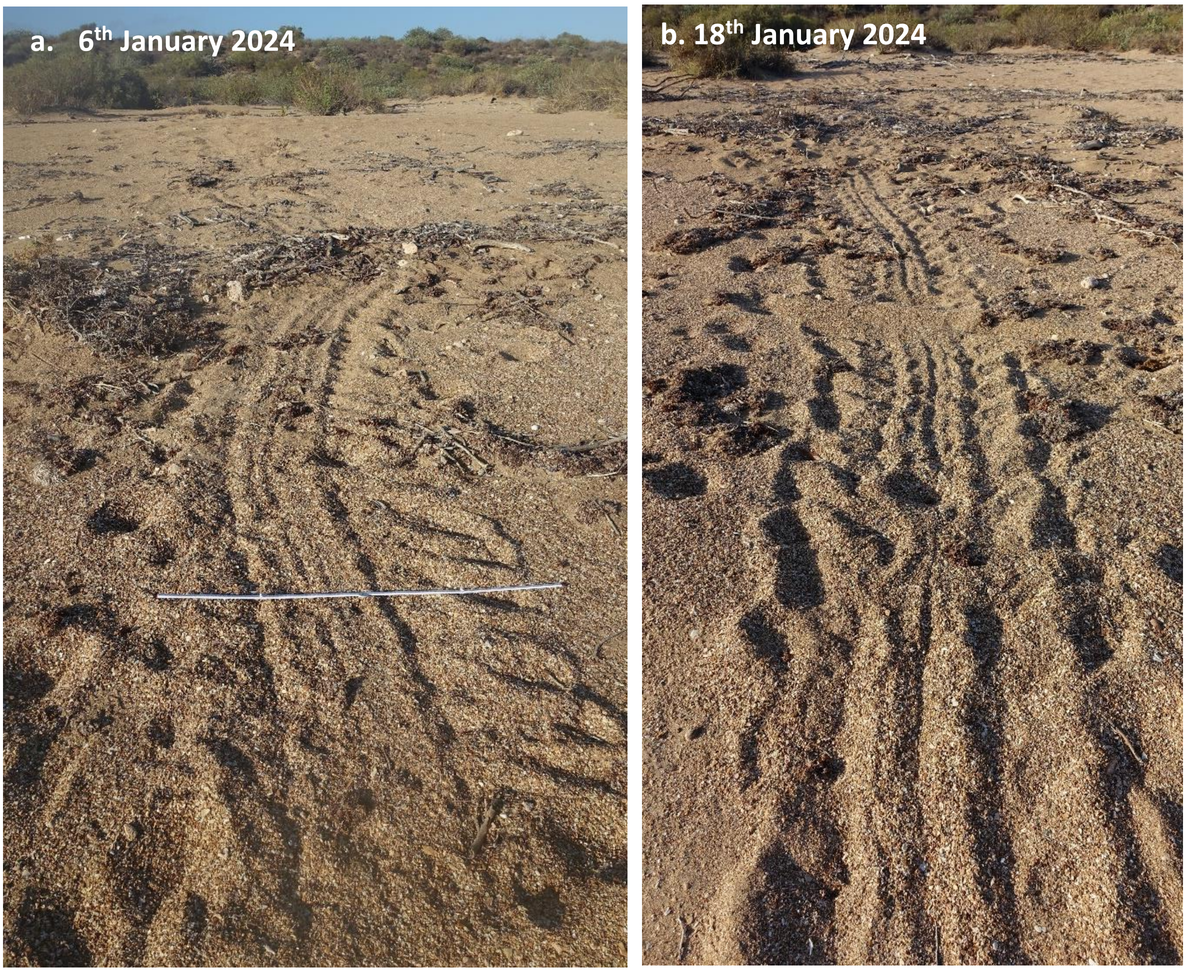

Figure B1: Example of track preservation on Cape Preston East. a. Track recorded on 6th January 2024; and; b. Same track recorded on 18th January 2024.