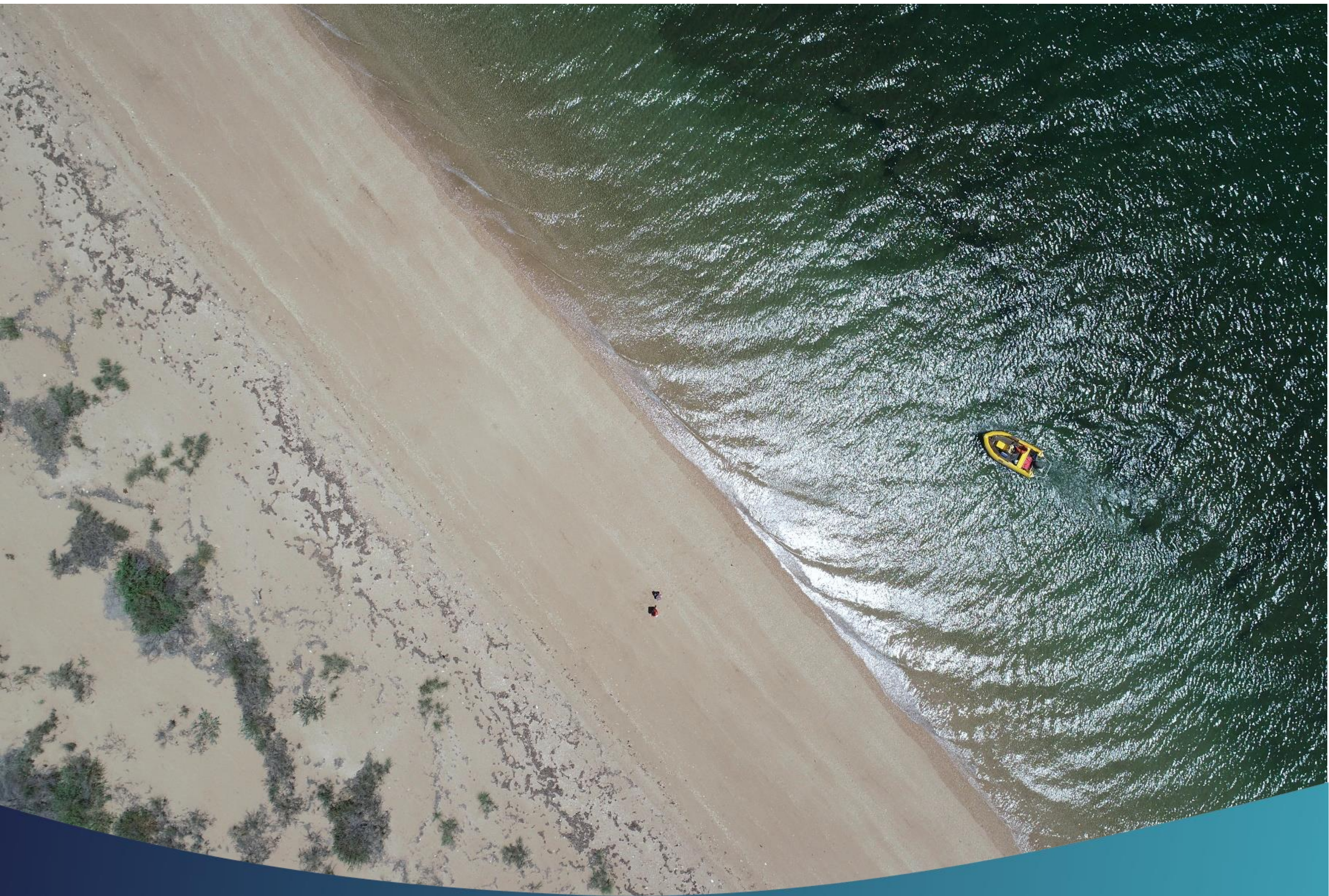
Eramurra Solar Salt Project

Turtle Nesting Study Report



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ENVIRONMENT
An O2Marine company

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Acronyms and Abbreviations

Acronyms/Abbreviation	Description
BVLOS	Beyond Visual Line of Sight
BC Act	*Biodiversity Conservation Act 2016*
BIA	Biologically Important Areas
CITES	*Convention on International Trade in Endangered Species of Wild Fauna and Flora*
DBCA	Department of Biodiversity, Conservation and Attractions
DE	Development Envelope
DJI GS Pro	DJI Ground Station Pro (software)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESD	Environmental Scoping Document
F-Pil	Flatback Pilbara (genetic stock)
GIS	Geographic Information Systems
G-NWS	Green North West Shelf (genetic stock)
H-WA	Hawksbill Western Australia (genetic stock)
IUCN	International Union for Conservation of Nature
O2M	O2 Marine
RP	Remote Pilot (or RPAS Controller)
RPAS	Remotely Piloted Aerial System
UAV	Unmanned Aerial Vehicle
WA	Western Australia

Executive Summary

Leichhardt Salt Pty Ltd ('the Proponent') intend to develop a solar salt production and export operation ('the Proposal') in Cape Preston East area, approximately 55 km west south-west of Karratha, within the Pilbara region of northern Western Australia (WA). Primary infrastructure includes concentrator and crystalliser ponds and processing plant. Supporting infrastructure includes bitterns outfall, drainage channels, product dewatering facilities, desalination plant and/or groundwater bores, pumps, pipelines, power supply, access roads, administration buildings, workshops, laydown areas, landfill facility, communications facilities and other associated infrastructure. The Proposal also includes dredging at the Cape Preston East Port and either offshore disposal of dredge material or onshore disposal.

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and WA *Environmental Protection Act 1986* (EP Act) govern the environmental approval process. They aim to support environmentally sustainable development while protecting environmental values, including biodiversity. The EPBC Act makes sure that 'nationally significant' animals, plants, habitats and places are identified, and any potential negative impacts on them are carefully considered before changes in land use or new developments are approved. Under the EP Act, 'Marine Fauna' is a key environmental factor to be considered within an impact assessment, with the objective of maintaining biological diversity and ecological integrity.

The north-west marine region is recognised as an important area for several species of marine turtles. Item 64 of the Environmental Scoping Document (ESD) work requirements is to "*Undertake a marine turtle field survey and assessment to identify the species present, key nesting beaches and current usage, potential foraging areas (based on BCH survey findings) and their significance on both the mainland and offshore islands. If significant turtle nesting activity is observed on either the mainland or offshore islands, undertake a study of hatchling orientation behaviour to determine the cause of any existing or future mis-orientation or disorientation. All field studies will be in accordance with the National light pollution guidelines for wildlife*" (Preston Consulting 2022). This report focuses on the marine turtle field survey undertaken to identify species present and describe nesting activity. The assessment of potential foraging areas based on findings from the benthic community and habitat (BCH) surveys is presented in the Conservation Significant Marine Fauna Desktop Study (O2 Marine 2021c).

The Proponent contracted O2 Marine (O2M) to undertake a nesting beach survey using a remotely piloted aerial system (RPAS). As the use of RPAS in marine wildlife studies remains novel, O2M consulted with scientists from the Department of Biodiversity and Conservation (DBCA)'s Marine Science and North West Shelf Flatback Turtle Conservation Programs during the early stage of survey design. The outcome was to adopt similar photographic methods of Fossette et al. (2021), who conducted a broad scale occupied aerial survey, with mounted cameras. This approach facilitated a direct comparison of nesting turtle species presence and densities at the Proposal site with results obtained for the Pilbara region.

Flatback and green turtle species were found to infrequently nest in low densities on the mainland throughout the survey period within the Proposal site, including at the beach nearest to the trestle jetty at the Cape Preston East Port. However, the island beaches surveyed exhibited no turtle nesting presence throughout this study. Based on this evidence, it is reasonable to conclude that although the Proposal site is situated within a flatback turtle biologically important area (BIA), it is of little regional significance. The beaches have been found to be used by only a few individuals and are, therefore, not considered key nesting beaches for the population. This survey was conducted at a relatively small spatial scale compared to Fossette et al. (2021), therefore survey effort could be repeated allowing for a high level of confidence in the findings. This study highlights the usefulness of RPAS as a tool to survey turtle nesting and the potential for obtaining further data to assess habitat suitability. It also demonstrates the benefits in compatible survey design at regional and local levels and contributes to initiating steps towards scientifically based spatially and temporally explicit management and recovery plans for Pilbara turtle stocks.

1. Introduction

1.1. Proposal Description

Leichhardt Salt Pty Ltd (the Proponent) propose to develop the Eramurra Solar Salt Project (the Proposal) in the Cape Preston East area, Western Australia (WA) (Figure 1). The Proposal will produce high purity industrial grade sodium chloride salt from seawater via a solar evaporation, crystallisation and raw salt purification operation. A short summary of the Proposal is presented in Table 1.

The export of salt is proposed to be via a trestle jetty. The jetty and associated stockpiles will be located at the Cape Preston East Port approved by Ministerial Statement (MS) 949. Dredging will be undertaken as part of this Proposal to remove high points at the Cape Preston East Port. Dredged material will either be disposed of at one or more offshore disposal locations (Figure 2), or onshore within the Ponds and Infrastructure Development Envelope (DE). The Cape Preston East Port jetty and associated stockpiles are excluded from the Proposal. Disturbance is proposed to be up to 14,300 ha within the terrestrial pond development envelope, 90 ha within the marine development envelope, and 320 ha within the dredge spoil disposal development envelope.

O2 Marine have been engaged by the proponent to undertake marine environmental investigations to help identify environmental risks of the Proposal, establish baseline conditions, guide appropriate monitoring and management to minimise potential environmental impacts and to inform Proposal design.

Table 1 Short Summary of the Proposal

Project Title	Eramurra Solar Salt Project
Proponent Name	Leichhardt Salt Pty Ltd
Short Description	Leichhardt Industrials Pty Ltd (Leichhardt) is seeking to develop a solar salt project in the Cape Preston East area, approximately 55 kilometres (km) west-south-west of Karratha in Western Australia (WA) (the Proposal). The Proposal will utilise seawater and evaporation to produce a concentrated salt product for export. The Proposal includes the development of a series of concentrator and crystalliser ponds and processing plant. Supporting infrastructure includes bitterns outfall, drainage channels, product dewatering facilities, desalination plant and/or groundwater bores, pumps, pipelines, power supply, access roads, administration buildings, workshops, laydown areas, landfill facility, communications facilities and other associated infrastructure. The Proposal also includes dredging at the Cape Preston East Port and either offshore disposal of dredge material or onshore disposal.

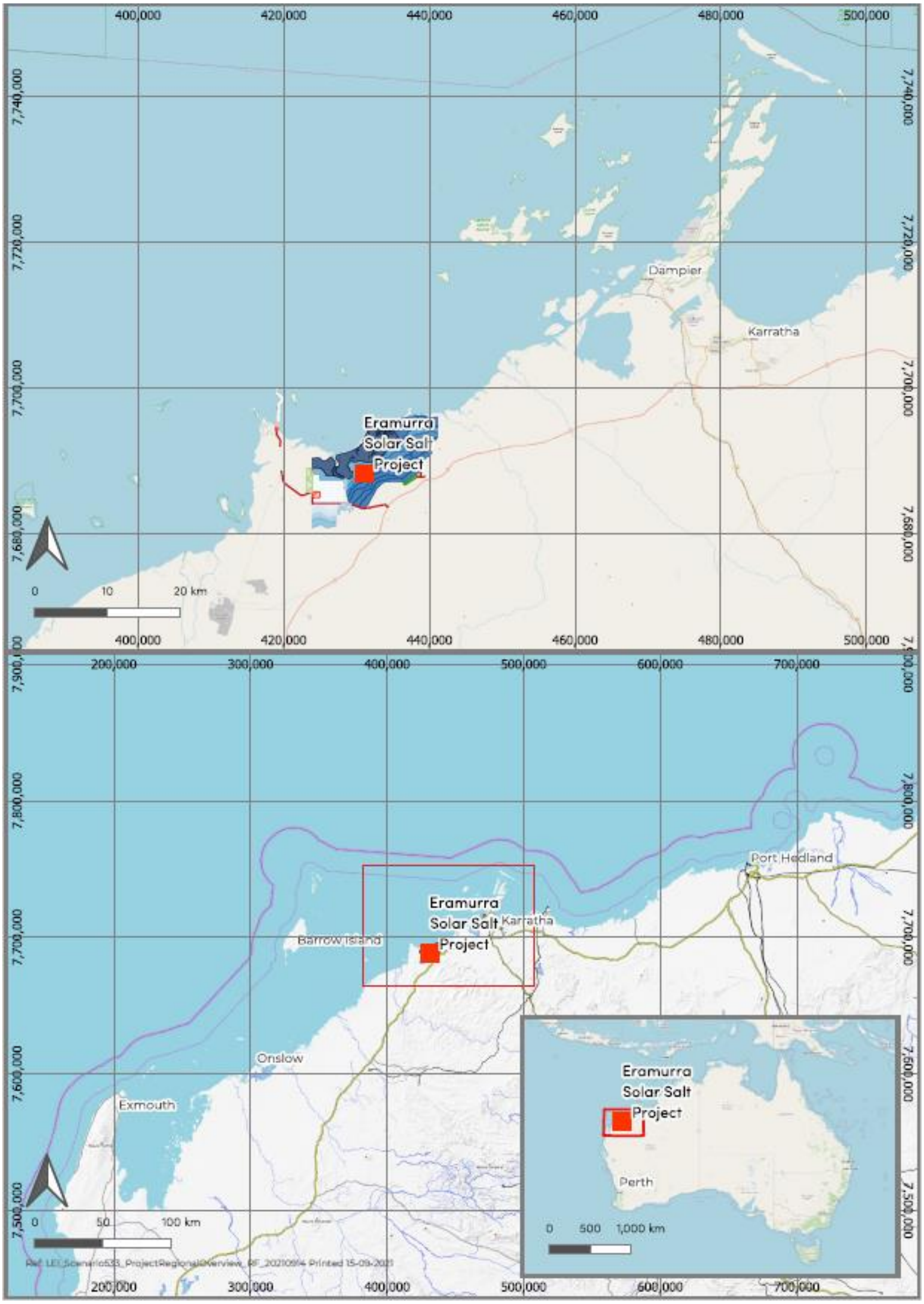

Figure 1 Regional location of the Proposal

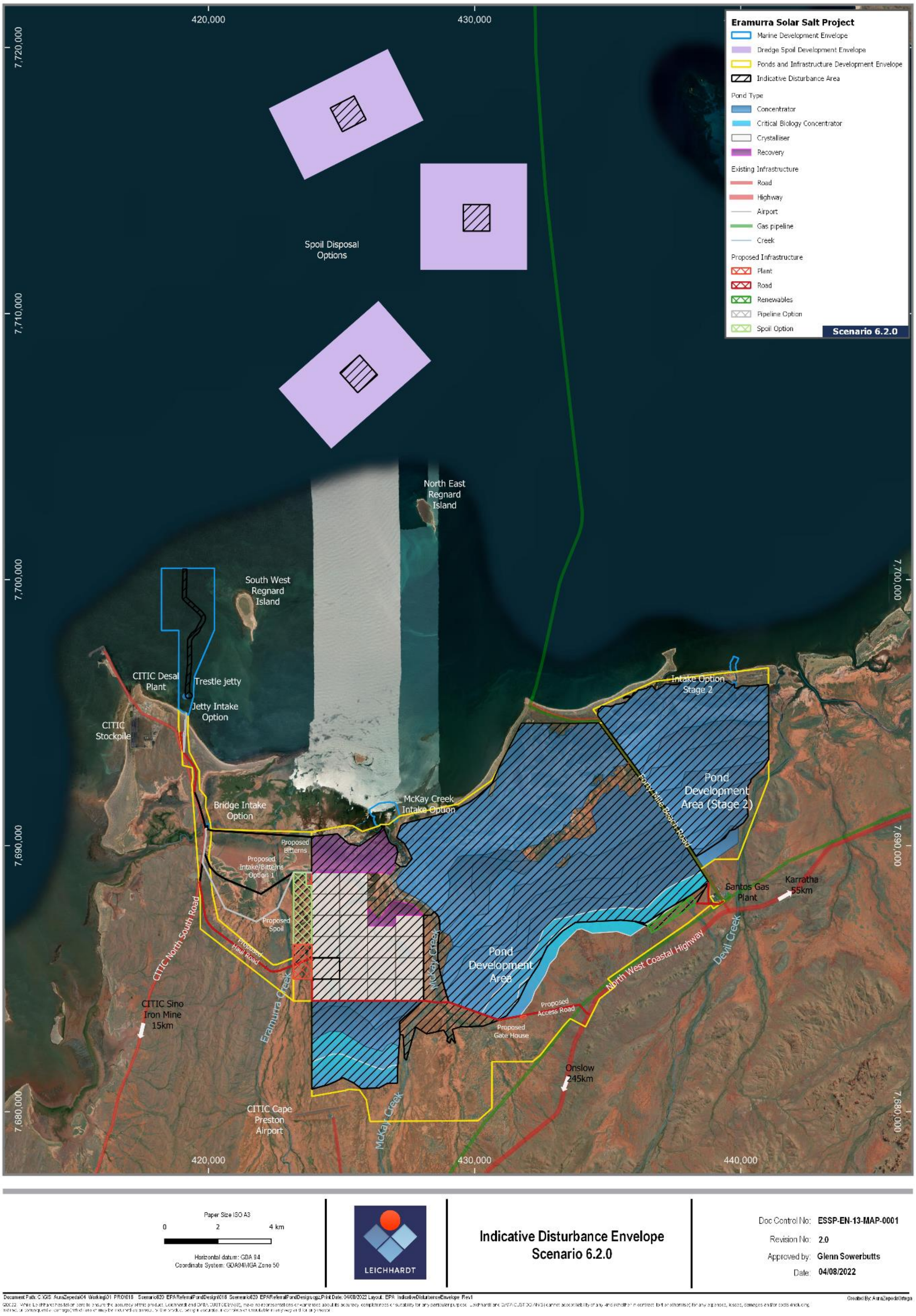

Figure 2 Proposal Development Envelope and indicative layout.

1.2. Study Purpose and Objective

The Proposal has been referred under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and Part IV of WA's *Environmental Protection Act 1986* (EP Act) and will be assessed under a Bilateral Agreement. Marine fauna has been identified as a key environmental factor to be considered by the Proposal, under both legislations.

Item 64 of the Environmental Scoping Document (ESD) work requirements is to:

"*Undertake a marine turtle field survey and assessment to identify the species present, key nesting beaches and current usage, potential foraging areas (based on BCH survey findings) and their significance on both the mainland and offshore islands. If the light spill study predicts that light emissions from the Proposal are likely to be significant (such that they would attract turtle hatchlings or otherwise alter their behaviour) and turtle nesting activity is observed on either the mainland or offshore islands, then undertake a study of hatchling orientation behaviour to determine the cause of any existing or future mis-orientation or disorientation. These field studies will be in accordance with the National light pollution guidelines for wildlife (DotEE, 2020);"* (Preston Consulting 2022).

This report focuses on the marine turtle field survey undertaken to identify species present and describe nesting activity. The assessment of potential foraging areas based on findings from the benthic community and habitat (BCH) surveys is presented in the Conservation Significant Marine Fauna Desktop Study (O2 Marine 2021c).

Other ESD items listed for marine fauna are outside the scope of this study. As such, this report should be read in conjunction with:

- Eramurra Salt Project Subtidal Benthic Communities and Habitats Study (O2 Marine 2021a);
- Eramurra Salt Project Intertidal Benthic Communities and Habitats Study (O2 Marine 2021b);
- Eramurra Salt Project Conservation Significant Marine Fauna Desktop Study (O2 Marine 2021c); and
- Eramurra Salt Project Sawfish Risk Assessment (O2 Marine 2021d).

2. Background: Turtles of the Pilbara Region

2.1. Species and Stocks

Six of the world's seven species of marine turtles are known to occur in Australian waters and are protected under the Commonwealth EPBC Act and WA *Biodiversity Conservation Act 2016* (BC Act). Flatback (*Natator depressus*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and leatherback (*Dermochelys coriacea*) turtles are listed as "Vulnerable", and loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles are listed as "Endangered" under the EPBC Act and all are listed in Schedule 1 (fauna that is rare or likely to become extinct) under the BC Act. All species are listed as "Migratory", reflecting their listing under the Convention for the Conservation of Migratory Species of Wild Animals (CMS/Bonn Convention) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The World Conservation Union (IUCN) has assigned "Critically Endangered" status to hawksbill and leatherback turtles, "Endangered" status to green and loggerhead turtles, "Vulnerable" status to olive ridley and have recognised flatback turtles as "Data Deficient" (IUCN 2021).

Marine turtles in Australia are recognised as belonging to discrete genetic stocks within each species, which are defined by the presence of regional breeding aggregations. Marine turtle breeding aggregations that overlap with the Proposal area include the Flatback – Pilbara (F-Pil), Green North West Shelf (G-NWS), and Hawksbill – Western Australia (H-WA) genetic stocks. The *Recovery Plan for Marine Turtles in Australia 2017 – 2027* (herein "Recovery Plan") (Commonwealth of Australia 2017) provides information on population trends and important areas for each stock (Table 2). Flatback turtles are the most restricted of these stocks in terms of nesting site distribution, whereas hawksbill turtles have the smallest range of genetic dispersal (Commonwealth of Australia 2017). The WA Department of Conservation, Biodiversity and Attractions (DBCA) implement 'The North West Shelf Flatback Turtle Conservation Program' which aims to conserve flatbacks of the North West Shelf Stock.

No discrete genetic stocks of loggerhead, leatherback or olive ridley turtles overlap with the Proposal site. Loggerhead turtles are infrequently recorded in the area during nesting season, but typically nest further south (Commonwealth of Australia 2017). Tracking of loggerheads from the Exmouth nesting population has revealed a northward migration, with foraging in waters off the Kimberley coast (Whiting et al. 2018). Leatherback (*Dermochelys coriacea)* and olive ridley (*Lepidochelys olivacea*) turtles have occasionally been documented foraging in Northwest Shelf waters but have rarely been observed in the Pilbara (DSEWPaC 2012a). Neither species are known to have nesting sites in the Pilbara region (Whiting et al. 2018).

2.2. Important Habitats and Behaviours

Important turtle habitats include those used for breeding (mating, nesting and inter-nesting), foraging, resting, and migration. Through consultation with an advisory panel of scientific experts, and the collation of available data, the Recovery Plan has identified areas of important habitats in which to guide marine planning.

- Habitat Critical for the Species: onshore nesting and offshore inter-nesting (i.e., the period between successive nesting events) habitat that is considered critical for the survival of the species. Inter-nesting habitats are located immediately seaward of designated nesting habitat critical to the survival of turtle species, using a 20 m buffer for green and hawksbill turtles and a 60 m buffer for flatback turtles. They are broad areas, having been agreed upon by an expert panel. The purpose of these defined areas is "To ensure maintenance of genetic diversity, habitat critical to the survival of marine turtles".
- "Critical Habitat" as defined under Section 207A of the EPBC Act (Register of Critical Habitat) has not been identified and listed for marine turtles.

  Inter-nesting buffer areas overlap with the Proposal site for each of these species (Table 2; Figure 3) (Commonwealth of Australia 2017).
- Biologically Important Areas (BIAs) include spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour. BIA maps reflect the best available information and are not necessarily accurate. The intent is that they are a dynamic tool, to be updated when new information is available.

  Inter-nesting BIAs for flatback turtles overlap with the entire Proposal site, whereas green and hawksbill turtle inter-nesting BIAs overlap only with the spoil disposal sites (Table 2; Figure 4) (Commonwealth of Australia 2017).

2.2.1. Nesting and inter-nesting

2.2.1.1. Flatback turtles

Within the Pilbara region, Pendoley et al. (2016) and Fossette et al. (2021) found that flatback turtle nesting activity is primarily island based (76% and 86% respectively), indicating a strong preference to island beaches for nesting over mainland beaches. Major nesting presence occurs within the Dampier, Onslow and Port Hedland subregions, and specifically on Barrow Island, Mundabullangana station and Delambre Island (Pendoley et al. 2016). Pendoley et al. (2016) found that the Onslow and Dampier subregions had the equal highest regional proportion of flatback nesting among surveyed locations. Flatback turtles also have minor nesting presence on Thevenard and Varanus islands as well as the Montebello Group, Cemetery Beach and other islands in the Dampier Archipelago such as Rosemary Island (Commonwealth of Australia 2017; Pendoley et al. 2016).

A recent study undertaken by Whittock et al. (2014) tracked six flatback turtles from Thevenard Island, culminating in a total of 12 inter-nesting tracks. Turtles had displacement distances that ranged from 3.4 to 62.1 km, and a mean inter-nesting period of 11 days. Tagged turtles undertook post-nesting circular movements for a short period (i.e., 3-20 days), typically remaining in the nearshore area before commencing post-nesting migration towards the Dampier Archipelago, Barrow Island and the Kimberley region (RPS 2010). Flatback turtle mating periods in the Pilbara typically range from September to January, with nesting occurring over October to March (peak nesting during November - January) (Commonwealth of Australia 2017; Fossette et al. 2021). Flatback turtle hatchlings typically emerge from February to March (Table 2; Commonwealth of Australia 2017).

2.2.1.2. Green turtles

Pendoley et al. (2016) found that the vast majority (93%) of green turtle nesting activity is located on outer islands. They have a major nesting presence throughout the Montebello islands and Barrow Island with 71% of sub regional nesting activity occurring within the Barrow group subregion (Pendoley et al. 2016). Green turtles also have minor nesting presence on Boodie, Middle, Serrurier, Thevenard, Lowendal, Rosemary, Legendre and Delambre Islands, as well as various mainland beaches (Commonwealth of Australia 2017).

Green turtle mating periods on the north-west shelf typically range from September to December, with nesting occurring from November to March (peak nesting during December- February) (Commonwealth of Australia 2017; Fossette et al. 2021). Green turtle hatchlings typically emerge from January to May with peak hatching during February to March (Table 2; Commonwealth of Australia 2017).

2.2.1.3. Hawksbill turtles

Pendoley et al. (2016) found that most hawksbill nesting in the Pilbara region is located within the Onslow subregion. This subregion accounted for 42% of all hawksbill turtle nesting in the assessed Pilbara region whereas Barrow and Dampier subregions accounted for 31% and 27% of hawksbill nesting respectively. Major nesting occurs on Delambre Island, the Montebello Islands and throughout the Dampier archipelago with Rosemary Island having the largest nesting aggregation recorded with approximately 1,000 nesting females per year (Commonwealth of Australia 2017). Research surveys undertaken at Varanus, and Rosemary Islands have revealed that survivorship of nesting females has remained constant and high over the past 20 years (Commonwealth of Australia 2017). Hawksbills also have a minor presence on the Lowendal Islands, including Varanus and Bridled islands (Commonwealth of Australia 2017). Mating periods for hawksbill turtles within the WA genetic stock occur from September to January, with nesting occurring from October to March (peak nesting during November-January) (Commonwealth of Australia 2017). Hawksbill turtle hatchlings typically emerge from February to March (Table 2; Commonwealth of Australia 2017).

Table 2 Population Trends and Important Areas for Turtle Stocks of the Proposal Site as presented by the Recovery Plan (Commonwealth of Australia 2017).

Species	Genetic stock	Population Trend	Habitat Critical for Species Survival	BIAs	Key Nesting Sites	Temporal Occurrence
Flatback	Pilbara coast (F-Pil)	Unknown.	Dampier Archipelago and coastal island inter-nesting buffers overlaps with the Proposal site.	Inter-nesting buffer overlaps with the Proposal site.	Major: Barrow Island, Mundabullangana Station, Delambre Island. Minor: Thevanard, Varanus, Muiron Islands, Montebello Group, Cemetery Beach.	Mating: Sep–Jan. Nesting: Oct–Mar (peak: Nov–Jan). Hatching: Feb–Mar.
Green	North west Shelf (G-NWS)	Stable. One of the largest green turtle stocks in the world; largest in the Indian Ocean.	Dampier Archipelago inter-nesting buffer overlaps with the Proposal site.	Inter-nesting buffer overlaps with spoil disposal sites.	Major: Lacepedes, Montebello, Barrow, Muiron, Browse Islands and Northwest Cape. Minor: Boodie, Middle, Serrurier, Thevenard, Lowendal, Rosemary, Legendre, Delambre Islands and various mainland beaches, Shark Bay to Ningaloo and Kimberley Coast.	Mating: Sep–Dec. Nesting: Nov–Mar (peak: Dec–Feb). Hatching: Jan–May (peak: Feb–Mar).
Hawksbill	Western Australia (H-WA)	Unknown.	Dampier Archipelago inter-nesting buffer overlaps with the Proposal site.	Inter-nesting buffer overlaps with spoil disposal sites.	Major: Dampier Archipelago (Including Rosemary Island and Delambre Island), Montebello Islands. Minor: Ah Chong Island, South East Island and Trimouille Island), Lowendal Islands, Sholl Island.	Mating: All Year Nesting: All year (peak: Oct–Jan). Hatching: All year (peak: Dec- Feb)

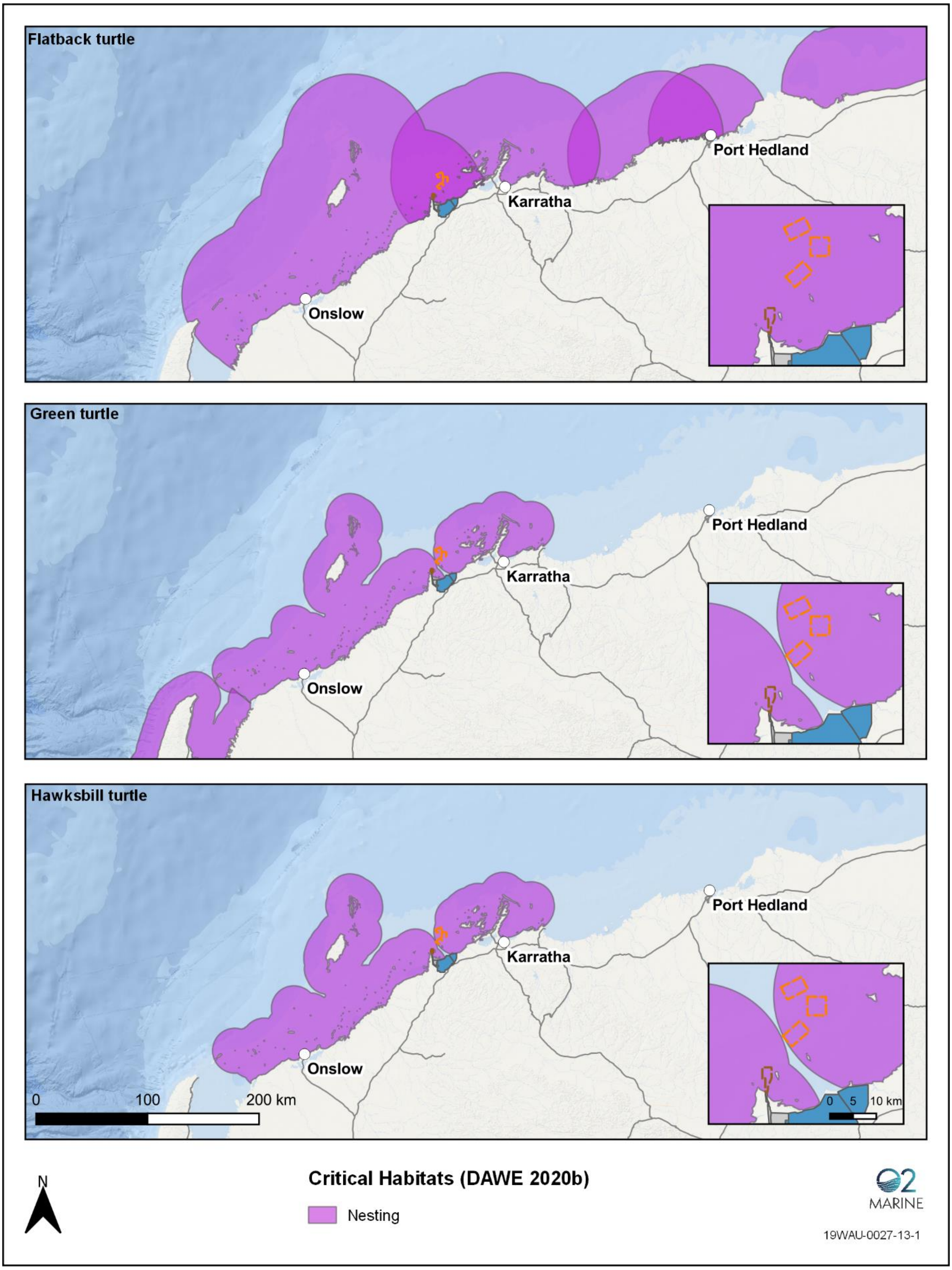

Figure 3 Habitat Considered Critical for the Survival of Turtles (Commonwealth of Australia 2017).

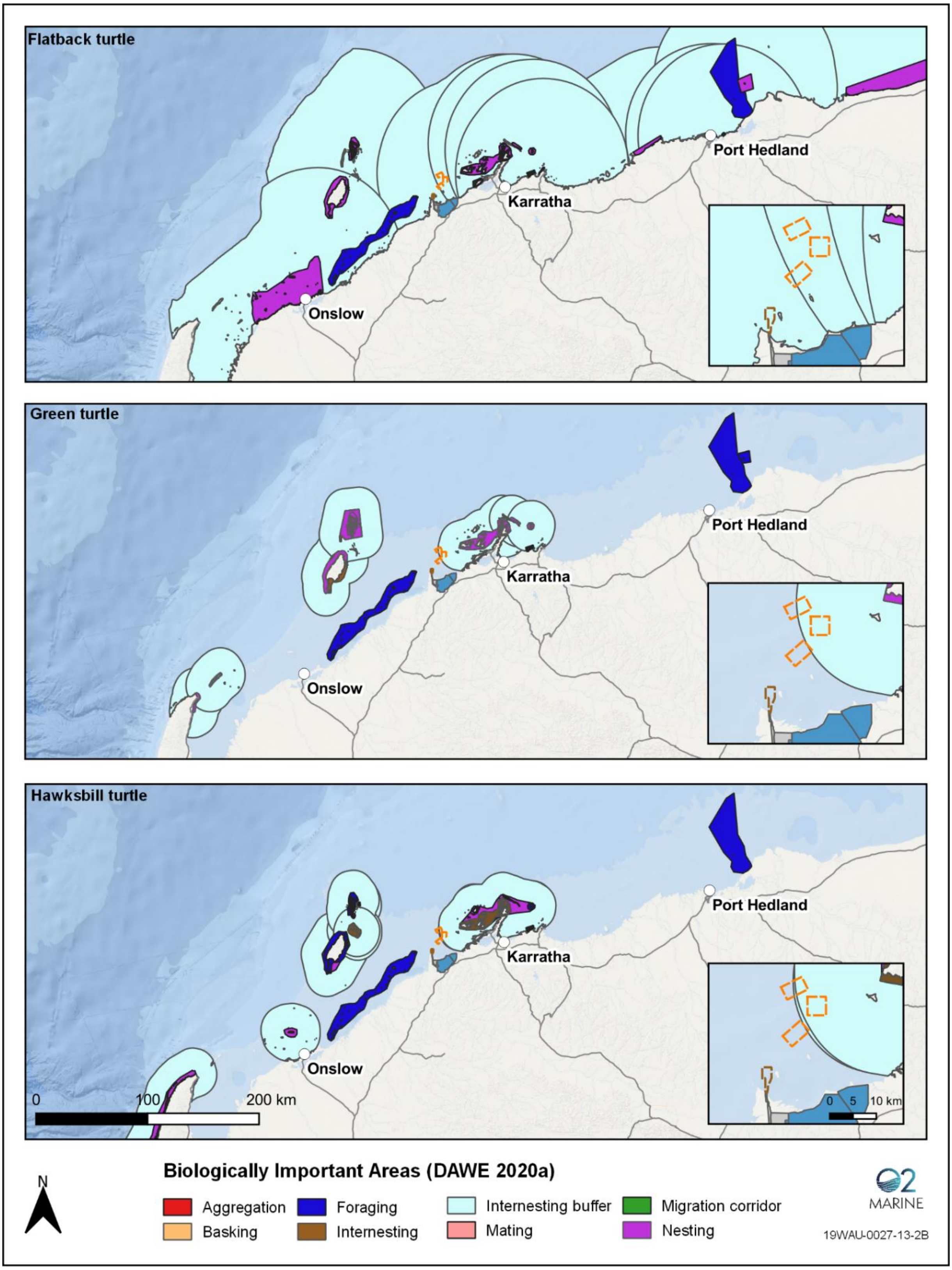

Figure 4 Biologically Important Areas (BIAs) for Turtles (Commonwealth of Australia 2017).

2.2.2. Foraging

No BIAs for foraging have been identified near the Proposal site. However, foraging is likely to occur.

Flatback turtles are known to favour soft sediment habitats that support benthic invertebrates (Table 3). Post-nesting satellite tracking indicates foraging occurs along the WA coast in water shallower than 130 m and within 315 km of shore.

Areas suitable for green turtle foraging include shallow reef that surround the offshore islands, and mangrove habitat close to the mainland, which are present at the Proposal site. Imbricata Environmental (2013) found that nearshore algal-rock benthic habitats and mangrove forests around the Proposal site were utilised as feeding habitats by large juvenile and sub-adult green turtles. Hawksbill turtles can be found in clear or turbid water, on reefs, seagrass meadows or on soft-bottom habitats (Commonwealth of Australia 2017).

Table 3 Generalised Diets of Turtle Species (Commonwealth of Australia 2017).

Species	Generalised diet	Foraging habitat
Flatback turtle	Primarily carnivorous, feeding on soft-bodied invertebrates. Juveniles eat gastropod molluscs, squid and, siphonophores. Limited data indicate that cuttlefish, hydroids, soft corals, crinoids, molluscs and jellyfish are also eaten.	Soft sediment habitats that support benthic invertebrates.
Green turtle	Primarily herbivorous, foraging on algae, seagrass and mangroves. In their pelagic juvenile stage, they feed on algae, pelagic crustaceans and molluscs.	Tidal/sub-tidal habitats with coral reef, mangrove, sand, rocky reefs and mudflats.
Hawksbill turtle	Omnivorous, feeding on algae, sponges, soft corals and other soft-bodied invertebrates.	Tidal and sub-tidal coral and rocky reef habitats.

2.2.2.1. Migration

Following the completion of breeding, adult flatback and green turtles are known to undertake a post-nesting migration from the nesting habitat in the Pilbara region to foraging grounds situated further north in the Kimberley region of WA (Whittock et al. 2014; Ferreira et al. 2021). Studies south-west of the Proposal site indicate their movements during this period are primarily within shallow water (i.e., <50 m depth) (Ferreira et al. 2021; Chevron Australia 2009). Limited studies on juvenile migration have been undertaken, and there is no information available from the Proposal site.

2.3. Conservation and Threats

The biology and ecology of turtles renders the survival of their population susceptible to changes in their environment. Turtle growth is slow, although it varies among species, habitats, sex and maturity. Depending on the species, turtles require 20-50 years to reach sexual maturity and female reproductive activity may vary from one to eight years depending on food availability to assist in fat storage for egg production and breeding migration (Pendoley 2005; Fossette et al. 2021). As turtles have a high site fidelity for breeding and nesting, they are vulnerable to natural or anthropogenic habitat alteration. As migratory animals, restrictions to movement can hinder their ability to reach these areas.

General threats to sea turtles include commercial and recreational fishing; coastal infrastructure and development (including industrial, residential and tourism development); Indigenous harvest; feral animal predation; agricultural activities and climate change (Commonwealth of Australia 2017; DSEWPaC 2012a; DSEWPaC 2012b;). In northern WA, coastal islands have become refugia for breeding turtles as they are isolated from mainland pressures including egg and hatchling predation by feral animals. Light pollution was assessed as a high-risk threat to all three turtle stocks that occur in the area, having the potential to extend to islands of nesting importance if unmitigated.

3. Method

3.1. Approach

A Remotely Piloted Aerial Systems (RPAS) was used to initially survey the mainland beaches along the Proposal site. Later survey efforts included South West (SW) Regnard and North East (NE) Regnard islands. These islands are part of the Great Sandy Island Nature Reserve (Class B, R 33831) which provides important nesting habitat for marine turtles. These flights follow recent methods employed by Fossette et al. (2021) who conducted a broad scale occupied aerial survey with mounted cameras for The North West Shelf Flatback Turtle Conservation Program. This approach facilitated a direct comparison of nesting turtle species presence and densities at the Proposal site with results obtained for the Pilbara region.

The Fossette et al. (2021) Pilbara-wide survey extended from Tent Island in Exmouth Gulf (22.025°S, 114.518°E) to Cape Keraudren (19.970°S, 119.750°E) over six days between 29 November and 6 December 2016. Sampling was designed to coincide with the flatback turtle peak nesting period, testing the utility of aerial photogrammetry for conducting large-scale surveys of nesting sea turtles (Fossette et al. 2021). The spatial and temporal efficiency of fauna monitoring allowed for key rookeries of the target flatback stock to be identified from georeferenced photographs collected over six days across 986 km of beaches in the Pilbara region of WA. Aerial tallies and multiple ground-survey flatback track tallies were highly correlated, and together with low intra- and inter-observer errors, advocated that reliable data can be attained via aerial photogrammetry for nesting sea turtles. Several of these key rookeries were identified as being relatively unexposed to industry-related pressures but were unprotected, highlighting the demand for a cumulative impact assessment to be compiled for this flatback stock (Fossette et al. 2021). The results of this work can inform the use of digitized aerial surveys in future stock-scale monitoring programs in the Pilbara which complement previous studies such as the Pendoley et al. (2016) survey. Pendoley et al. (2016) collated a 20-year dataset of (primarily) in-situ track observations and aerial photography to compile track-based abundance and distribution estimates of flatback, green and hawksbill turtles. While estimates were robust, they suggested that efficiency can be enhanced if an increased proportion of surveys are based on RPAS operations.

RPAS, otherwise known as Unoccupied Aerial Vehicles (UAVs), and more colloquially ‘drones’, are rapidly increasing as a key tool to study marine wildlife (Johnston 2019), including sea turtles (Schofield et al. 2019). For instance, Bevan et al. (2018) and Witt et al. (2009) used RPAS to monitor stock populations of turtles in areas where traditional monitoring methods would be deemed unfeasible by obtaining data on habitat use and deliver real-time information on the spatial efficacy of protected area networks. In WA, RPAS has been used to report on turtle nesting when used in conjunction with field studies (Pendoley 2016) and traditional ecological knowledge (Tucker et al. 2021). RPAS have numerous benefits including spatially efficient monitoring (i.e., reduced time in the field) on-demand remote sensing capabilities, image capture that can be verified and archived, tailored resolution to resolve individual turtles and tracks, structured flight planning, removal of distance-related observation biases and reduced human risk (Johnston 2019; Rees et al. 2018). As RPAS remain a relatively novel tool in wildlife monitoring, consultation with scientists from DBCA’s Marine

Science and North West Shelf Flatback Turtle Conservation Programs was conducted during the early stage of survey design.

3.2. Flights

The survey area extended along the Proposal site mainland, from east of Preston Island (20.838°S, 116.210°E) to the north-eastern tip of 40-mile beach, Gnoorea (20.828°S, 116.396°E) (Figure 5). Transects were placed on beaches likely to support turtle nesting which avoided mangroves and rocky inaccessible beaches through utilisation of satellite imagery. Survey flights were also conducted on SW Regnard Island (20.808°S, 116.244°E) and NE Regnard Island (20.775°S, 116.420°E) in 2022.

Five surveys were carried out between December 2020 and January 2022 (Table 4) to capture the peak nesting season for each local turtle stock, as indicated by the Recovery Plan (Table 2). The aim was to repeat four flights of each beach within each survey.

Table 4 Survey Timing

Survey	Dates
1	15 – 18 December 2020
2	19 – 22 January 2021
3	15 – 18 February 2021
4	15 – 18 March 2021
5	18 – 21 January 2022

A remote pilot (RP) flew a DJI Phantom 4 RTK RPAS along transects pre-programmed on the iPad application DJI Ground Station (DJI GS Pro,2021). Planning and executing flights with DJI GS Pro meant that transects were repeated at centimetre level accuracy. The Phantom 4 RTK RPAS records high resolution (20mp) stills and accommodates an inboard GPS which accurately geo-tags photographic images, both features allowing for accurate post analysis. Key flight settings are presented in Table 5. Flights were constrained to low wind conditions, altitudes of 60 m and were not undertaken beyond visual line of sight (BVLOS). Transects one and two (T1 and T2) were accessible only by small vessel, whereas the remaining transects were accessed by four-wheel drive vehicle. Flight times were dependant on access and wind.

Table 5 Flight Variable Specifications

Variable	Specification / Value
Altitude (m)	60
Wind speed (knots)	<20
Sensor	1" CMOS (downward facing)
Flight speed (m/s)	11.3
Shutter interval (sec)	2
Resolution (cm/px)	1.6
Distance (km)	~≤ 1 (within line of sight)

O2 MARINE

Figure 5 Survey Transect Locations*

* T7 and T8 exhibit wider transect widths due to the digital pre-programmed aerial flights necessary to survey all habitable island areas for nesting activity.

3.3. Image Processing

All georeferenced images (jpegs) recorded during the transect flights were loaded into Pix4Dmapper Pro software (Pix4D 2016). This program stiches the individual images together using common tie points (75% front and side overlap). The output of the stitched imagery is a high resolution georeferenced geotiff image encompassing the entire transect length (including an approximate 10% buffer outside the study area). This geotiff is then ready for detailed data analysis. This step is repeated for each of the eight transects. These images were imported into the geographical information system (GIS) QGIS (QGIS 2021) for analysis.

3.4. Data Analysis

3.4.1. Turtle Track Identification

When female turtles are ready to deposit their eggs, individuals move up the beach to deposit their eggs above the high tide mark to avoid inundation. In doing so they leave an up-track, a body pit (shallow depression in the sand), a nest and possible egg chamber and a down-track in the sand whilst returning to the ocean. Each track is unique to individual turtle species and is therefore identifiable for abundance estimates and distribution estimates (Fossette et al. 2021). Turtles may also 'false crawl'. False crawls can be classified where an egg chamber is created but no eggs are laid or where turtles approach the beach to their potential nesting area regardless of whether any nest digging occurs. Evidence from these behaviours is defined as 'nesting activity'.

Following Fossette et al. (2021) and associated DBCA methodologies, imagery was analysed by a single experienced and trained observer assessing each transect for the presence or absence of turtle tracks. Survey footage was reviewed using the software program QGIS, turtle tracks identified within a transect were marked as a feature and associated track information was recorded. Each track counted was assigned to a species and assessed for nest age and nesting outcome. Care was taken to avoid double counting duplicate images of the same track. Using this method allows calculations such as track density (recent tracks per day, per km) and abundance (tracks per day) to be made to assess the relative turtle activity across the study transects. In addition, the observer recorded notes on image quality and beach characteristics. Outputs from this method include an accurate and informative geospatial representation (GeoJSON file) of where nesting effort occurred within surveyed transects.

3.4.2. Species Presence

Turtle species were identified from nesting tracks. This method is commonplace and considers a number of physical characteristics, including gait, track width, plastron drag, tail drag, and flipper mark characteristics (e.g., Fossette et al. 2021; Pendoley et al. 2016). When there was uncertainty in species identification (due to reduced track condition via weathering, or poor image quality), the track was defined as 'unknown'.

3.4.3. Track Age

Track age was categorised into fresh, recent and old, based on the position of the track in relation to the most recent high tide mark as well as the general condition of the track. Tracks were considered 'fresh' if they were made within the last 24 hours, 'recent' tracks were defined as made in the last 48 hours, any tracks older than that were listed as 'old'.

3.4.4. Nesting Outcome

Nesting outcome refers to the success of the nesting attempt and was determined by examining the apex of the track and assessing the activity and categorising the outcome into either false crawl, successful nest, or uncertain. False crawls were categorised by a turtle track with no digging, or what appeared to be unsuccessful digging (body pits), while a successful nest was deemed so if a typical backfilled nest was evident. When a confident determination of nesting success could not be made, the outcome was classified as uncertain.

3.4.5. Beach Characteristics

The observer noted characteristics for each beach which could affect nesting suitability, including human activity and beach topography. Beach width was determined in QGIS by measuring from the low tide line to start of the dune (indicated by scrub/vegetation line) observed from the georeferenced image taken at the time of survey. Four-wheel drive activity was recorded as a binomial presence/absence. Distance from light was measured from the nearest permanent light source by anthropogenic infrastructure in QGIS.

3.4.6. Image Quality

As part of quality control, and to inform an assessment of RPAS viability in data collection for turtle tracks, image quality was recorded post-processing. Transect images were rated as good, average or poor at the (experienced and trained) observer's discretion (refer to Appendix 1 for examples of good and poor images-based on resolution).

4. Results

4.1. Effort

In total, 71 transects were flown over 19 flying days, covering the peak turtle nesting season over two consecutive seasons. Spatially, this equates to a cumulative transect length of 132.87 km and 696.75 ha capture area (Table 7).

Flights were not able to be flown on T1 and T6 in February 2021, or T3-6 in March 2021 due to inaccessibility or wind speeds exceeding safe flying conditions. Only T1, T2, T7 and T8 were flown in 2022. Overall, the highest effort was undertaken on T1 and T2 in terms of flight repeats, those nearest to the marine elements outlined in the Proposal. T1 and T7 had the highest effort in terms of cumultiave capture area (Table7).

Table 6 Repeated flights per transect

Transect	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Jan 2022	Total
1	4	3	0	4	4	15
2	4	3	4	4	4	19
3	3	1	4	0	0	8
4	2	1	4	0	0	7
5	4	1	4	0	0	9
6	4	1	0	0	0	5
7	0	0	0	0	4	4
8	0	0	0	0	4	4
Total	21	10	16	8	16	**71**

Table 7 Survey effort

Effort	T1	T2	T3	T4	T5	T6	T7	T8	TOTAL
Transect length (km) - singular	0.9	2.58	1.96	1.23	1.96	1.81	2.89	2.09	**15.42**
Transect length (km) - cumulative	13.50	49.02	15.58	8.61	17.64	9.05	11.56	8.36	**132.87**
Capture area (ha) - singular	12.08	4.02	4.26	4.04	3.74	6.95	46.8	30.3	**112.90**
Capture area (ha) - cumulative	181.20	76.38	34.08	28.28	33.66	34.75	187.2	121.2	**696.75**

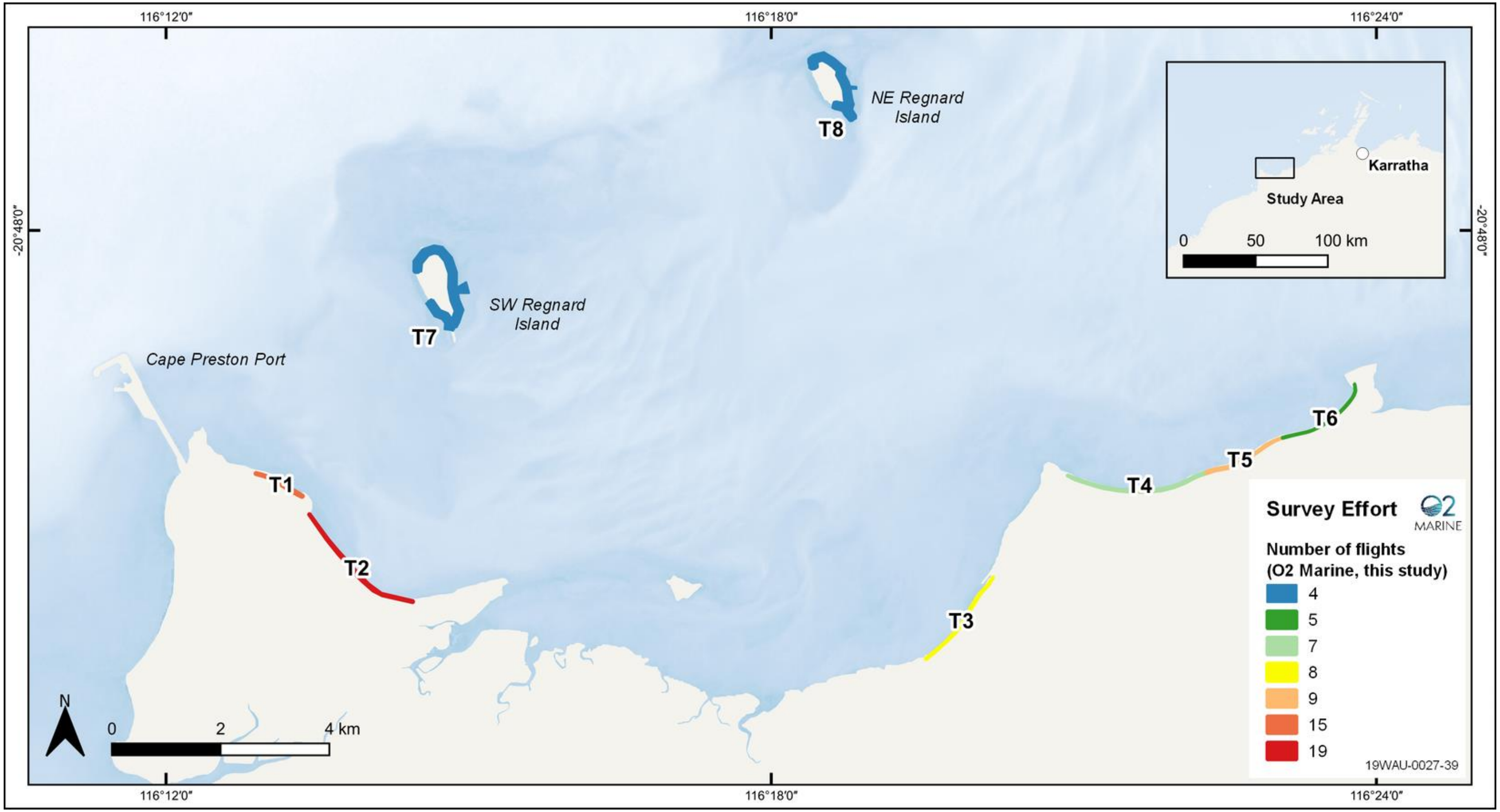

Figure 6 Survey effort. *

* T7 and T8 exhibit wider transect widths due to the digital pre-programmed aerial flights necessary to survey all habitable island areas for nesting activity.

4.2. Turtle Nesting Tracks

Turtle nesting activity was defined as any track, nest or body pit of any age observed on a beach and/or in sand dunes and made by any turtle species. A total of 31 turtle tracks, including old tracks but excluding repeated captures, were recorded over the study period (Table 8). Turtle nesting activity was recorded from each transect except for T5, T7, and T8 at some time during the entire survey period (Figure 7). Most tracks were of unknown species (n=20), followed by flatback (n=9) and green (n=2) turtles (Table 9; Figure 8A). No hawksbill tracks were identified.

There was a lower proportion of successful nesting events (26%; n=8) compared to false crawls and uncertain outcomes (35%, n=11 and 39%, n=12 respectively) (Figure 8B). Most tracks were old (80%; n=25), with few tracks fresh or recent (equally, 10%; n=3) (Figure 8C).

This survey recorded flatback nesting activity at T1 and T3, which contrasts with Fossette et al. (2021) results which indicated no nesting activity (Appendix B Figure 3). No turtle nesting activity (any age, any species) found on island beaches (T7, T8) also contrasts with findings from Fossette et al. (2021) which exhibited flatback turtle nesting activity on T7 and Turtle nesting activity (any age, any species) on T8 (Appendix B Figure 3).

4.2.1. Abundance and Density

Overall, most turtle nesting activity was recorded at T1 (n=17), followed by T2 (n=8) and T3 (n=4) (Table 8). One track was recorded at T4 and T6 and no tracks were recorded at T7 and T8.

Based on the Fossette et al. (2021) method of calculating density as 'fresh number of tracks *per night* per km of beach', medium density flatback nesting was recorded at T1 and low-density nesting at T3. Low density green and uncertain species nesting was recorded at T2 (Table 8; Figure 9). Thus, our results differed from Fossette et al. (2021) in that turtle nesting occurs on the mainland at those sites (Appendix B Figure 4).

Table 8 Number of turtle nesting activity incidents identified and respective density per transect over the survey period

	T1	T2	T3	T4	T5	T6	**T7**	**T8**	TOTAL
FB	3	1	4	-	-	1	-	-	9
GN	-	2	-	-	-	-	-	-	2
HB	-	-	-	-	-	-	-	-	0
UN	14	5	-	1	-	-	-	-	20
TOTAL	17	8	4	1	-	1	-	-	31
Density -Total Tracks 'Fresh, Recent, Old'	18.88	3.10	2.04	0.81		0.55			
Density (FB)- 'Fresh Tracks'	2.22	-	1.02	-	-	-	-	-	-
Density (GN)- 'Fresh Tracks'	-	0.77	-	-	-	-	-	-	-
Density (UN)- 'Fresh Tracks'	-	0.77	-	-	-	-	-	-	-

*(Density is derived from 'fresh' tracks per kilometre of beach per night-1. Total track density is included for comparison. FB= Flatback turtle, GN=Green Turtle and UN=Uncertain)

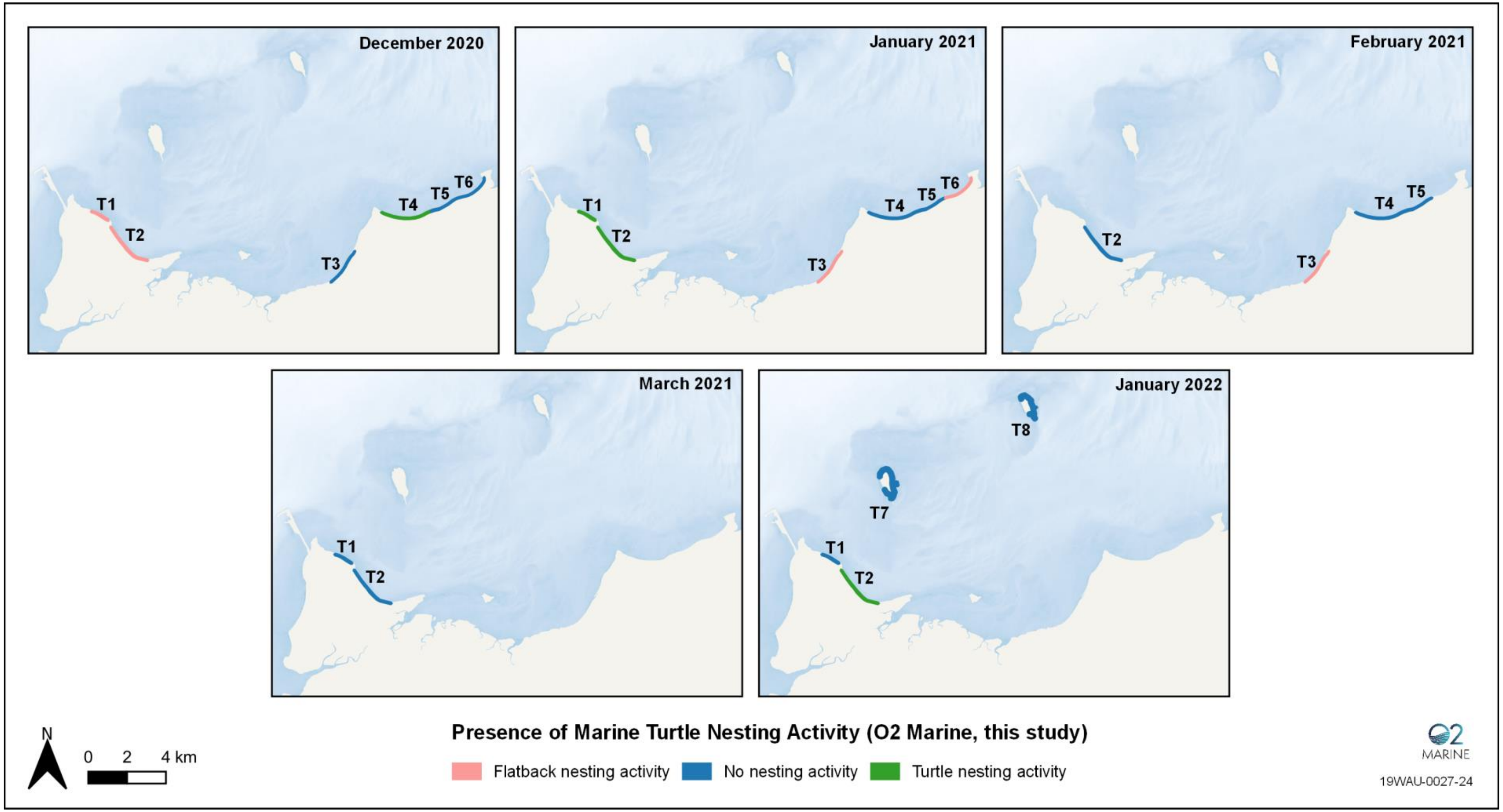

Figure 7 Presence of nesting activity December, January, February and March.

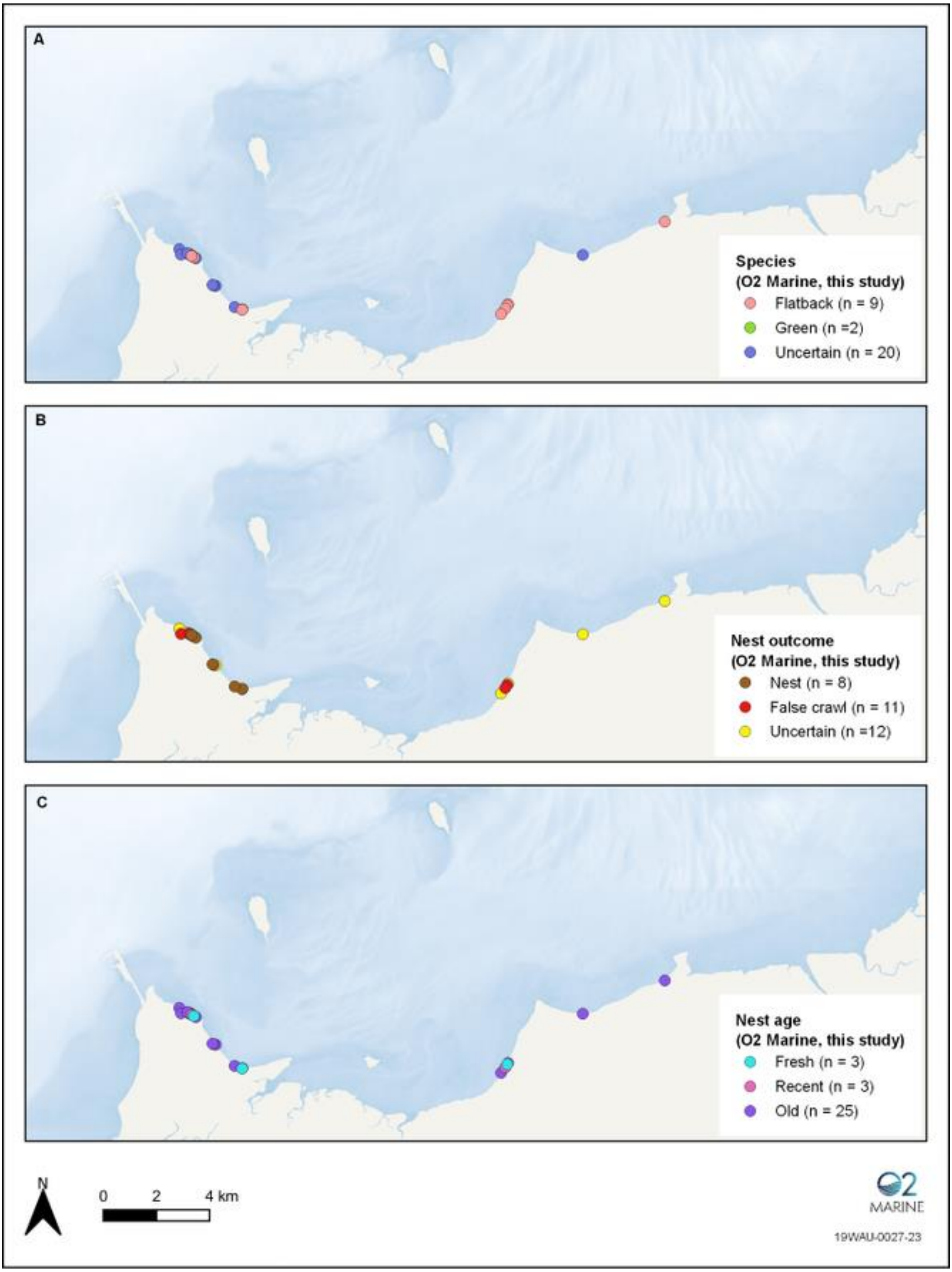

Figure 8 Species, nesting outcome and nest age for identified turtles engaging in nesting activity throughout the full survey period.

4.2.2. Beach Characteristics

Transects were flown over sandy beaches of variable widths, with T1 and T2 being the widest (Table 9). Four-wheel drive activity was observed on all beaches except for T7 and T8, with most activity on T4 in January. Distance from light increased across transects, from T1 to T8, based on their proximity to existing infrastructure at Cape Preston.

Table 9 Beach characteristics of transects surveyed

Beach characteristics	T1	T2	T3	T4	T5	T6	T7	T8
Width (m) (range)	30-50	25-45	8-15	15-25	10-20	10-20	10-25	10-25
Four-wheel drive activity	Y	Y	Y	Y	Y	Y	N	N
Distance from light (m)	90	2,999	2,197	2,200	2,573	3,830	4,583	12,230

4.2.3. Image Quality

A post-processing assessment of 20 images from 31 identified track captures demonstrated that 75% of images were of good quality, 15% were average and 10% were poor (Table 10).

Table 10 Image quality

Quality category	Number	Proportion (%)
Good	15	75
Average	3	15
Poor	2	10

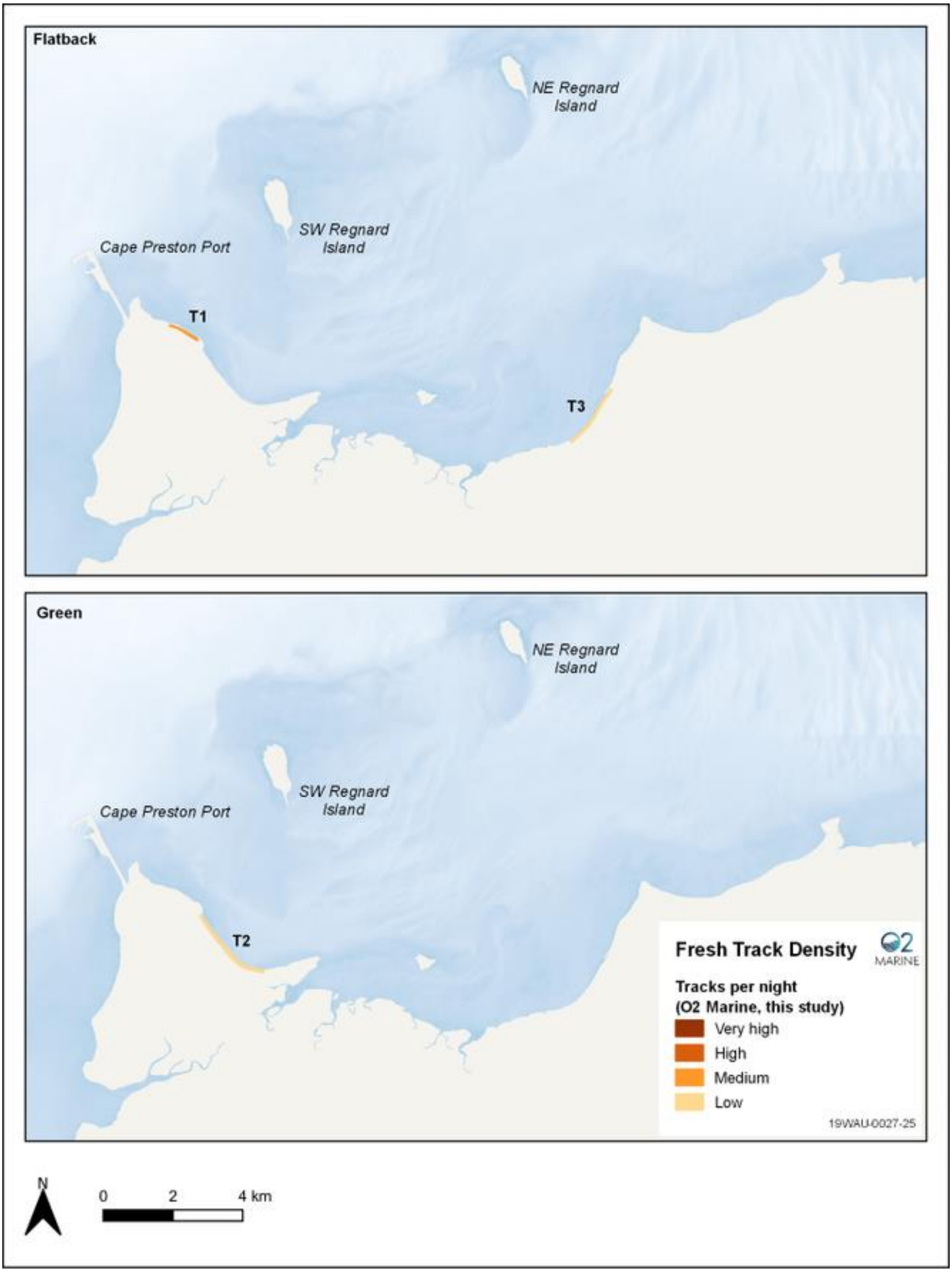

Figure 9 'Fresh' flatback, green and uncertain turtle track densities for the combined survey period. Flatback *

* Measures of track density were assigned to one of three categories: 0-(Absent), 1 (low), 2-10 (medium) and 11-50 (high) fresh tracks km−1 night−1. Flatback T1 = Medium; Flatback T3 = Low; Green T2 = Low.

5. Discussion

This study used an RPAS to collect and analyse aerial imagery of turtle nesting tracks at a localised level, following methods of Fossette et al. (2021) who collected imagery with mounted cameras on an occupied Cessna 172 aircraft at a regional scale. Through open engagement with DBCA, this approach allowed the development of complementary methods that facilitated a direct comparison of nesting turtle species presence and densities at the Proposal site within the context of the Pilbara region.

Flatback and green turtles were found to use beaches of the Proposal site at low and varying levels. Based on the limited nesting activity recorded throughout the Proposal site from Cape Preston to Gnoorea Point, it is reasonable to assume that this area does not represent regionally important turtle habitat. Similar conclusions were derived by previous nesting suitability assessments and nesting surveys at Cape Preston/Gnoorea Point (Imbricata Environmental 2013; Pendoley et al. 2003; Maunsell 2004; Pendoley 2007; Astron 2006) that this area is unlikely to be of reproductive significance at a regional or population level. Results from this study indicated low levels of nesting at certain beaches which were not reported in Fossette et al. (2021).

Along the mainland coast of the Proposal site, T1 and T2 had the highest levels of turtle nesting activity. The Imbricata Environmental (2013) turtle nesting study at Cape Preston also recorded nesting activity within this location, and Pendoley et al. (2016) also indicated that turtle nesting is more prevalent throughout beaches adjacent to Cape Preston. The uneven distribution across the study site is likely attributed to wider beaches offering higher habitat suitability for nesting due to decreased risk of high tide inundation. Less nesting activity at T4–T6 may have resulted from beach characteristics deemed unsuitable for nesting such as high mangrove density, or short beach widths catering to increased risk of high tide nest inundation (Pike et al. 2015). Possible increases in egg and hatchling predation rate from mainland fox populations and close proximity to anthropogenic activity and infrastructure around Cape Preston may have affected turtle nesting location selection over the long term (Fossette et al. 2021).

Generally, Pilbara islands are recognised as being important for turtle nesting. At broad spatial (Fossette et al. 2021) and temporal (Pendoley et al. 2016) scales, islands in the Pilbara have been found to be more important for nesting than the mainland. However, habitat characteristics, and therefore nesting importance, varies across islands. This study initially focussed on surveying turtle tracks on mainland beaches due to the nearer proximity to the Proposal Development Envelope than islands offshore. Survey flights over SE and NW Regnard islands were added in January 2022. At that time, limited nesting activity was recorded, which aligns with Fossette et al. (2021) survey which showed that, across the region, SE and NW Regnard islands are of relatively lower significance.

5.1. Strengths and Limitations

Survey method strengths and challenges were documented to support continual improvement. Overall, this RPAS-based study proved to be a reliable method for identifying the distribution, density, track age and nesting outcome of nesting turtles across the study site, over the study period. Due to the remote nature of certain Pilbara beaches in conjunction with the highly mobile nature of sea turtles, gathering accurate population data is challenging. This poses difficulties for marine ecologists to assess local turtle abundances and, therefore, create effective species management plans. RPAS were successfully utilised throughout this study to conduct surveys aligning with relevant DBCA methodologies (Fossette et al. 2021) with findings that will contribute data for future stock-scale monitoring programs in the Pilbara.

Expending their time and budget on flying a large area, Fossette et al. (2021) were unable to assess temporal variation. By focussing on a smaller spatial area, this study was able to repeatedly survey beaches within a survey period and the turtle nesting season which increased capture probability. In addition, the repeated transects with quality check of data provided confidence in survey findings by providing further evidence for the observer in identifying species, track age and nesting outcomes in instances of uncertainty. There is an intrinsic problem with track and species identification in that track condition is inconsistent, as influenced by environmental variables. Fossette et al. (2021) suggest environmental conditions including fine sand, strong winds, flat, low, sloping beaches and rain, combined with shallow body pits left by nesting females and lightly incised turtle crawl tracks can act together to erase the physical evidence of a turtle from the beach within a few hours. However, the inverse is also true in that in certain conditions old tracks will persist and lead to issues in track double counting (J. Gee., pers. comm).

A key challenge in implementing the survey was scheduling and avoiding strong winds. The turtle nesting season coincides with some of the highest monthly wind averages for the region (BOM 2021), which may have affected initial flight calibration, captured image quality and subsequent track and species identification. This is specifically evident in the low image quality captured from T1 on January and T3 in February (Appendix A).

Marine fauna studies are usually strengthened by increased repetition of data collection. Increased temporal coverage assists in accounting for environmental fluctuations between and across years, and patterns of occurrence exhibited by different species. Ideally, islands should have received the same effort as mainland sites.

6. Conclusion

Flatback and green turtle species were found to nest infrequently and in low densities on the mainland within the Proposal site, including at the beach nearest to the trestle jetty at the Cape Preston East Port. No turtle activity was recorded on the islands surveyed. Based on this evidence, it is concluded that although the Proposal site is situated within a flatback turtle BIA, it is of relatively low regional significance. The beaches surveyed are not likely to represent key nesting sites for the population.

Collection of aerial imagery by RPAS proved to be a successful and reproducible approach in collecting this data. Using established methods to analyse and interpret the data has proven to be a useful tool in collecting fine-scale information that can be placed in a broader spatial and temporal context. This may be viewed as a case-study to encourage localised monitoring programs to adopt consistent methods that contribute to a larger dataset able to inform the conservation and management of WA turtle stocks.

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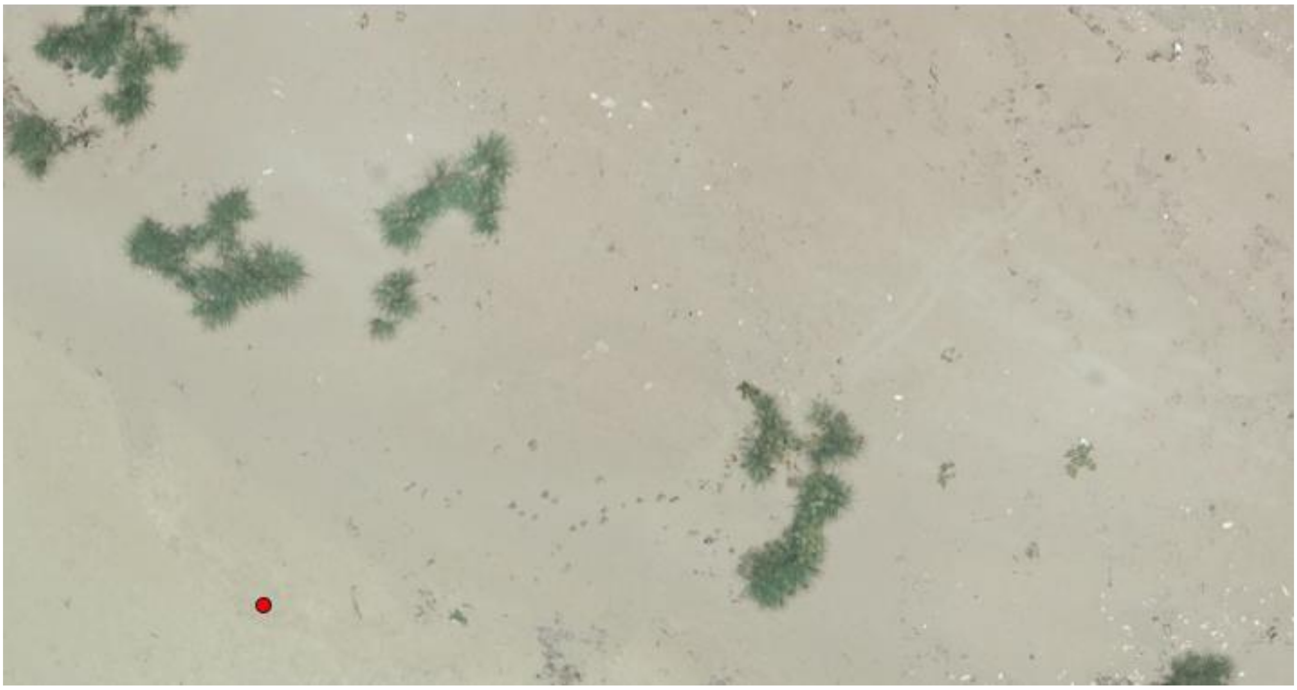
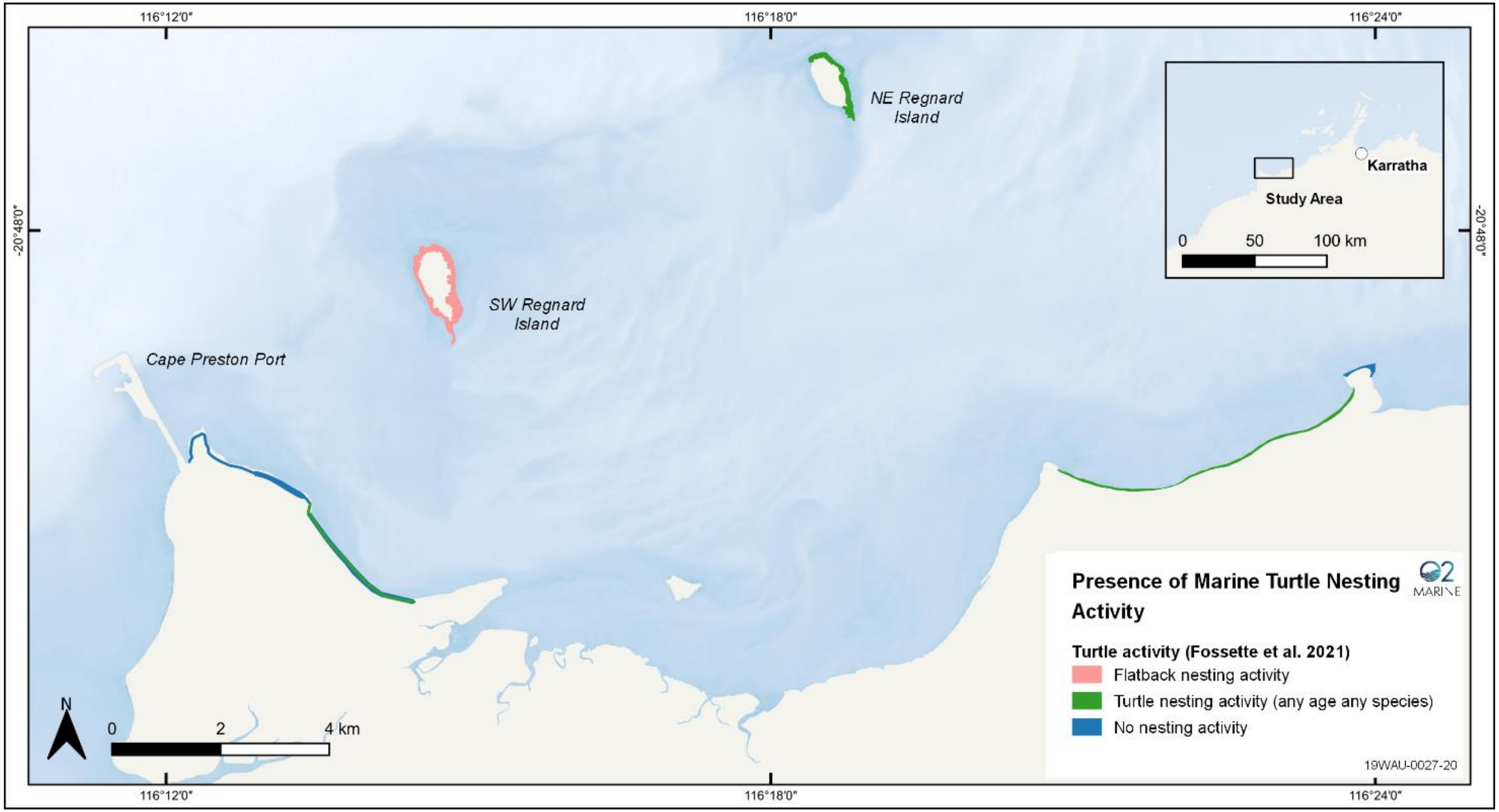
Appendix A. Image quality

Appendix Figure 1. Example of a 'good' quality survey image capture (red dot indicates track)-High resolution

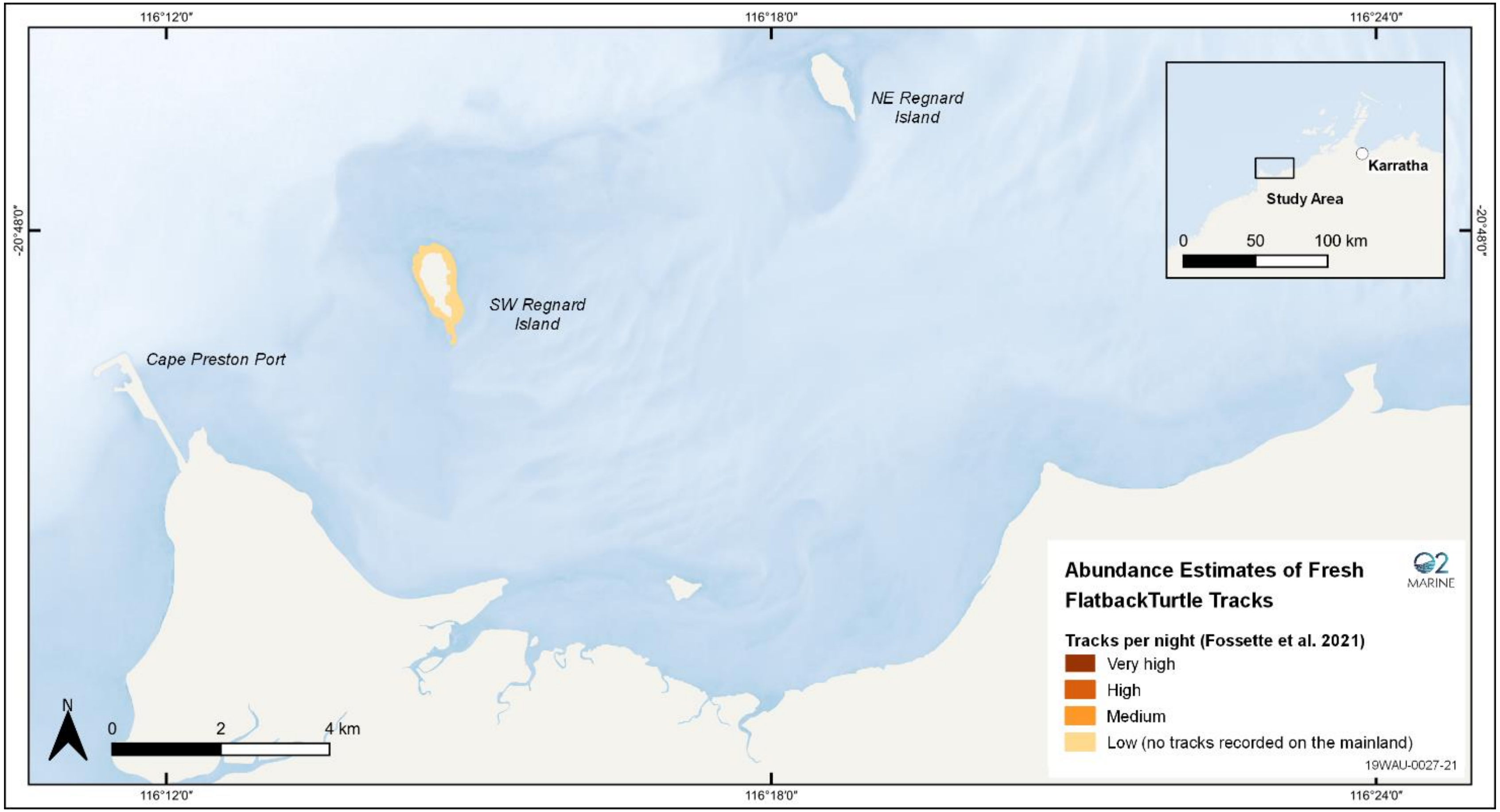


Appendix Figure 2. Example of a 'poor' quality survey image capture (red dot indicates track)-Low Resolution

Appendix B. Fossette et al. (2021) Results for Comparison



Appendix Figure 3. Presence of Marine Turtle Nesting Activity recorded by Fossette et al. (2021)



Appendix Figure 4. 'Fresh' flatback and green turtle track abundance reported by Fossette et al. (2021). Measures of track abundance are assigned to one of three categories: 1-4 (low), 5-9 (medium) and 10-49 (high), 50 to 249 (very high) tracks.km−1.night−1