BHP BILLITON IRON ORE

PROPOSED OUTER HARBOUR DEVELOPMENT PORT HEDLAND

SATELLITE TRACKING OF FLATBACK TURTLES FROM CEMETERY BEACH 2009/2010 – INTERNESTING HABITAT

Prepared by

Pendoley Environmental Pty Ltd

For

SKM/BHP Billiton Iron Ore

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DOCUMENT CONTROL INFORMATION

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EXECUTIVE SUMMARY

BHP Billiton Iron Ore proposes to expand their iron ore operations in the Pilbara. The proposed Outer Harbour Development is located on the coast near Port Hedland in the Pilbara region of Western Australia. The proposed Outer Harbour Development involves the construction of infrastructure (jetty and wharves) and dredging, to allow ship access to the infrastructure for loading of iron ore.

The dredge entrainment and spoil disposal activities proposed as part of the Outer Harbour Development have been identified as providing a high inherent risk to internesting flatback turtles that may be present within the near shore waters surrounding Port Hedland during their internesting period. There is therefore a need to obtain a better understanding of flatback turtle behaviour within and surrounding the proposed dredge entrainment and spoil disposal area in order to better define and mitigate the risk to the internesting flatback turtle population.

The aim of this project was to use all aspects of advanced satellite tracking technology to study the internesting movements and dive behaviour of flatback turtles nesting on Cemetery Beach, Port Hedland. Understanding this movement and dive behaviour within these areas will help to better define the risk to internesting flatback turtles from the proposed work and is critical for better management of the dredging program to reduce the potential impact to turtles.

Satellite transmitters (MK10-A Platform terminal transmitters (PTTs)) were deployed on 10 flatback turtles on Cemetery Beach between 10th and 12th December 2009. All MK10-A units were combined with Argos receivers and Time Depth Recorders (TDRs). Internesting migration and dive behaviour were identified using set definitions for each activity. Internesting home range areas were identified using 50% and 95% Fixed Kernel Density (FKD) estimators and Minimum Convex Polygons (MCP).

Additionally, aerial surveys were conducted to confirm and quantify the presence of marine turtles within the marine study area. These data combined with the satellite/TDR data from this study will allow an accurate estimate of the total number of turtles (including submerged animals by using a conversion factor) within the area, particularly the dredge and spoil disposal areas.

Potential interactions of internesting flatback turtles with proposed construction activities were predicted using the data collected and derived from the transmitters including; the number of positions within the proposed development footprint, the percentage of core activity and home range areas within the proposed development footprint, and the percentage of dives spent on the seabed floor. It is likely that further interaction with activities outside of these areas, including impacts from sedimentation and turbidity from the dredge plumes and increased ship movement, may occur. Therefore all estimates of construction interaction should be taken as a conservative estimate.

A total of ten internesting periods were tracked from six flatback turtles between the 10th December 2009 and 16th January 2010, with the remaining four turtles departing from Port Hedland without nesting again providing no further internesting data. The six turtles tracked during internesting displayed notable consistency in direction of movement with all but one internesting period migration track remaining within 50 km of Cemetery Beach in a north or north-east direction. The exception to this was internesting track 52897_1 which passed through the existing shipping channel and headed west to nest at Mundabullangana, 50 km away. The mean home range area was 143.2 km^2 (95 % utilisation distribution, UD) and core activity area (50 % UD) was 14.8 km^2 for the internesting flatback turtles.

Flatback turtles exhibited relatively short dives where 75 % of dives recorded were less than 15 minutes and the majority of dives were less than 5 minutes in duration. All recorded dives were less than 60 minutes. The flatback turtles recorded shallow dives, with 85 % of their dive time spent at 20 m water depth or less, with most time spent between 5 – 10 m. The maximum dive depth for the internesting flatback turtles showed a very similar pattern to the time spent at depth, indicating that when turtles dived they generally dive to their maximum depth and remain there for the duration of the dive. The average percentage of time spent at the surface was 31.5 %, with 68.5 % of time spent diving.

None of the Argos positions or the core activity areas of the internesting flatback turtles overlapped with the proposed development footprint. However, turtles are known to occur within the proposed development footprint, as shown by one of the flatback turtles tracked in 2008/09 (Pendoley Environmental, 2009). The aerial survey results also showed that approximately 3 % of the turtles sighted were within the proposed development footprint.

In addition, turtles were found to spend 34 % of their time on the seabed floor, where they are more at risk from dredge entrainment. Therefore, dredging is a potential risk to marine turtles.

Further studies involving the use of recoverable TDR units on internesting flatbacks, and hence having access to individual dive profiles, may confirm the exact dive behaviour of internesting flatback turtles at Cemetery Beach. While the aerial survey recorded turtles within the proposed development footprint, it is unknown whether these were internesting flatback turtles that are present during the summer, or resident foraging turtles that are present all year round. It is likely that some of these turtles are resident foraging turtles and it is recommended that satellite tracking of these foraging turtles be undertaken to determine their movements and behavior within the dredging and spoil disposal areas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1 INTRODUCTION

BHP Billiton Iron Ore currently exports iron ore through port facilities in Port Hedland, Western Australia. The current port operations consist of processing, stockpiling and shiploading facilities at Nelson Point and Finucane Island (referred to as the Inner Harbour), located on opposite sides of the Port Hedland Harbour. The proposed Outer Harbour Development includes a new port facility linked to Finucane Island to provide an export capacity of 240 Mtpa (**Figure 1**).

1.1 Movement Patterns in the Flatback Turtle

Cemetery Beach is located approximately 6 km to the east of the proposed Outer Harbour Development (**Figure 1**) and is considered a moderate density flatback turtle nesting beach, with 188 flatback turtles tagged in 2009/10 as part of the BHP Billiton Iron Ore tagging program (Pendoley Environmental 2010). The flatback turtle (as well as all species of marine turtles) is protected by the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (Commonwealth), and is also afforded protection under the *Wildlife Conservation Act 1950-1979* (Western Australia). Although it has been the subject of study in eastern Australia for a number of years and more recently in Northern and Western Australia, knowledge of its internesting movements and dive behaviour remains poor.

All species of marine turtles are oviparous, meaning that the females lay eggs on their natal beach. Females lay multiple clutches of eggs over a two to three month time frame during each nesting season (Hamann *et al*. 2003; Limpus 2009). Between each nesting event, the female moves to an internesting area offshore while they form their next clutch of eggs. This period is known as the internesting period. It is thought that during this period female flatback turtles remain in near shore waters close to their nesting beaches, however this has not been confirmed in published studies and the extent of their movements during this time is poorly known (Plotkin, 2003). Monitoring of nesting flatback turtles on Cemetery Beach in Port Hedland has identified this internesting period as 13.3 ± 0.8 days (Pendoley Environmental 2010).

Knowledge of dive behaviour in all stages of the flatback turtles' life cycle in Western Australia is also limited. Flatback turtles inhabit the coastal waters of Western Australia and have been shown to follow offshore migratory pathways associated with 30 - <70 m bathymetric contours (Chevron Australia 2009; Pendoley, unpublished data, www.seaturtle.org), indicating that the maximum dive depth to which this population of flatback turtles is likely to be restricted to is 50 m. Specific details relating to dive duration, frequency, and exact dive depth remains unknown, particularly during the internesting period.

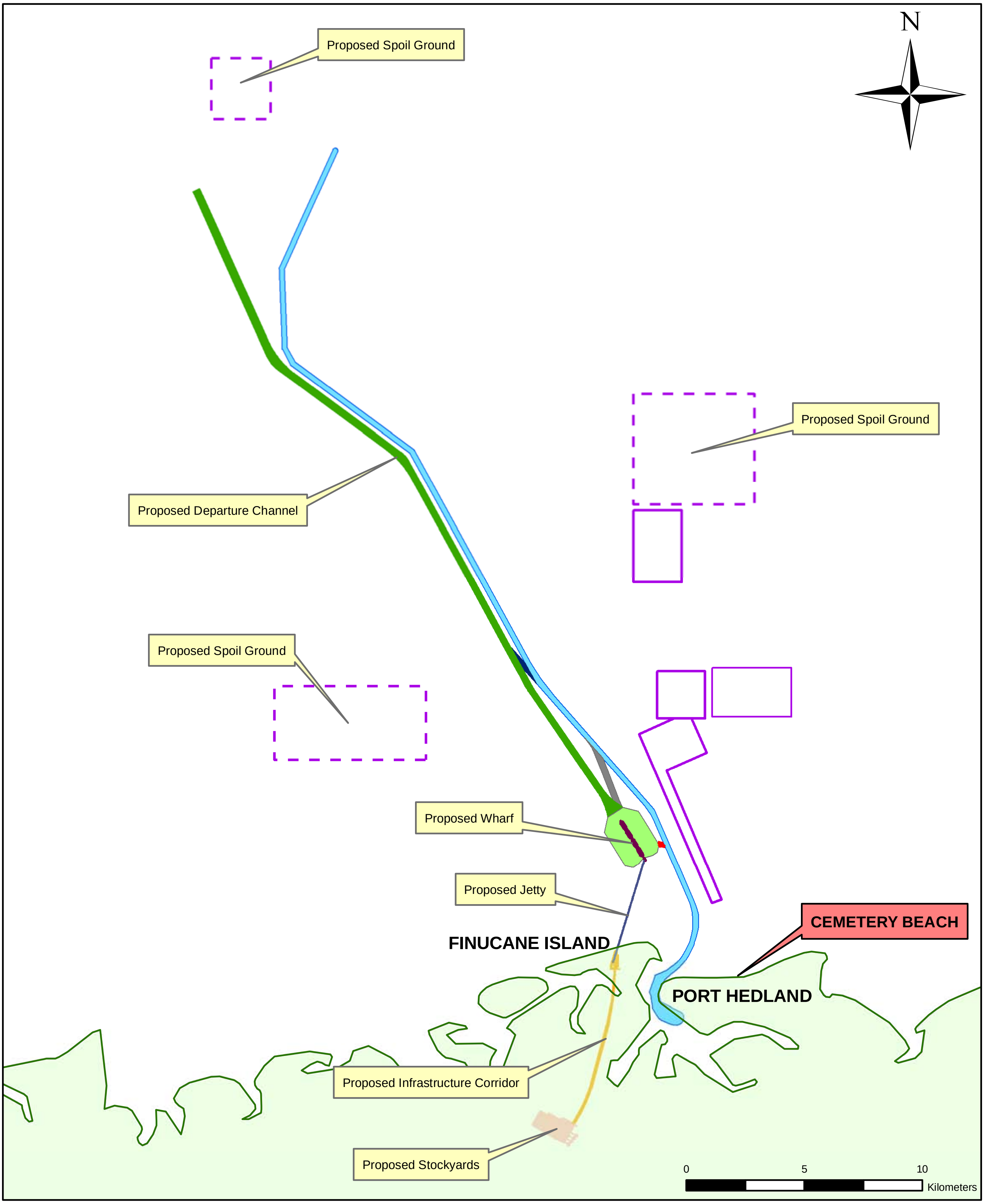
In recent years the advances in satellite tracking technology and the use of onboard time depth recorders (TDRs) has provided a means to overcome the difficulties in obtaining relatively precise location data and detailed diving behaviour of wide-ranging marine vertebrates including marine turtles (Fedak *et al*. 2002; Hays *et al*. 2004). These advances have allowed marine turtle biologists to gain more accurate and detailed information on the movements and behaviour of marine turtles (Godley *et al.* 2008).

1.2 Scope of Work and Objectives

The dredge entrainment and spoil disposal construction activities for the proposed Outer Harbour Development have been identified as providing a high inherent risk to internesting flatback turtles that may be present within the near shore waters surrounding Port Hedland during their internesting period. There is therefore a need to obtain a better understanding of flatback turtle behaviour within and surrounding the proposed dredge entrainment and spoil disposal area in order to better define and mitigate the risk to the internesting flatback turtle population.

The aim of this project is to use all aspects of advanced satellite tracking technology to study the internesting movements and dive behaviour of flatback turtles nesting on Cemetery Beach, Port Hedland. Understanding this movement and dive behaviour will help to better define the risk to internesting flatback turtles from the proposed construction activities and is critical for better management of the dredging program to reduce the potential impact to turtles.

Additionally, aerial surveys were conducted to confirm and quantify the presence of marine turtles within the marine study area. These data will enhance information gathered in the last year and contribute to delineation and characterisation of marine turtle habitat in the Port Hedland Harbour and wider regional area. In addition, these data combined with the satellite/TDR study will allow an accurate estimate of the total number of turtles (including satellite tracked submerged animals) within the area, particularly the dredge and spoil disposal areas.



Project	J22008 Outer Harbour Development Port Hedland Satellite/TDR Study		
Title	Figure 1: Project area and proposed Outer Harbour Development infrastructure		
Drawn JEO	Date 19/05/2010	Scale	As shown
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Approved KLP	Date 19/05/2010		
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Legend

- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel
- Tug access channel
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards

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2 METHODOLOGY

2.1 Satellite/TDR Study

2.1.1 Location and Site Description

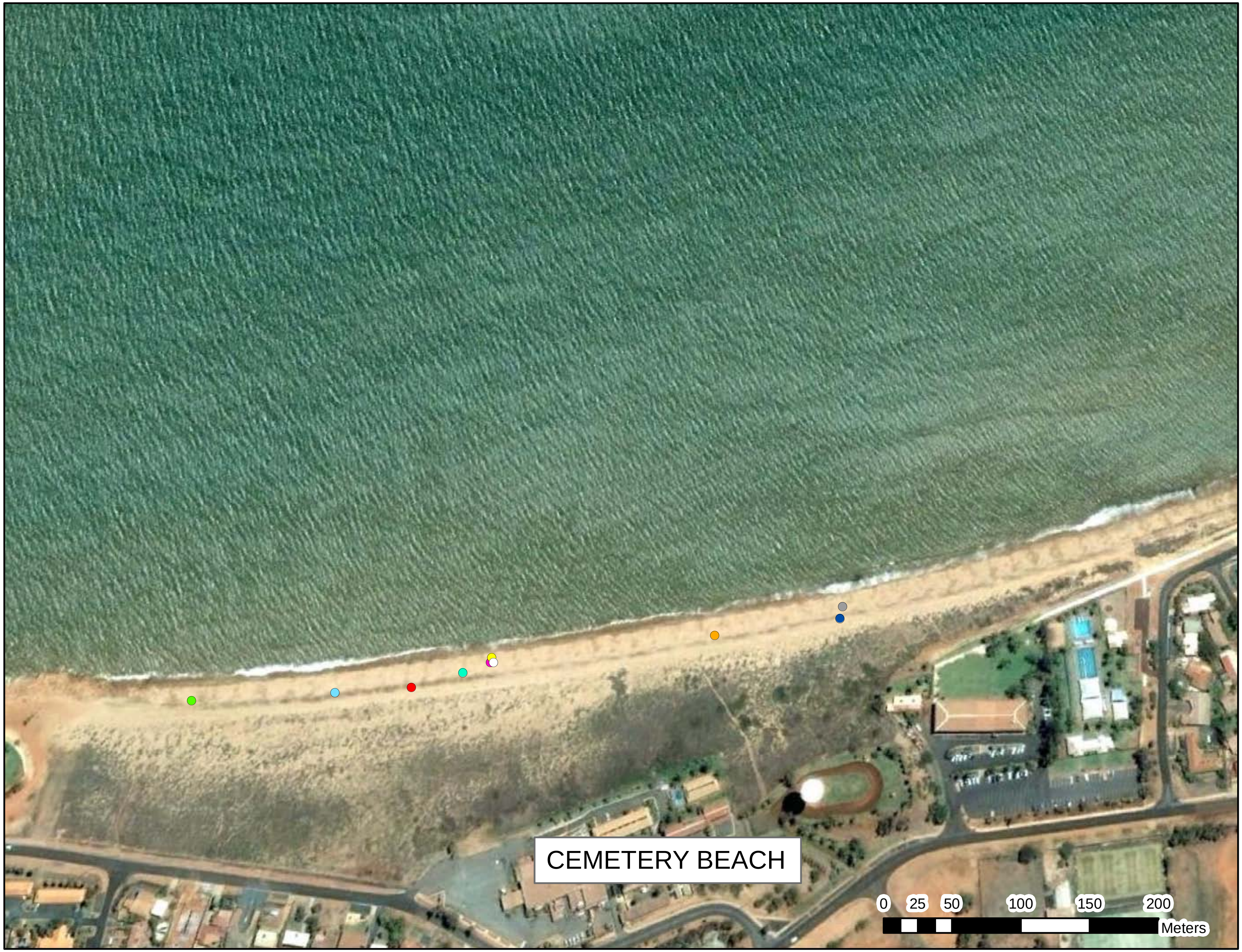
Cemetery Beach is a 1 km long sandy beach situated along the northern coastal boundary of the town of Port Hedland in Western Australia (**Figure 1**). The north facing beach is known to host a rookery of nesting flatback turtles and is approximately 6 km to the east of the proposed dredging entrainment and spoil disposal area. The location of Cemetery Beach and the nesting turtles when the satellites transmitters were attached are shown in **Figure 2**.

2.1.2 Field Deployment

MK10-A Platform Terminal Transmitters (PTTs) (Wildlife Computers) were deployed on 10 flatback turtles on Cemetery Beach between 10th and 12th December 2009, in accordance with Pendoley Environmental's Satellite Transmitter Attachment Standard Operating Procedures. The attachment was carried out in conjunction with the established tagging program on Cemetery Beach. Individual turtle details were recorded according to standard protocols (passive integrated transponder (PIT) tag and single flipper tag).

Each PTT was mounted on a polycarbonate plate lined with a neoprene wetsuit material and the plate positioned on the turtle using webbing threaded through six slits made on the plate. Each PTT was positioned on the central-anterior portion of the flatback turtle carapace, covering approximately the first and second vertebral scutes (**Figure 3**). The PTT is positioned so that when the flatback surfaces to breathe, the PTT breaks the water, and a salt water switch turns the PTT on. The salt water switch is located near the Argos antenna and was used to conserve battery power when the tag was submerged. The harnesses and webbing were designed and built by Paul Tod (Crackpots Pty Ltd). The design was adopted from Sperling & Guinea (2004), but the harnesses were made longer to account for the larger size of flatback turtles in Western Australia. The harnesses were made from nylon seat belt webbing with six straps centred about a magnesium ring. Velcro was attached to the straps to secure the harness in place and corrodible magnesium wire was used to hold the straps in place. The 'weak link' of this design is the magnesium ring used to hold the straps in place, which eventually corrodes and allows the Velcro straps to work loose. The life of this ring is unknown as it is dependent upon water temperature and individual turtle movement.

During deployment, Cemetery Beach was patrolled during the night around high tide for suitable flatback turtles. A flatback turtle was considered suitable if it was uninjured with no signs of damage, had no barnacles on its carapace, and was an appropriate size for the harness (curved carapace length between 840 and 870 mm). The average time taken for each PTT deployment was 10 minutes (**Table 1**) and each turtle was allowed to complete their nesting activity before deployment, unless it was returning to the water.



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Project

J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

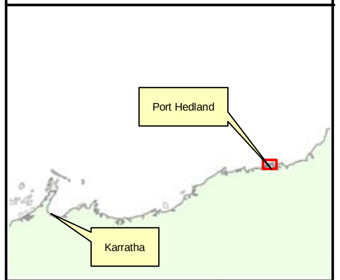
Title

Figure 2: Location of satellite transmitter attachments to flatback turtles nesting at Cemetery Beach

Legend

Turtle ID

52895	52903
52896	52904
52897	52907
52900	52909
52901	52911



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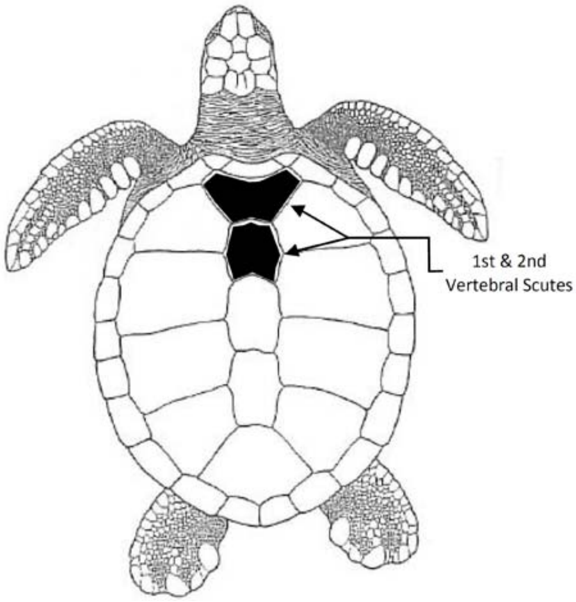

Figure 3: Location of satellite transmitter attachment on a flatback turtle (outline image from Eckert *et al*. 1999).

2.1.3 Data Acquisition

2.1.3.1 Accuracy

Argos

The location of the Argos transmitter was calculated from the Doppler shift in the frequency of transmissions received by a satellite as it approaches and then moves away from the transmitter on a single overpass (Hays *et al*. 2001). Argos data relies on multiple transmissions to generate a position, and the more transmissions received, the more accurate the position. For this reason, more, higher quality positions are generated when turtles spend more time at the surface (Hays *et al.* 1999).

The accuracy for each individual position was categorised by a quality index (termed the location class or LC). Locations are designated as LC 3, LC 2, LC 1, LC 0, A or B. Of these, LC 3, LC 2, LC 1 and LC 0 were provided only when at least four transmissions were received by the overhead satellite; LC A was provided when a location was determined from three transmissions; and LC B when a location was determined from two uplinks. Argos state that the estimated accuracy of latitude and longitude coordinates is <150 m for LC 3, between 150 and 350 m for LC 2, between 350 and 1000 m for LC1, and >1000 m for LC 0 (Hays *et al*. 2001). Locations classified as Classes A and B have been ill defined, but probably indicate poor accuracy (particularly LC B) (Hays *et al*. 2001).

Time Depth Recorder (TDR)

The MK10-A PTTs incorporated a Time Depth Recorder (TDR) which provided depth measurements from -40 m to +1000 m, with 0.5 m resolution and an accuracy of ±1% of the reading. Water temperatures were measured between -40 °C and +60 °C, with 0.05 °C resolution and an accuracy of 0.1 °C.

2.1.4 Data Processing

2.1.4.1 Location Data

Once dry at the surface (i.e. when the turtle surfaces to breathe) the PTT automatically transmits a signal to an Argos polar orbiting satellite. This message was then relayed by the receiving satellite to the Argos processing centre (**Figure 4**).

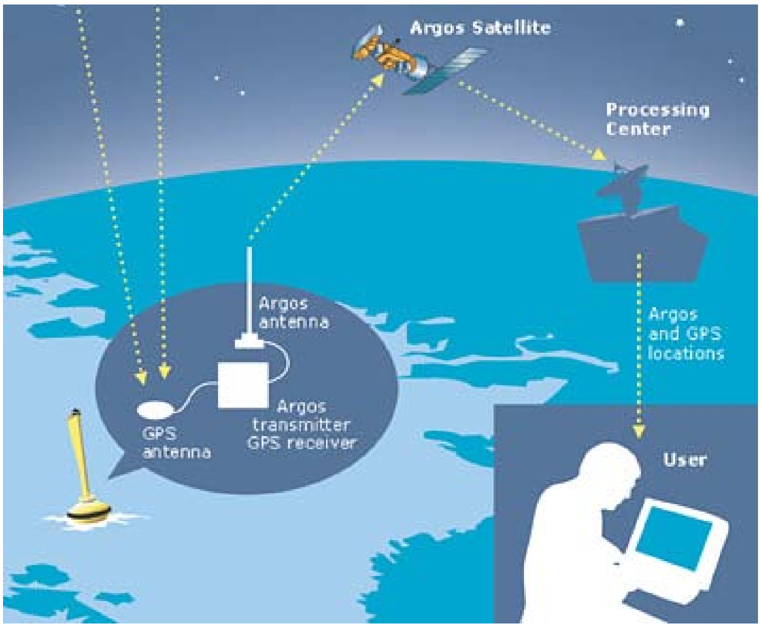

Figure 4: Sending Argos positions via the Argos satellite system.

The Argos processing centre calculated the PTT positions by processing the received frequency measurements (to calculate the Doppler Effect). The final Argos position was provided in latitude and longitude using the WGS 84 (World Geodetic System 1984) reference system.

The Satellite Tracking and Analysis Tool (STAT), which is a computer program developed by Dr Michael Coyne (www.seaturtle.org) was used to download, sort and filter the received data from the Argos processing centre (Coyne & Godley 2005). Argos positional data were generated using the following filter:

- Filter 1 was used to retain the more accurate positions using only the positions with a quality index of LC 3, LC 2, or LC 1 (herein referred to as LC321). This filter was used to determine offshore locations during the internesting period and swimming speeds (km/hr).

Two sets of data were created from the Argos position data:

- Dataset 1: Incorporated all Argos points (with errors filtered).
- Dataset 2: The dataset was created from temporally separating the first dataset to only include one Argos position for every 12 hours of transmissions (taken as the first position within the defined 12 hour window). This method removed any bias towards PTTs that transmitted more location fixes than other PTTss within the same time frame. The 12 hour

period was used to increase the likelihood of an Argos position actually being transmitted and received by an Argos satellite.

2.1.4.2 Time Depth Data

Each TDR collected information on dive behaviour and transmitted the summarised data in six hour periods via Argos in histogram format. The data are summarised due to the restrictions in the message size that is transmitted (31kb) and the life of the battery. The summarised data included dive duration, maximum dive depth, time at depth and temperature within the six hour period. It is important to note that only a subset of dive data that is transmitted is received by the satellites.

For the frequency of maximum depth of each dive the upper bin values were 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90 and >90 m. For the frequency of the time spent at each depth, the upper bin values were 5, 10, 15, 20, 25, 30, 45, 60, 90, 120, 150, 180, 240 and >240 m. For dive duration, the upper bin values were 5, 10, 15, 20, 25, 30, 45, 60, 90, 120, 150, 180, 240 and >240 min. For temperature the upper bin values were 10, 15, 18, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, >31 °C.

2.1.4.3 Bathymetric Data

Bathymetric contour data (collected by Tenix LADS Corporation) was obtained from SKM and the contour data was used to generate a 10 m x 10 m resolution grid using XTools Pro 6.1 in ArcGIS (see **Figure 6** for extent and values of bathymetric grid).

The bathymetric contour data is relative to a ‘chart datum’, which is the lowest possible astronomical tide (LAT) and therefore the minimum water depth during the tidal cycle. However, the recorded depths of dives include the current tide level relative to the ‘chart datum’ during the six hour blocks in which the data were recorded. Therefore to identify the absolute maximum depth of the bathymetry during the six hour block of time, the bathymetric depth value had to be adjusted according to the tide level relative to the ‘chart datum’ at that time. The Port Hedland tide station was used for the tide levels. The maximum tide level during the six hour period was calculated and added to the bathymetric depth at the Argos fix location for the six hour block of time.

2.1.5 Data Interpretation

2.1.5.1 Nesting and Internesting

The following definitions were used to calculate nesting and internesting data. These definitions are modified from Whiting *et al.* (2007) and will allow direct comparisons of the work in future studies:

- Nesting attempt: Where a satellite fix was located on a nesting beach.
- Successful nesting event: Where a fix was located on a beach and the turtle was not recorded on the beach for the next ten days. If a turtle moved within 200 m of the nesting beach and the subsequent fix on the nesting beach would make the internesting interval > 10 days then it was deemed that the turtle had nested at some point during this period. Where this was the case, the last record close to the beach before it moved away was used as the nesting date. Ten days was selected as this is the physiological limit within which a turtle can produce a new clutch of eggs (Hamann *et al.* 2003).
- Internesting interval: The time in whole days from one successful nesting event to the next nesting attempt (whether successful or not; Whiting *et al.* 2007).

- Internesting period: The time between successful nesting events, individual turtles may have multiple internesting periods in a nesting season and each period is defined spatially and temporally.
- Displacement during internesting: The straight line distance from the deployment/successful nesting event location to the furthest location during the internesting period.
- End of internesting: The final successful nesting event recorded with no further nesting attempts recorded.
- Overall internesting period: Defined as the period from initial deployment to the end of internesting.

A unique number was given to each internesting period allowing easy identification and reference of each internesting period. The number was based on the unique Argos PTT number and a successive number for each internesting period by that specific turtle starting from one i.e. 52896_1 for the first internesting period and 52896_2 for the second successive internesting period.

2.1.5.2 Home Range Analysis

For this project two home range analysis techniques were used for comparison:

- Minimum Convex Polygon (MCP): MCPs were calculated using the Home Range Tools (HRT; www.blueskytelemetry.co.uk) for ArcView 9.3 Geographic Information System (GIS) software (Environmental Systems Research Institute; Redlands, CA, USA). The MCP analysis technique identifies the home range as the area within the polygon formed by joining the outermost positions of an animal's observed distribution (Burt 1943). The polygons were based on both the 50% and 95% outer edges. The 95% polygon was used to estimate the overall home range used by a turtle, where as the 50% polygon was used to establish the core area of activity. This has been the most commonly applied technique (Mendonca 1983; Renaud & Carpenter 1994; Renaud *et al*. 1995; Whiting & Miller 1998).

- Fixed Kernel Density (FKD): FKD home range areas were calculated using Biotas 1.03.2 software (Ecological Solutions). FKD home ranges are based on probability 'kernels', which are regions around each point location containing some likelihood of animal presence. The width of the kernel is based on the smoothing parameter (h) which was calculated using least-square cross validation (based on properties of the data; see Silverman, 1986 and Seaman & Powell 1996). As with the MCP a 95% utilization distribution (UD) was used to estimate the overall home range used by a turtle, whereas a 50% UD was used to establish the core area of activity (Worton 1987; White & Garrott 1990). A UD is a grid where the value for each cell represents the probability of the animal occurring in that cell. Among other uses, a UD allows for a more precise estimate of home range overlap than a simple outline (as produced by MCP analysis). Sample sizes are recommended to be at least 30, and preferably >50 for FKDs (Seaman *et al.* 1999).

To avoid data quality and data volume from creating a bias on the extent of the MCP and FKD areas for individual turtles, 50% and 95% MCPs and FKDs were calculated from the temporally restricted dataset. ArcGIS was used to remove any MCP and FKD home range area (for both 50% UD and 95% UD) that overlapped the Australian mainland coast.

Construction Impacts: Internesting Migration and Home Range Analysis

To identify the potential interaction of internesting flatback turtles with construction activities associated with the proposed Outer Harbour Development, the number of Argos locations and the percentage of the FKD home range area for both the 95% and 50% UD based on the temporally restricted dataset for each internesting interval track within or overlaying the proposed development footprint was calculated. The footprint encompasses the areas disturbed by dredging activities, and dredge spoil disposal at the spoil grounds, and the direct placement of infrastructure on the sea bed (see **Figure 1** for footprint boundaries). The MCP home range area was not used to identify potential construction interactions due to constraints of the MCP home range analysis technique. The MCP analysis technique strongly relates to the distribution of the outermost points and is constrained by its inability to identify fine scale spatial use patterns by only revealing one area of activity for each internesting period. In contrast the FKD home range analysis technique reveals areas of disproportionately high use (i.e. multiple core areas of activity) for each internesting period while appropriately weighing outlier observations.

The identified construction interactions are based purely on the proposed development footprint and do not include the zone of predicted impact associated with turbidity and sedimentation (dredge plume) or increased ship movement outside the proposed footprint. Therefore all estimates of construction interaction in this report should be taken as a conservative estimate.

2.1.5.3 Dive Behaviour

The six hour blocks of histogram data for time and depth recordings were grouped according to the dates of each unique internesting period prior to any data interpretation to allow for the direct comparison of spatial behaviour with dive behaviour during each internesting period.

All dives were defined as starting when the turtle submerged below 2 m. To eliminate any periods spent just below the surface, a single dive was registered when a turtle descended below 2 m for at least 20 seconds continuously. A dive was recorded as ending when the turtle reached a depth of 2 m on ascent.

The 2 m depth limitation was necessary to allow the capture of the highest possible number of dives for transmission by not recording and hence transmitting shallow dives close to the surface, which are often difficult to distinguish from short inter-breath submergences and occur when turtles travel. However, this configuration may potentially underestimate the dive ratios for turtles that preferably dived to shallow depths of less than 2 m depth or greater than 2 m depths but for a short duration of less than 20 seconds (Hochscheid *et al*. 2007). Nevertheless, using this configuration ensured that only dives of adequate depth and duration for analysis were transmitted.

Information generated from TDR data within six hour blocks that was calculated is listed below:

- Percentage of time spent at depth (m);
- Percentage of dives to maximum dive depth (m);
- Percentage of time of dive duration (min);
- Percentage of time spent at temperature (°C);

- Percent minimum time spent diving and at the surface.

Construction Impacts: Dive Behaviour

Results calculated from transmitted dive data were further processed and interrogated to identify the potential interaction of diving internesting flatback turtles with construction activities associated with the proposed Outer Harbour Development. The aim of this further processing was to better define the potential risk to internesting flatback turtles from the proposed dredging and construction activities, and assist with developing relevant mitigation options to manage the predicted impacts to internesting flatback turtles from dredging and construction activities. The additional results included calculating:

- the percentage of time spent on the seabed floor, which was calculated by the percentage of time spent within the dive depth bin that corresponded to the tidally adjusted bathymetry at the particular location within the six hour blocks; and
- the percentage of time spent on the seabed floor was compared during daylight and night time hours.

2.1.6 Data Analysis

All data are presented as mean ± standard error. Statistical analyses were conducted using XLStat 2010.

2.1.6.1 Home Range Analysis

The MCP area (km^2) and FKD area (km^2) based on a 50% UD for the temporally restricted dataset for each individual internesting period was compared with a Wilcoxon rank sum test. The MCP area (km^2) and FKD area (km^2) (50% & 95% UD) for all data points and the MCP area (km^2) and FKD area (km^2) (50% & 95% UD) for the temporally restricted dataset was compared using a Wilcoxon rank sum test. The 50% UD FKD area (km^2) for the temporally restricted dataset was also compared with the overall distance (km) travelled for each internesting period using a Kendall correlation matrix.

2.1.6.2 Dive Behaviour

The percentage of time spent at depth was compared with the percentage of dives to the maximum dive depth (m) using a Wilcoxon rank sum test. The percent of time spent on the seabed floor was compared during the day and night using a Mann-Whitney test.

2.2 Aerial Survey

2.2.1 Field Methodology

An aerial survey was conducted in over two days on the 12th and 13th January 2010 by Dr Jessica Oates and Mr Paul Tod to map turtle presence/absence in offshore waters. It is impossible to determine whether the turtles observed were foraging, mating, internesting or migrating through the area at the time of the survey.

The aerial survey was conducted within offshore waters from Mundabullangana to the De Grey River and 30 strip transects (**Figure 5)** were flown approximately perpendicular (NW-SE) to the coastline out to the 20 m depth contour. Separation from the coast to the 20m depth contour was generally between 20 and 45 km. All transect lines were spaced at 2.5' latitude (4.65 km or 2.5 nm) and followed the same methodology as Prince *et al.* (2001) as it is an accepted method and allowed comparison of results between the two surveys. Observations were made at an altitude of no less than 155 m and a ground speed of 100 knots. Two observers independently scanned 200 m wide survey strips on each side of the aircraft. The 200 m transect width was marked using tape on the wing struts. The number and species (if possible) of turtles were relayed into a voice recorder and the location was recorded using a handheld GPS. This information was later transferred onto datasheets. The weather conditions during the summer aerial survey were favourable with winds generally between 10-15 knots from the south to south-west, and minimal cloud cover, haze and glare. Visibility was generally suitable for the sighting of turtles from the aircraft. The weather conditions during the winter aerial survey were generally favourable with winds between 10-15 knots, however, cloud cover ranged from 0-100%, reducing visibility at times.

2.2.2 Data Analysis

The number of turtles sighted during the aerial transect survey was used to calculate the number and density of turtles within the whole survey area. Not all turtles that were within the survey area would have been seen as they may have been diving. Therefore, the aerial survey data were also combined with the satellite/TDR study to calculate a conversion factor that enabled us to accurately estimate the total number of turtles including the submerged animals within the area, including the proposed dredge and spoil disposal ground areas. The data on the number of turtles sighted was used to generate a 2 km x 2 km grid using Spatial Analyst in ArcGIS to display the data. The conversion factor was calculated from the proportion of time the tracked flatback turtles spent diving compared to the proportion of time spent at the surface.

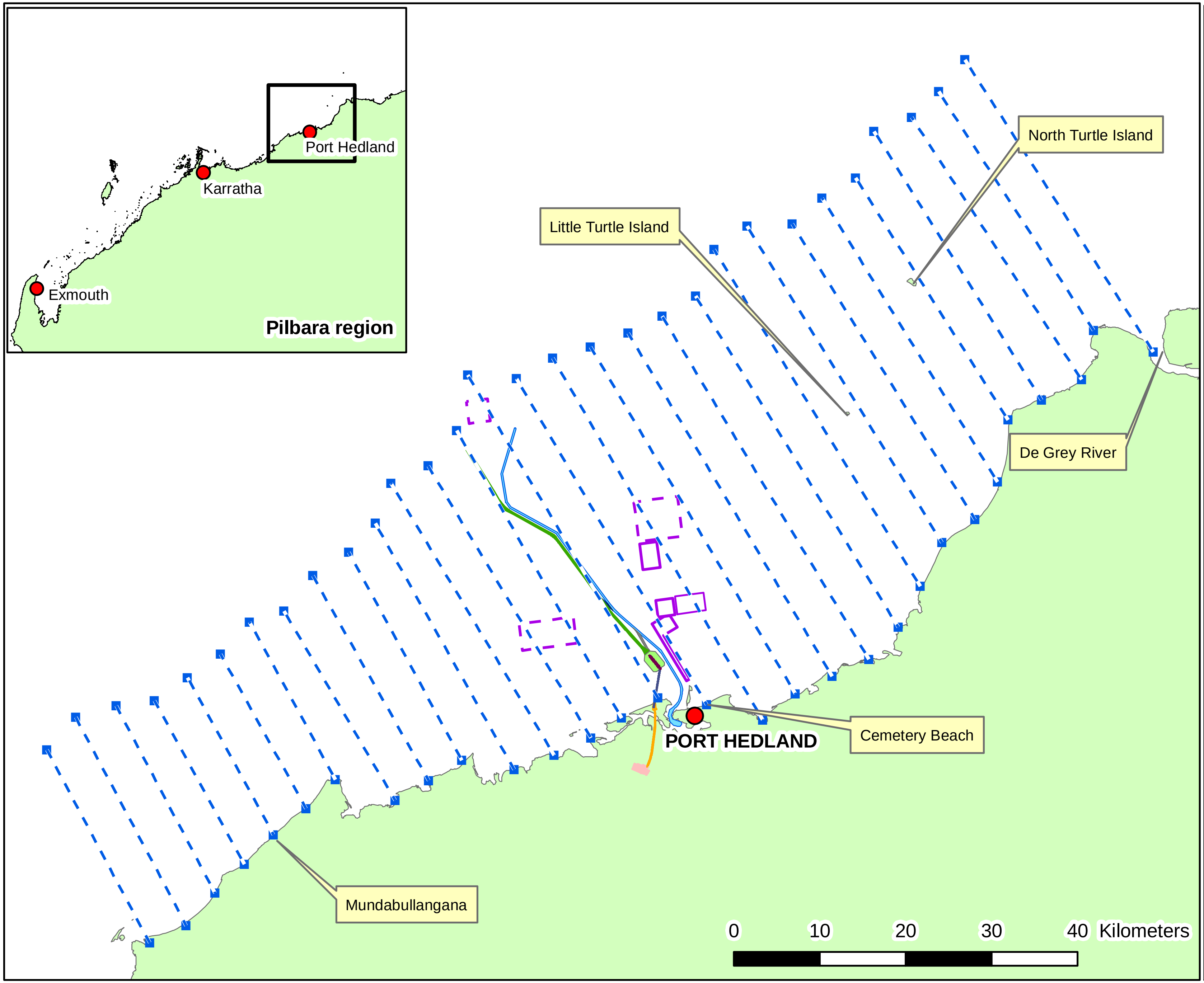

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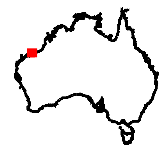
Figure 5: Location of in-water aerial survey transects

Legend
- Aerial survey transects

Existing and Proposed Infrastructure
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel



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3 RESULTS

3.1 Transmitter Attachment

As of the 20th May 2010, nine of the 10 applied Mk10-Argos tags were still active and transmitting signals. All data transmitted during the overall internesting period for each tracked flatback turtle up to this date have been processed and are presented in this report. No transmitted signal has ever been received from Argos PTT number 52911 since its attachment on 11th December 2009, reasons for which remain unknown (**Table 1**).

The number of filtered Argos locations per turtle during each turtle's overall internesting period averaged 21.1 (range = 29 – 76, n = 10; see **Table 2**). The temporally restricted filtered Argos dataset produced an average of 8.1 positions per turtle (range = 16-28, n = 10).

Table 1: Summary of turtle identification and satellite attachment details.

Tag ID	Curved Carapace Length (mm)	Date of Attachment	Time Taken to Attach PTT (min)	GPS Location		Days Transmitted
				Latitude	Longitude	
52895	922	12/12/09	10	-20.30746	118.60931	Ongoing
52896	848	10/12/09	15	-20.30698	118.61229	Ongoing
52897	861	12/12/09	10	-20.30736	118.60967	Ongoing
52900	866	10/12/09	8	-20.30756	118.60778	Ongoing
52901	873	11/12/09	10	-20.30729	118.60986	Ongoing
52903	863	12/12/09	9	-20.30750	118.60878	Ongoing
52904	860	11/12/09	8	-20.30726	118.60987	Ongoing
52907	925	10/12/09	12	-20.30690	118.61231	Ongoing
52909	942	11/12/09	8	-20.30729	118.60988	Ongoing
52911	861	11/12/09	12	-20.30710	118.61142	0
Mean	**882.1**	**-**	**10.2**	**-**	**-**	**-**

Table 2: Argos fix information.

PTT	Date released	Date of Last Nesting Attempt	During Overall Internesting Period Only		
			Days at Large	# of Fixes (Argos)	# Fixes (Argos-Temporally Restricted)
52895	12/12/2009	16/01/2010	35	29	28
52896	10/12/2009	04/01/2010	25	24	16
52897	12/12/2009	27/12/2099	15	60	22
52900	10/12/2009	22/12/2009	12	76	24
52901	11/12/2009	-*	NA	NA	NA
52903	12/12/2009	06/01/2010	25	68	28
52904	11/12/2009	-*	NA	NA	NA
52907	10/12/2009	-*	NA	NA	NA
52909	11/12/2009	28/12/2009	17	61	20
52911	11/12/2009	Never transmitted	NA	NA	NA
Total			**129**	**358**	**138**
Mean per day			**-**	**2.78**	**1.07**
Mean per turtle			**-**	**21.06**	**8.12**

* No further nesting attempts made following satellite transmitter attachment

3.2 Internesting

Three flatback turtles departed from Cemetery Beach without providing any internesting data (52901, 52904 and 52911). The remaining tracked flatback turtles nested between one and three times before migrating away from the Cemetery Beach area. The highest number of nests laid within the season by a tracked flatback turtle was four (52895; includes the nest laid on the night of transmitter attachment).

In total the tracked flatback turtles were recorded on the beach a total of 31 times. Of these 31 events, 16 were recorded as successful nesting events from six flatback turtles (including the nests laid on the nights that the satellite transmitters were attached) providing a total of 10 tracked internesting periods. Specific details of tag application and tagging team observation for each attempt/nest can be found in **Appendix A**. Of these 16 successful nesting attempts, eight were observed by the tagging team at Cemetery Beach (**Appendix A**). The final nest recorded from a tracked flatback turtle (52895) was laid on the 16th January 2010.

Of the 31 events, a total of 15 were recorded as unsuccessful nesting attempts. Of these 15 attempts, eight were observed by tagging groups (see **Appendix A**). The average number of attempts per turtle prior to a successful nesting event was 1.5 ± 0.6 attempts (range = 0 - 6, n = 15). The average internesting interval was 11.5 ± 0.4 days (range 10 – 14, n = 10). The average internesting period was 13.0 ± 0.7 days (range 10 - 17, n = 10; see **Table 3**).

3.2.1 Internesting Migration

The average overall distance travelled during the internesting periods was 95.4 ± 18.0 km (range = 37.5 – 206.8 km, n = 10; **Table 3**). The locations of the turtles during the internesting periods overlayed with bathymetry are shown in **Figure 6** and overlayed with benthic primary producer habitat (BPPH) in **Figure 7** (refer to **Appendix B** for maps of individual turtle internesting period tracks). The average speed for the internesting period migration was 7.6 ± 3.5 km/day (range 3.1 –

16.0 km, n = 10; **Table 3**). The six turtles tracked during internesting displayed notable consistency in direction of movement with all but one internesting period migration track remaining within 50 km of Cemetery Beach in a north or north-east direction. The exception to this was internesting track 52897_1 which passed through the existing shipping channel and headed west to nest at Mundabullangana, 50 km away (**Figure 6** and **Map B3** in **Appendix B**).

Internesting turtles generally remained within 10 km of the mainland coast, except for the internesting track of 52903_1, which headed away from the coast to between Little Turtle and North Turtle Islands. Turtles also exhibited consistency in their habitat selection during the internesting period, with turtles generally selecting bare sediment habitat (**Figure 7**).

3.2.1.1 Construction Impacts: Internesting Migration

The number of Argos locations based on the temporally restricted dataset within the proposed development footprint was calculated to highlight the amount of time turtles may potentially be exposed to dredging and construction activities associated with the proposed development. The number of locations recorded within the existing shipping channel and spoil disposal grounds was also calculated to determine whether the turtles currently avoid or use these areas. None of the temporally restricted Argos locations were located within the proposed development footprint. Three temporally restricted Argos locations were located within existing spoil grounds, resulting in 2 % of all temporally restricted Argos positions within existing spoil disposal grounds. It should be noted that more points may fall within the proposed footprint development due to the accuracy of the Argos positions (see Section 2.1.3.1).

Table 3: Internesting details of flatback turtles from Cemetery Beach.

Internesting Number	Date of Nesting (night of)	Date Returned (night of; attempt or nest)	Date of Successful Nest (night of)	Number of Attempts Prior to Next Successful Nesting Event	Internesting Interval (days)	Internesting Period (days)	Max Distance from Beach (km)	Distance Travelled in Internesting Period (km)	Average Daily Distance Travelled During Internesting Period (km/day)	Speed (km/hr)
52895_1	12/12/2009	22/12/2009	22/12/2009	0	10	10	39.0	103.9	10.4	0.43
52895_2	22/12/2009	02/01/2010	03/01/2010	1	11	12	36.1	107.8	9.0	0.38
52895_3	03/01/2010	15/01/2010	16/01/2010	1	12	13	13.6	46.7	3.6	0.15
52896_1	9/12/2009	21/12/2009	22/12/2009	1	12	13	14.3	37.5	2.9	0.12
52896_2	22/12/2009	02/01/2010	04/01/2010	1	11	13	18.6	44.8	3.4	0.14
52897_1	12/12/2009	22/12/2009	27/12/2009	3	10	15	56.8	206.8	13.8	0.58
52900_1	10/12/2009	22/12/2009	22/12/2009	1	12	12	6.0	71.7	6.0	0.25
52903_1	12/12/2009	22/12/2009	22/12/2009	0	10	10	49.2	159.5	16.0	0.67
52903_2	22/12/2009	05/01/2010	06/01/2010	1	14	15	12.7	46.1	3.1	0.13
52909_1	11/12/2009	24/12/2009	28/12/2009	6	13	17	29.2	128.9	7.6	0.32
			Mean	1.5	11.5	13.0	27.5	95.4	7.6	0.32
			Std Dev	1.8	1.4	2.2	17.2	56.9	4.7	0.19
			Range	0-6	10-14	10-17	6.0-56.8	37.5-206.8	3.1-16.0	0.12-0.66
			n	10	10	10	10	10	10	10
			SE	0.6	0.4	0.7	5.4	18.0	1.5	0.06

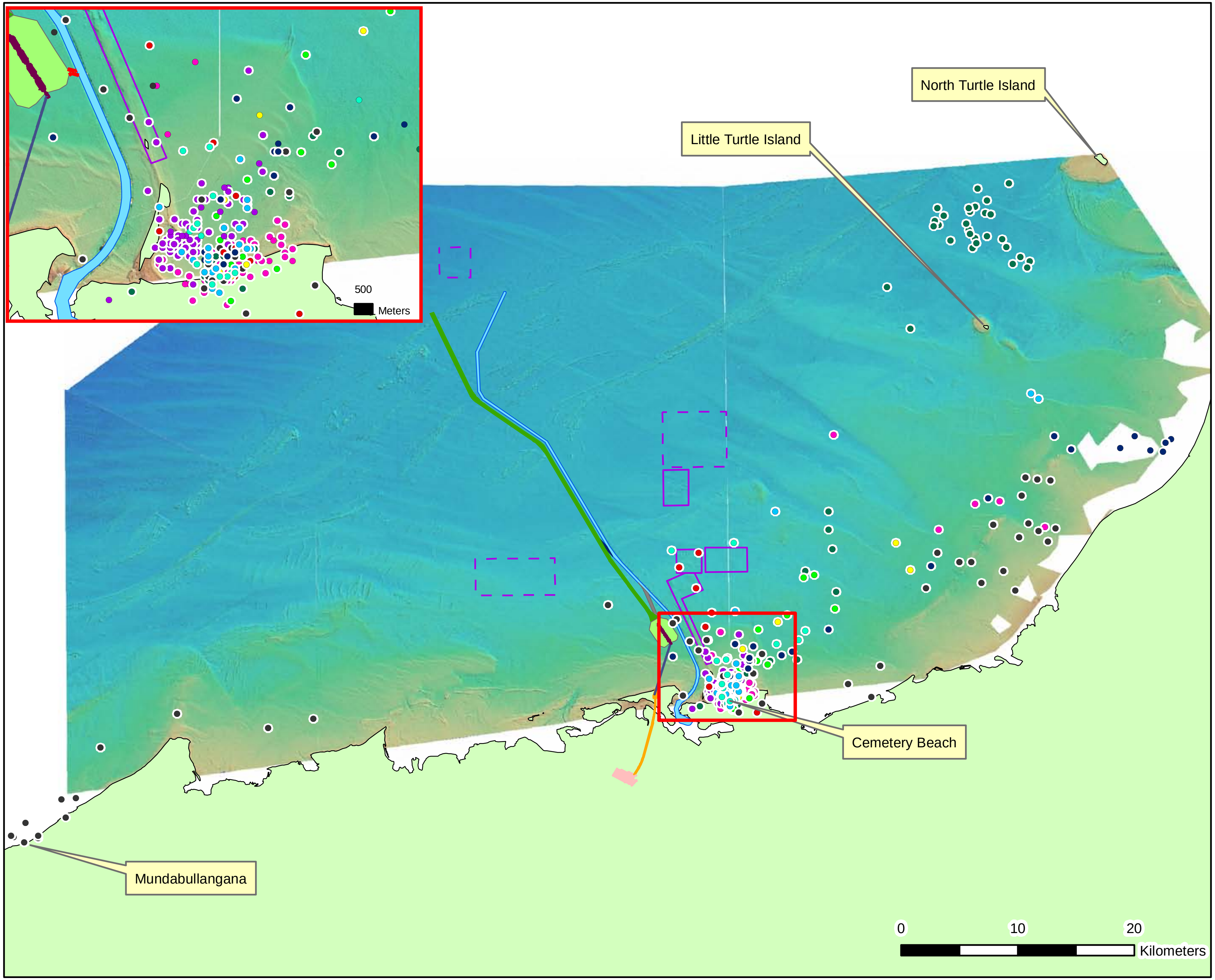

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Figure 6: Argos locations (unrestricted dataset) for all flatback turtles tracked from Cemetery Beach overlayed with LIDAR imagery

Legend

Argos locations
- 52895_1
- 52895_2
- 52895_3
- 52896_1
- 52896_2
- 52897_1
- 52900_1
- 52903_1
- 52903_2
- 52909_1

Existing and Proposed Infrastructure
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

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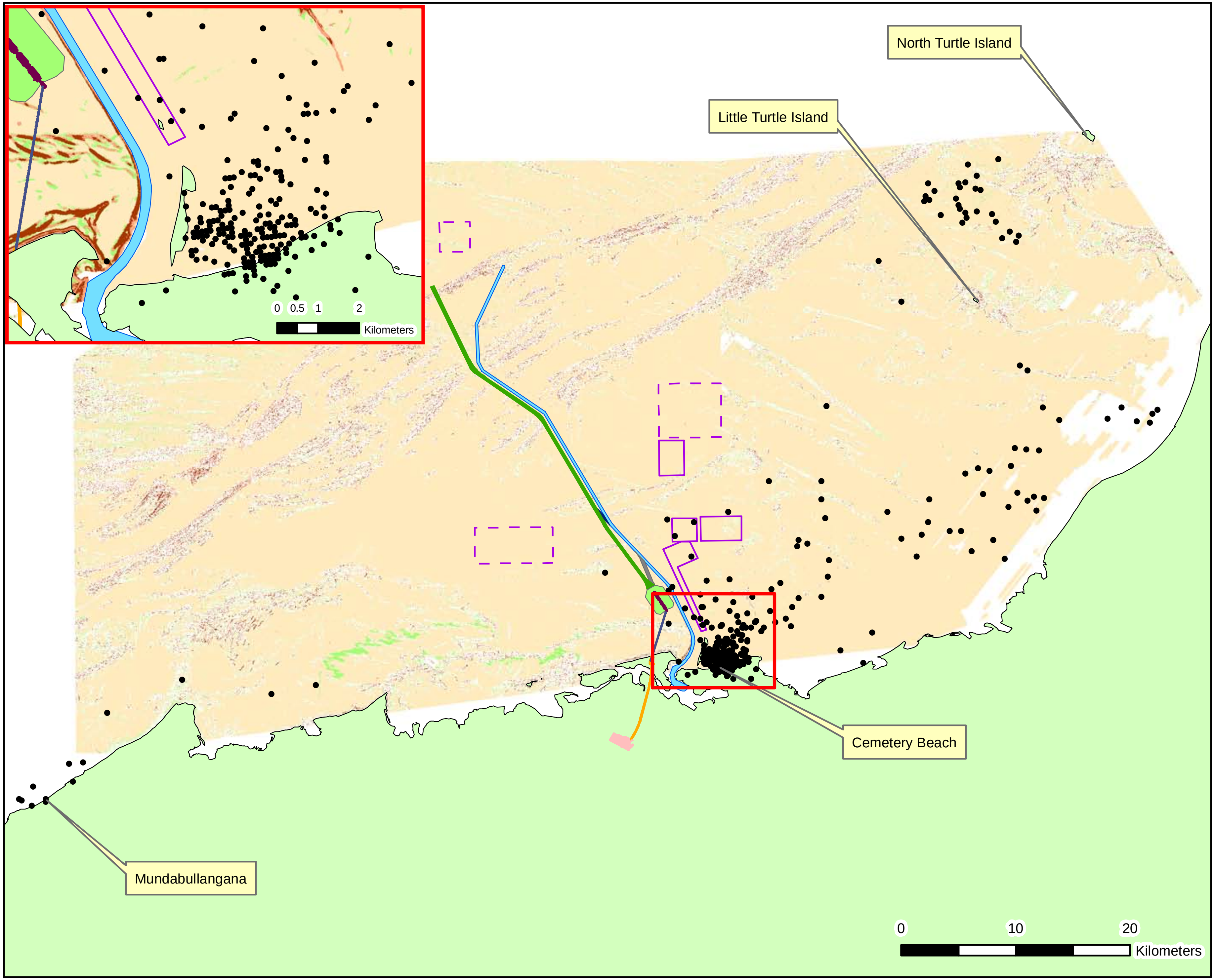

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Figure 7: Argos locations (unrestricted dataset for all flatback turtles tracked from Cemetery Beach in relation to BPP habitat mapping

Legend

- Argos locations (unrestricted dataset)

Benthic Primary Producer Habitat (SKM, 2009)

- Hard substrate with/without BPP
- None modelled with confidence
- Bare sediment
- Sediment/hard substrate with BPP
- Sediment with BPP

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

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3.3 Home Range Analysis

There was substantial variation in home range size among the 10 internesting periods tracked during this project. MCP and FKD overall home range estimates (95% UD, based on all filtered Argos positions) ranged from 8.2 – 887.5 km^2 and 16.9 – 121.2 km^2, respectively (**Table 4;** refer to **Appendix C** for individual home range analysis for each internesting period based on a unrestricted dataset). MCP and FKD overall home range estimates based on a temporally restricted dataset and 95% UD produced a range from 7 – 733.2 km^2 and 4.8 – 556.5 km^2, respectively (**Table 4** and **Figures 8 - 13**). The MCP and FKD core areas of activity estimates (50% UD, based on all points) ranged from 1.1 – 213.2 km^2 and 2 – 9.6 km^2, respectively (**Table 4** and **Appendix C**). MCP and FKD core area of activity home range estimates based on a temporally separated dataset and 50% UD produced a range from 0.2 – 63.4 km^2 and 0.5 – 57.2 km^2, respectively (**Table 4**and **Figures 8 - 13**).

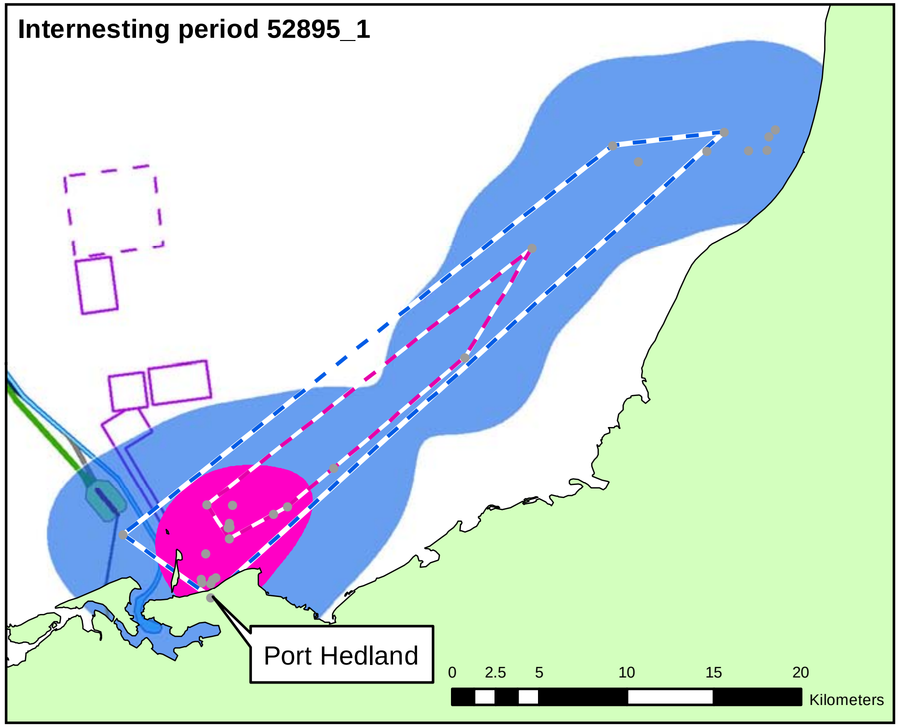
The MCP and FKD home range estimates for the individual turtles are shown in Figures 8 – 13 for the temporally restricted dataset, as this is more of an unbiased dataset. The average MCP area (195.1 ± 83.4 km^2, n = 10) for the overall home range estimates (95% UD, based on all points) for each internesting period was 72 % larger than the average FKD area (54.0 km^2 ± 11.2, n = 10). The average MCP area (41 ± 21.8 km^2, n = 10) for the core areas of activity estimates (50% UD, based on all points) was 90 % larger than the average FKD area (4.2 ± 0.7 km^2, n = 10).

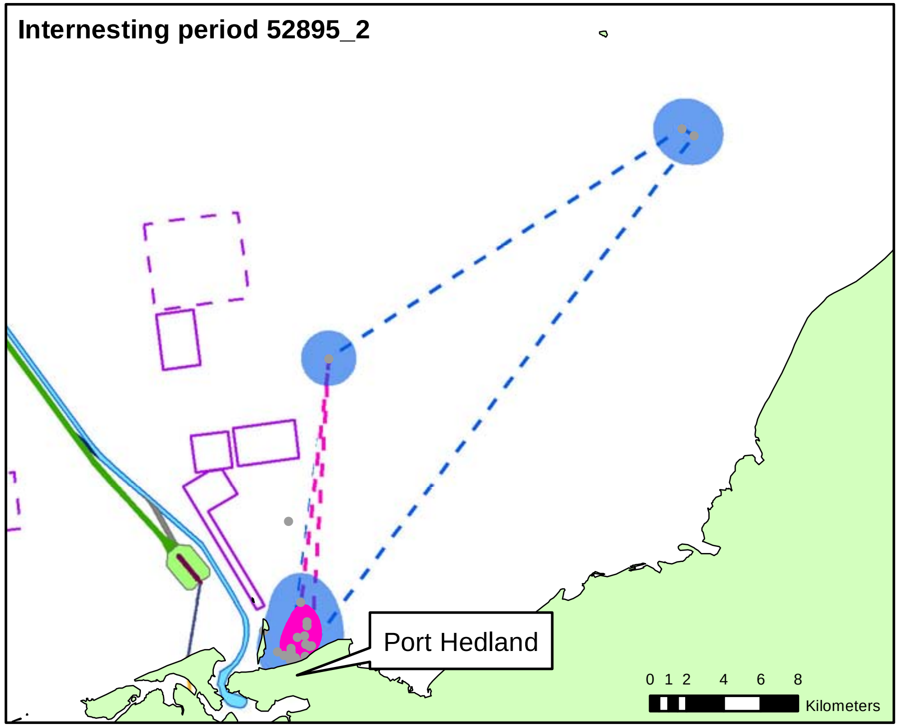
There was less difference between the temporally separated dataset with the average MCP area (173 ± 70.2 km^2, n = 10) for the overall home range estimates (95% UD, based on temporally separated dataset) for each internesting period was only 8 % larger than the average FKD area (159.1 ± 67.5 km^2, n = 10). The average MCP area (20 ± 8.1 km^2, n = 10) for the core areas of activity estimates (50% UD, based on temporally separated dataset) was 18% larger than the average FKD area (16.4 ± 7 km^2, n = 10). The calculated MCP and FKD core activity area (50% UD, based on temporally separated dataset) were statistically similar ($V = 29$, $p = 0.922$).

There was no correlation between the size of the core activity area (using FKD 50% UD, based on temporally separated dataset) and the overall distance travelled for each internesting period ($r^2 = 0$, $p = 0.494$, tau = 0.246).

Table 4: Minimum Convex Polygons and Fixed Kernel Density Home ranges for internesting turtles tracked from Cemetery Beach. Areas of home range that overlapped terrestrial mainland were not included in the area calculations.

Internesting Number	MCP & FKD based on all filtered Argos positions dataset					MCP & FKD based on temporally restricted filtered Argos position dataset				
	Total number of positions for each internesting period	Minimum Convex Polygon (km²)		Fixed Kerned Density (km²)		Total number of positions for each internesting period	Minimum Convex Polygon (km²)		Fixed Kernel Density (km²)	
		50%	95%	50%	95%		50%	95%	50%	95%
52895_1	27	63.1	228.5	5.4	85.9	16	54.7	179.9	48.8	503.2
52895_2	25	1.9	169.3	2.6	17.4	10	5.8	164.8	5.3	34.3
52895_3	17	3.0	49.7	3.3	26.6	7	0.2	45.8	0.4	4.2
52896_1	15	8.3	19.8	1.5	32.9	8	5.0	19.9	23.2	125.6
52896_2	9	6.9	49.8	2.4	44.4	8	6.9	27.8	2.2	21.8
52897_1	60	94.6	751.4	1.4	78.8	22	50.3	605.1	1.9	122.1
52900_1	76	1.1	7.9	2.8	14.6	25	0.5	5.9	0.9	7.9
52903_1	49	213.1	312.2	8.4	112	19	63.4	306.9	57.2	512.4
52903_2	19	9.1	35.8	3.8	46.2	11	4.5	22.9	4	65.8
52909_1	61	1.5	184.3	2.6	12.5	22	5.4	217.1	4.2	35
Mean	35.8	40.3	180.9	3.4	47.1	14.8	19.7	159.6	14.8	143.2
Std Dev	23.6	68.6	225.2	2.1	34.1	6.8	25.4	187.4	21.3	196.8
Range	9-76	1.5-213.1	7.9-751.4	1.4-8.4	12.5-85.9	7-25	0.2-63.4	7.0-605.1	0.4-57.2	4.2-512.4
n	10	10	10	10	10	10	10	10	10	10
SE	7.5	12.7	57.2	1.1	14.9	2.2	6.2	50.5	4.7	45.3





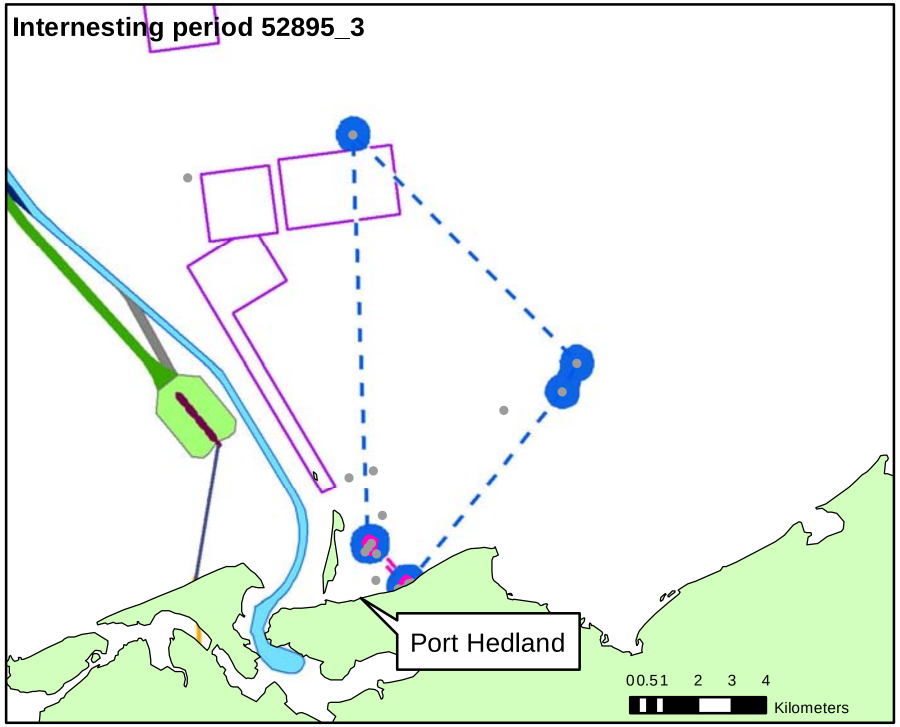


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Figure 8: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52895 (based on temporally restricted dataset)

Legend

- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

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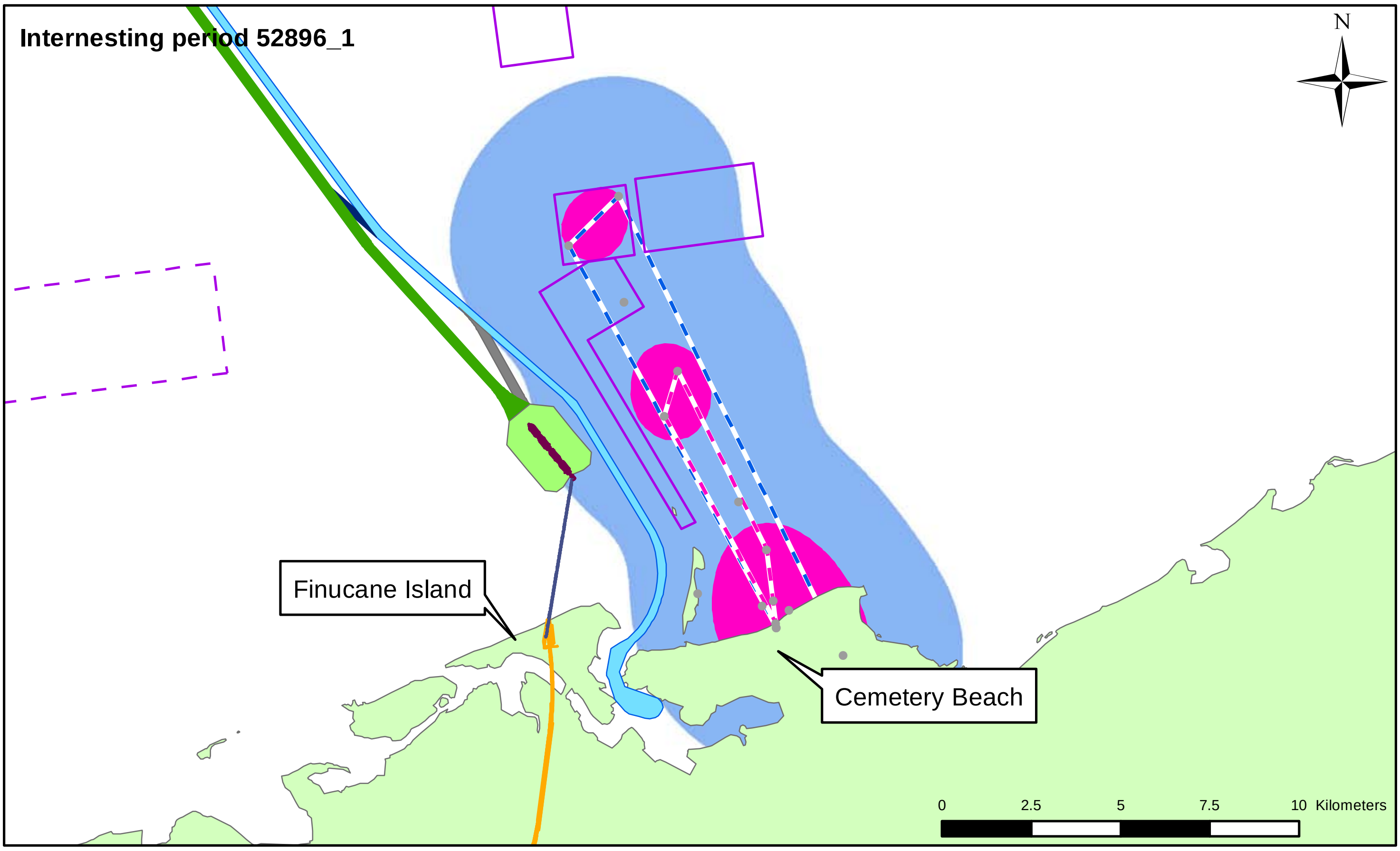

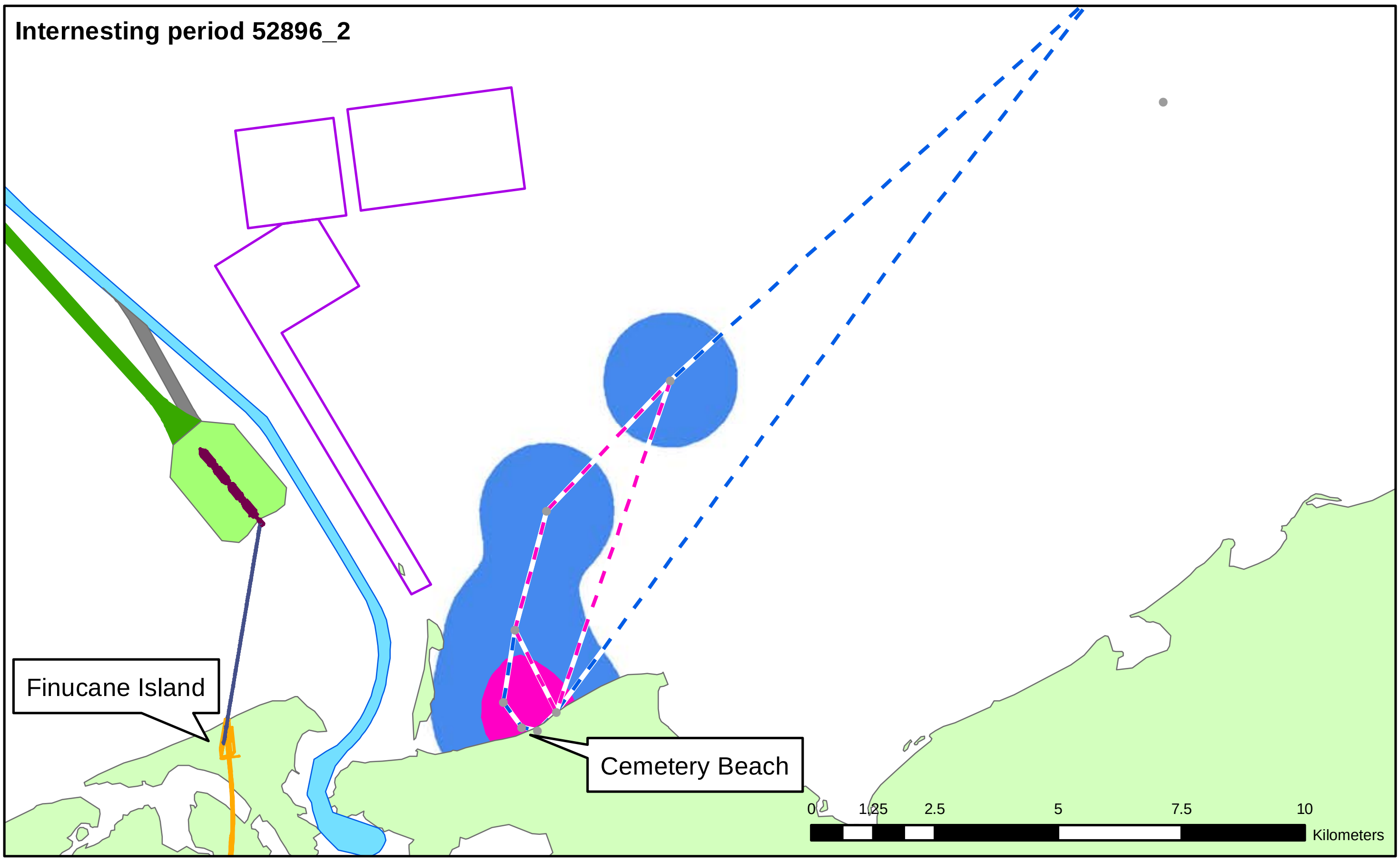

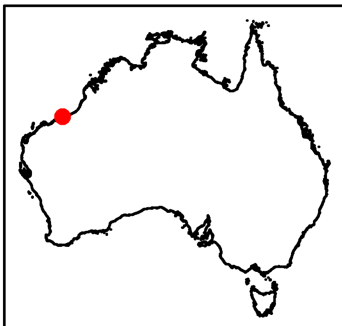

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Figure 9: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52896 (based on temporally restricted dataset)

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Legend

Existing and Proposed Infrastructure

- Internesting locations
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Spoil Ground One
- Tug access channel
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD

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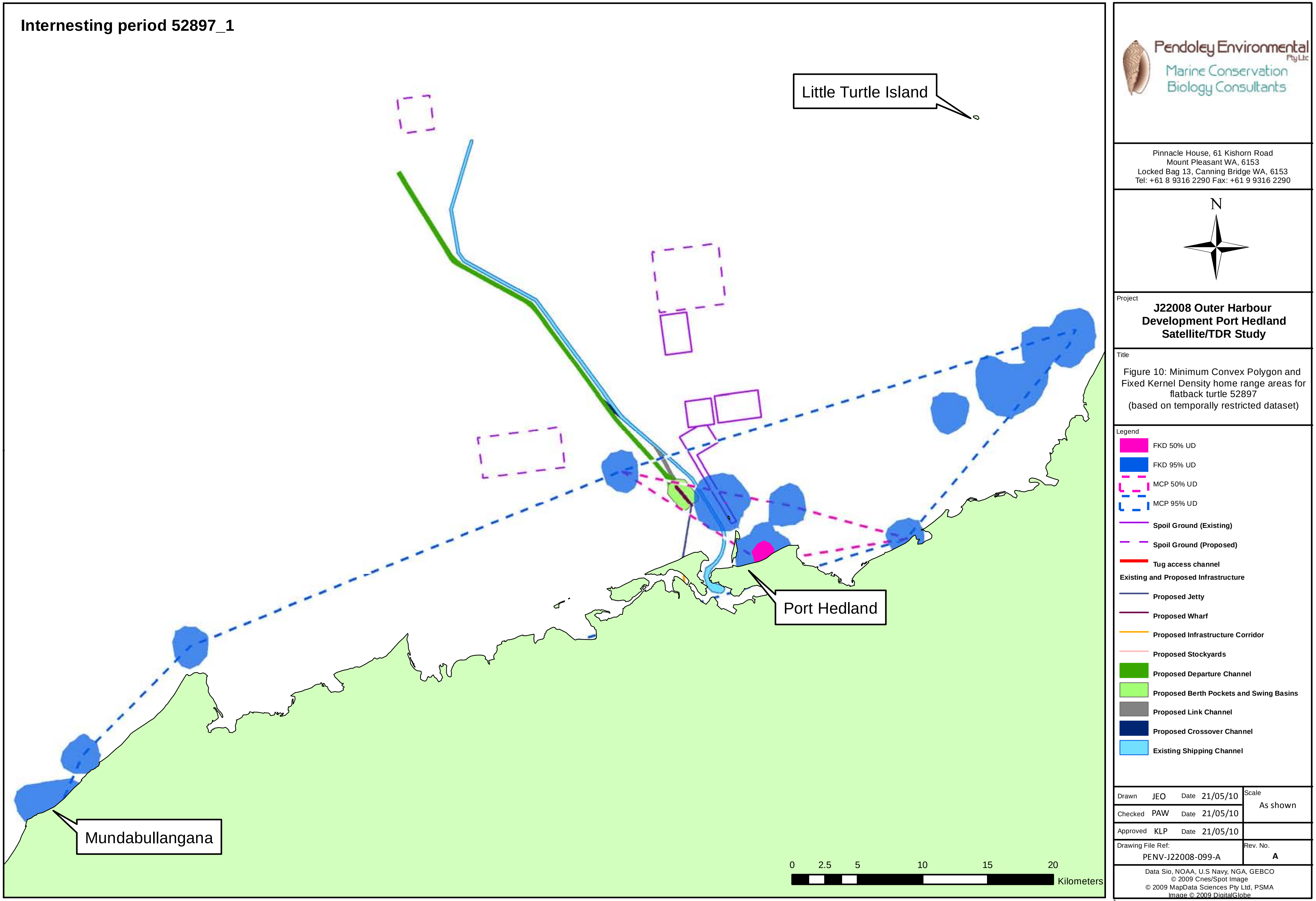

Internesting period 52897_1
Little Turtle Island
Port Hedland
Mundabullangana
0 2.5 5 10 15 20
Kilometers
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Figure 10: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52897 (based on temporally restricted dataset)
Legend
FKD 50% UD
FKD 95% UD
MCP 50% UD
MCP 95% UD
Spoil Ground (Existing)
Spoil Ground (Proposed)
Tug access channel
Existing and Proposed Infrastructure
Proposed Jetty
Proposed Wharf
Proposed Infrastructure Corridor
Proposed Stockyards
Proposed Departure Channel
Proposed Berth Pockets and Swing Basins
Proposed Link Channel
Proposed Crossover Channel
Existing Shipping Channel
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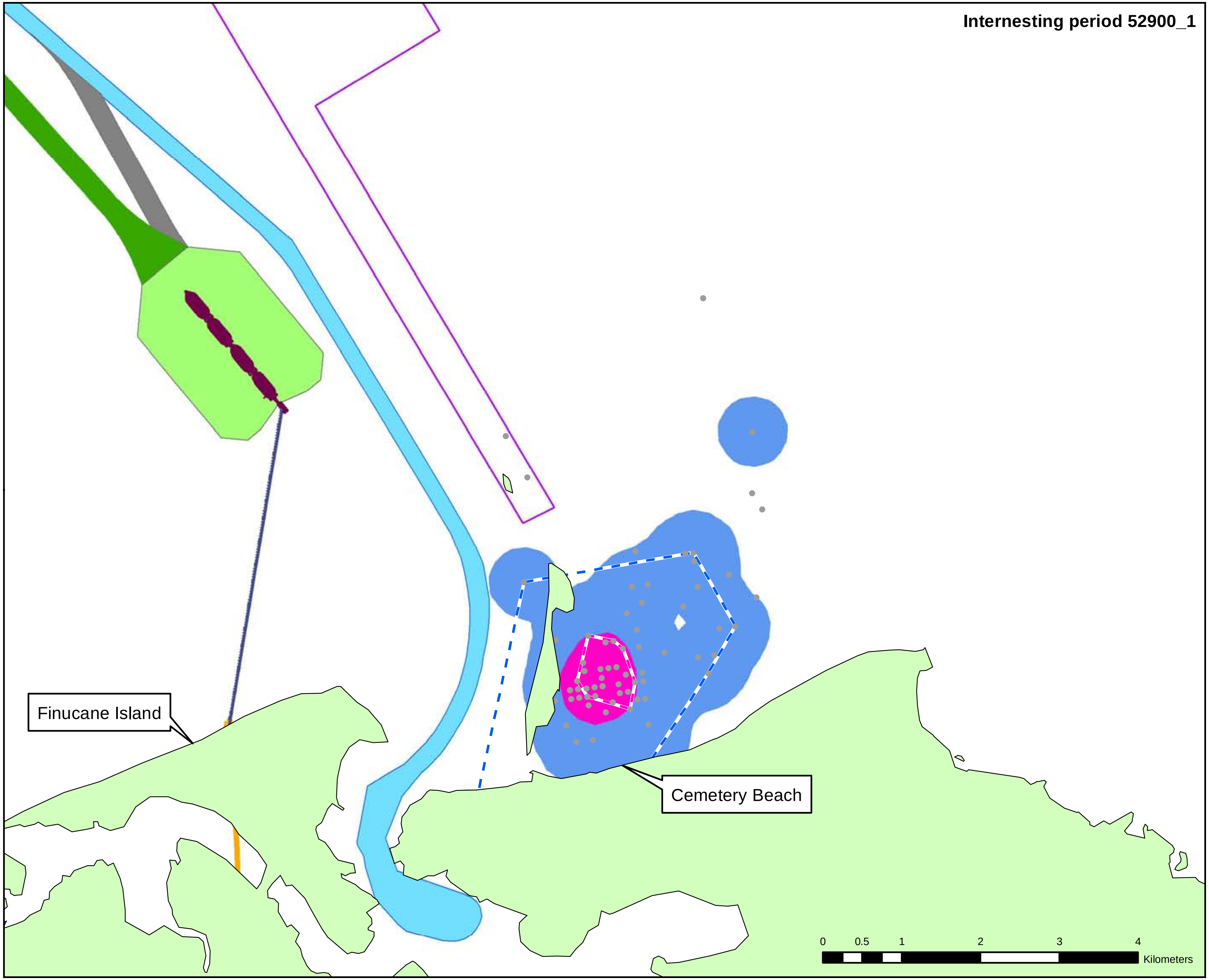

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Title

Figure 11: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52900 (based on temporally restricted dataset)

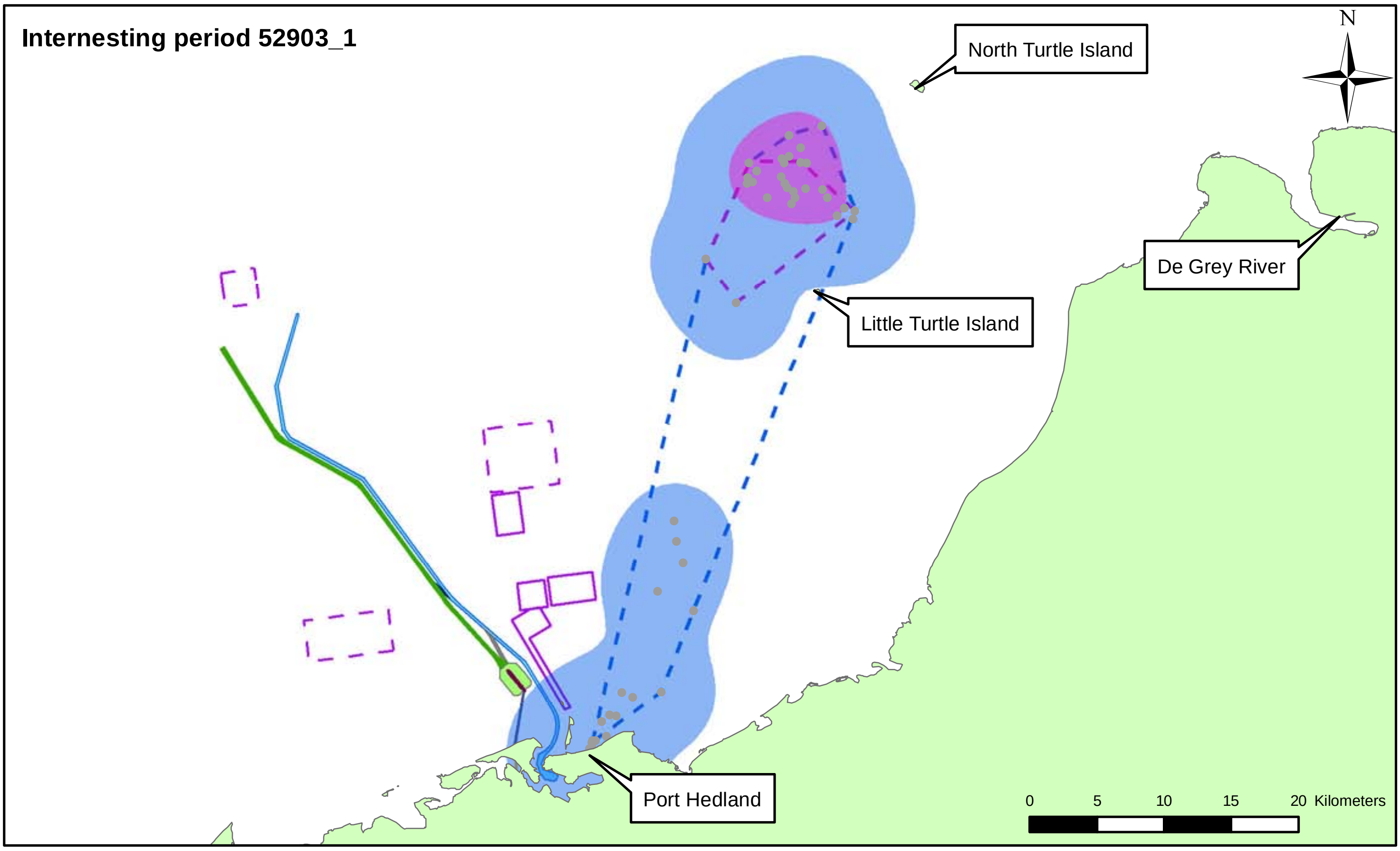
Legend

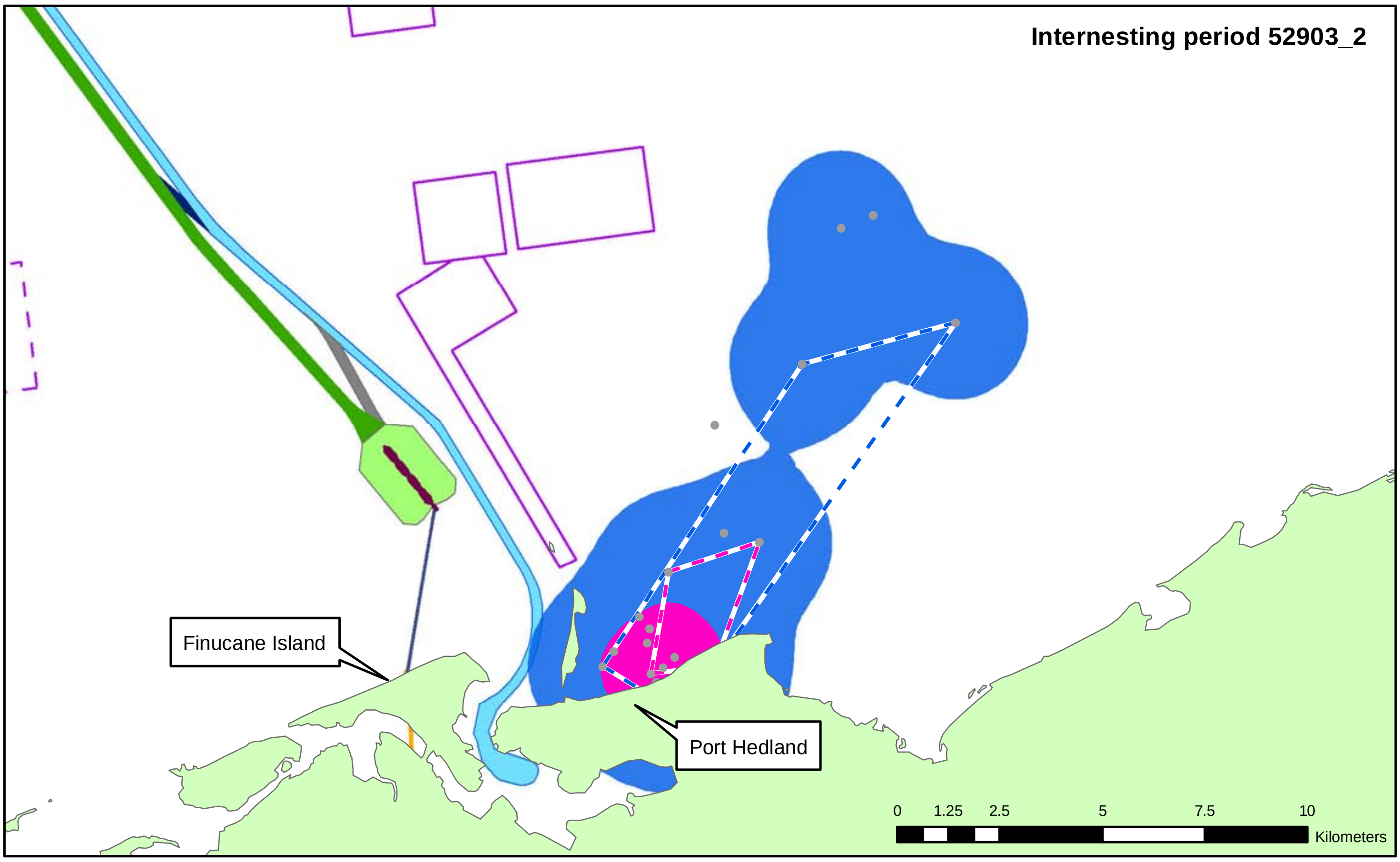
- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel

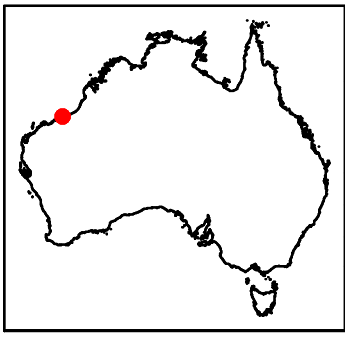
Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	21/05/10	Scale: As shown
Checked	PAW	Date	21/05/10	
Approved	KLP	Date	21/05/10	
Drawing File Ref:	PENV-J22008-100-A			Rev. No. A







Project	J22008 Outer Harbour Development Port Hedland Satellite/TDR Study	
Title	Figure 12: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52903 (based on temporally restricted dataset)	
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Legend

- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Spoil Ground One
- Tug access channel

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

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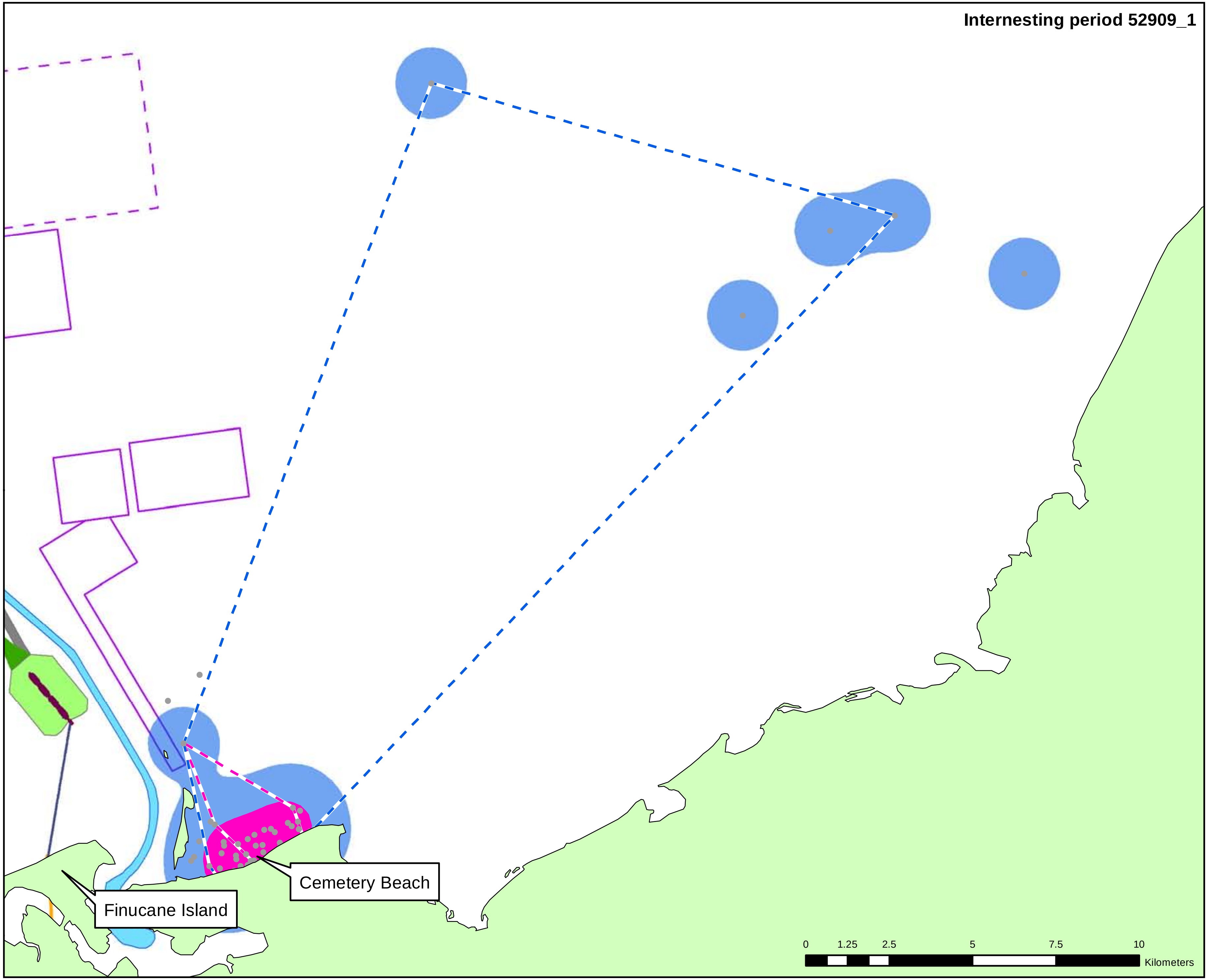

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Project

J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Figure 13: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52909
(based on temporally restricted dataset)

Legend

- Internesting locations
- MCP 95% UD
- MCP 50% UD
- FKD 50% UD
- FKD 95% UD
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	21/05/10	Scale: As shown
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Approved	KLP	Date	21/05/10	
Drawing File Ref:	PENV-J22008-102-A			Rev. No.: A

3.3.1.1 Construction Impacts: Home Range

The average percentage of the FKD overall home range area (95% UD, based on temporally restricted dataset) which overlay the proposed development footprint was 0.28 ± 0.17% (range = 0 – 1.55, n = 10) and consisted of three home range areas (**Table 5**). The average percentage of the FKD overall home range area that overlay the existing shipping channel and spoil disposal grounds was 4.01 ± 2.34% (range = 0 – 19.72, n = 10) and consisted of six home range areas (**Table 5**).

The FKD core home range area (50% UD, based on temporally restricted dataset) did not overlap with the proposed development footprint (**Table 5**). The average percentage of the FKD core home range area (50% UD, based on temporally restricted dataset) which overlapped with the existing shipping channel and spoil disposal grounds was 0.21 ± 0.21% (range = 0 – 2.1, n = 10; **Table 5**).

Table 5: Percentage of Fixed Kernel Density core home range areas within the proposed footprint and existing shipping channel and spoil disposal grounds (based on temporally restricted dataset).

Turtle Internesting Period	Percentage Area of FKD that lies within proposed footprint		Percentage Area of FKD that lies within existing shipping channel and spoil disposal grounds	
	50%	95%	50%	95%
52895_1	0	0.87	2.1	1.35
52895_2	0	0	0	0
52895_3	0	0	0	0
52896_1	0	1.55	0	16.05
52896_2	0	0	0	0
52897_1	0	0.34	0	19.72
52900_1	0	0	0	0
52903_1	0	0	0	0.76
52903_2	0	0	0	0.26
52909_1	0	0	0	1.91
Mean	0	0.28	0.21	4.01
St Dev	0	0.53	0.66	7.4
Range	0	0-1.55	0-2.1	0-19.72
n	10	10	10	10
SE	0	0.17	0.21	2.34

3.4 Dive Behaviour

The mean minimum percentage of time spent at the surface (<2 m depth) during each internesting period was 31.5 ± 2.6% (range 23.6 – 48.5, n = 10), with a minimum of 68.5 ± 2.6% of time spent diving (range = 51.5 – 76.4, n = 10; **Table 6**). The flatback turtles exhibited relatively short dives where 75% of dives recorded were less than 15 min. The majority of dives undertaken by the nine turtles were less than 5 min in duration (42.5 ± 3.9%), with 20.9 ± 1.7% of dives between 5-10 min and 12.4 ± 0.9% of dives between 10-15 min (**Figure 14**). All recorded dives were less than 60 min in duration. There was a lower percentage of dives recorded within each dive duration bin as the dive duration bin values increased. One exception was for the percentage of dives between 30 and 45 min in duration which was higher than the number of dives between 20 and 25 min, and 25 and 30 min (**Figure 14**).

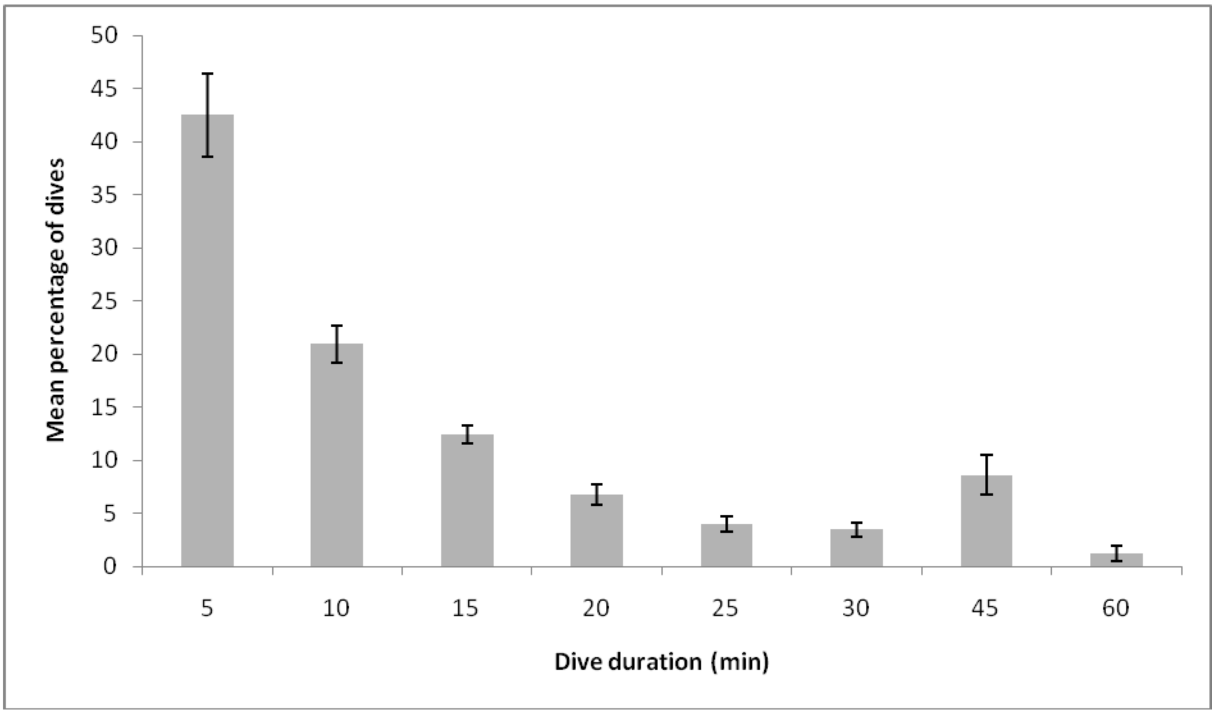


Figure 14: Dive duration and the mean percentage of dives recorded for the flatback turtles during internesting.

All recorded dives were less than 30 m in depth (**Table 7; Figure 15**). The flatback turtles recorded relatively shallow dives, with a mean of 85 % of their time spent at 20 m or less (**Table 7**). The majority of time was spent between 5-10 m (27 ± 2.7%), followed by between 10-15 min (22.3 ± 3.5%; **Table 7**). The maximum depth the turtle dived also followed a similar pattern to the time spent at depth (**Figure 15**). The maximum dive depth was not deeper than 30 m and the majority of the dives were to a maximum depth of between 5 and 10 m (38.5 ± 5.1%). The percentage of time/dives spent at depth and maximum dive depth were similar ($V = 937$, $p = 0.163$), indicating that turtles dived to their maximum depth and tended to remain there for the duration of the dive. Graphs of each transmitted dive profile for each internesting period can be found in **Appendix D**.

The mean overall percentage of time spent for the internesting flatback turtles showed that 96 % of their time was spent at temperatures greater than 30 °C (**Figure 16**).

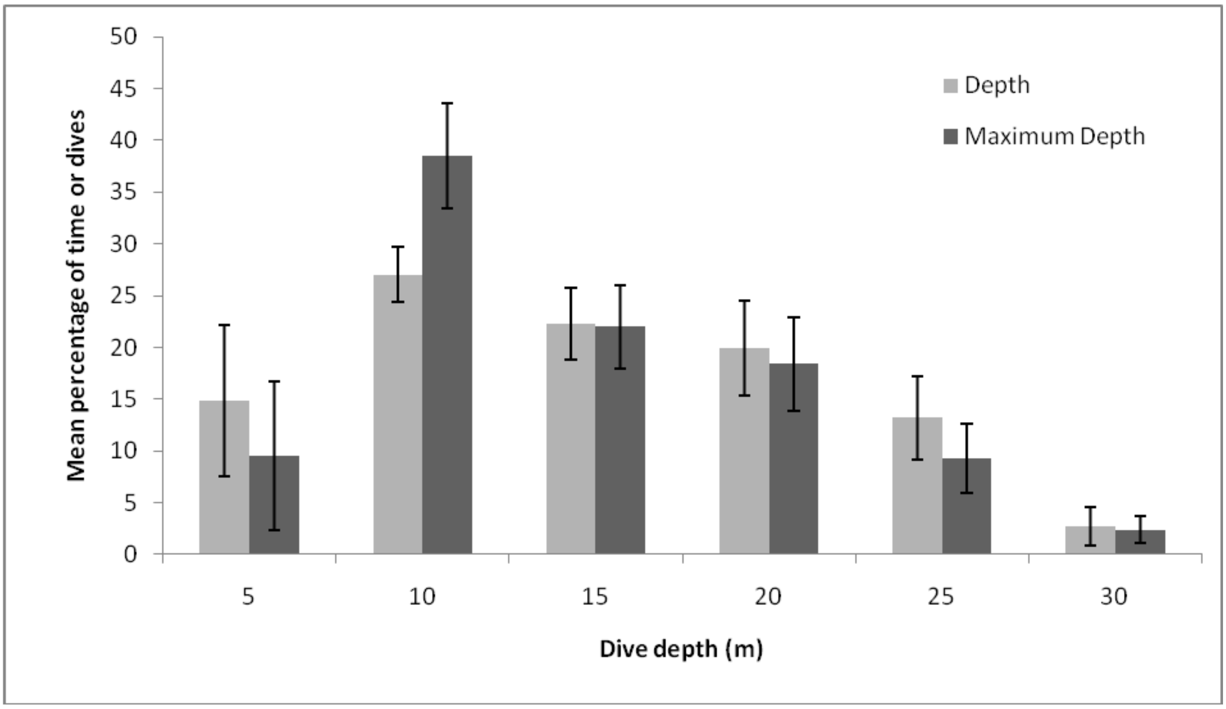


Figure 15: Mean percentage of time spent at depth (light grey) and mean percentage of dives to maximum depth (dark grey).

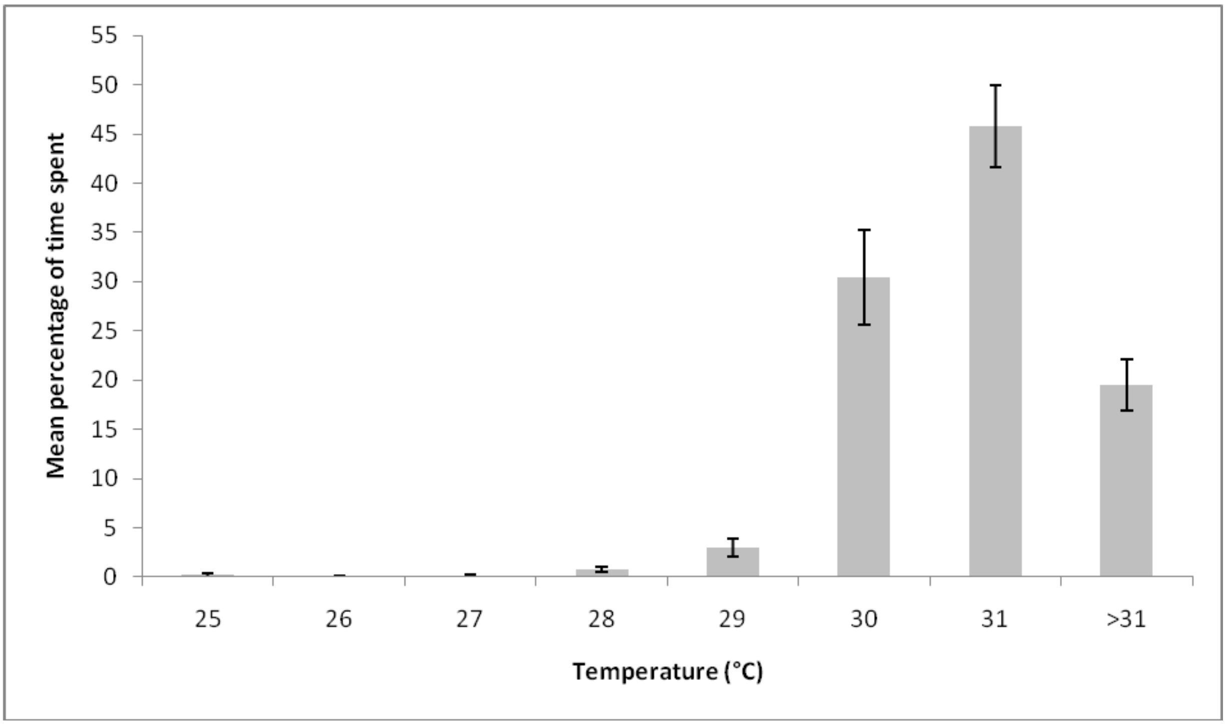


Figure 16: Mean percentage of time spent at temperature (°C).

Table 6: Dive duration and time spent diving for internesting turtles tracked from Cemetery Beach (upper limits of the bins are shown).

Internesting Period Track	Min % time spent diving	Min % time spent at surface or within 1.5m of surface	Dive Duration (% of dives)							
			5min	10min	15min	20min	25min	30min	45min	60min
52895_1	68.9	31.1	38.4	30.1	13.5	7.3	4.7	3.8	2.2	0
52985_2	75.7	24.3	34.2	22.9	13.9	7.5	5.4	6.8	9.3	0
52895_3	73.6	26.4	37.5	21.8	13.3	10.5	6.8	4.0	6.0	0.1
52896_1	75.6	24.4	24.5	17.1	16.6	10.3	4.4	3.9	16.3	6.9
52896_2	76.4	23.6	29.2	16.8	13.6	8.4	5.7	6.5	16.5	3.3
52897_1	58.3	41.7	55.0	30.0	8.6	1.3	0.4	1.0	3.7	0
52900_1	51.5	48.5	61.5	22.0	14.4	1.9	0.2	0	0	0
52903_1	66.1	33.9	43.5	14.8	11.8	7.6	5.4	3.1	12.6	1.2
52903_2	71.2	28.8	43.3	17.5	11.0	6.9	3.9	2.9	13.6	0.8
52909_1	67.4	32.6	58.4	16.4	7.5	5.6	3.2	2.8	6.0	0.1
Mean	68.5	31.5	42.5	20.9	12.4	6.7	4.0	3.5	8.6	1.2
Std Dev	8.2	8.2	12.4	5.5	2.7	3.1	2.2	2.1	5.9	2.3
Range	51.5-76.4	23.6-48.5	24.5-61.5	14.8-30.1	7.5-16.6	1.3-10.5	0.2-6.8	0-6.8	0-16.5	0-6.9
n	10	10	10	10	10	10	10	10	10	10
SE	2.6	2.6	3.9	1.7	0.9	1.0	0.7	0.7	1.9	0.7

Table 7: Time spent at depth and maximum dive depth for internesting turtles tracked from Cemetery Beach (upper limits of the bins are shown).

Internesting Period Track	Dive Depth (% of time spent at depth)						Maximum Dive Depth (% of dives)					
	5m	10m	15m	20m	25m	30m	5m	10m	15m	20m	25m	30m
52895_1	0	23.1	40.7	22.0	9.4	4.7	0.1	21.8	46.4	25.1	3.5	3.1
52985_2	1.0	26.5	36.6	35.1	0.9	0	0	26.6	33.8	38.1	1.4	0
52895_3	8.9	27.6	21.0	23.8	18.4	0.3	0.2	49.0	19.5	19.0	11.9	0.5
52896_1	2.2	27.1	19.6	8.3	40.5	2.2	0	22.8	35.9	6.3	30.4	4.6
52896_2	4.1	27.8	31.4	32.7	4.0	0	0.1	38.6	17.7	40.6	3.0	0
52897_1	49.4	39.8	20.5	7.9	11.0	1.4	6.6	60.0	18.4	8.9	4.5	1.5
52900_1	77.5	19.0	3.4	0	0	0	72.8	19.5	7.7	0	0	0
52903_1	7.4	19.3	15.2	11.8	27.5	18.9	0	39.1	9.1	12.1	26.5	13.2
52903_2	8.8	17.5	18.6	46.3	8.8	0.1	3.0	41.9	19.5	29.5	5.9	0.2
52909_1	18.9	42.6	15.8	11.4	11.3	0	12.2	65.8	11.7	4.3	5.8	0.2
Mean	**14.8**	**27.0**	**22.3**	**19.9**	**13.2**	**2.8**	**9.5**	**38.5**	**22.0**	**18.4**	**9.3**	**2.3**
Std Dev	**23.1**	**8.4**	**11.1**	**14.6**	**12.6**	**5.9**	**22.6**	**16.2**	**12.7**	**14.4**	**10.6**	**4.1**
Range	**0-77.5**	**17.5-42.6**	**3.4-40.7**	**0-46.3**	**0-40.5**	**0-18.9**	**0-72.8**	**19.5-65.8**	**7.7-46.4**	**0-40.6**	**0-30.4**	**0-13.2**
n	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
SE	**7.3**	**2.7**	**3.5**	**4.6**	**4.0**	**1.9**	**7.1**	**5.1**	**4.0**	**4.5**	**3.4**	**1.3**

3.4.1.1 Construction Impacts: Dive Behaviour

No filtered Argos locations and only 0.2% of the FKD overall home range area (95% UD, based on temporally restricted dataset) occurred within the proposed development footprint. Although this is a very small percentage, internesting flatback turtles may still have occurred in the footprint area, but due to the inaccuracies of the Argos positions depending on their location class, their position fix may have been recorded as being outside the footprint. Flatback turtles have been recorded in the footprint during the 2008/09 satellite tracking program (Pendoley Environmental 2009).

Therefore, the dive behaviour of internesting flatback turtles with regards to the potential risks from proposed dredging activities (i.e. time spent on the bottom of the seabed) was still assessed. There were Argos location and bathymetric data (adjusted for tides) for 54 % of the corresponding dive depth histogram data (in 6 hour blocks). The depth of the seabed floor during the 6 hour blocks of histogram data was compared with the time spent at depth to calculate the percentage of time the turtle was on the seabed floor, given that earlier data showed that turtles dived to their maximum depth and tended to remain there for the duration of the dive. Of the dives that had corresponding data, the six turtles spent an average of 34.4 ± 3.1% (n = 10) of their time at the seabed floor. The time spent at the seabed floor varied between 19.1 ± 5.4 % recorded for internesting period 52896_1 and 45.9 ± 4.6% for internesting period 52909_1. There was no significant difference in the percent time spent on the seabed floor between daylight and night time hours ($U = 7527$, $p = 0.787$).

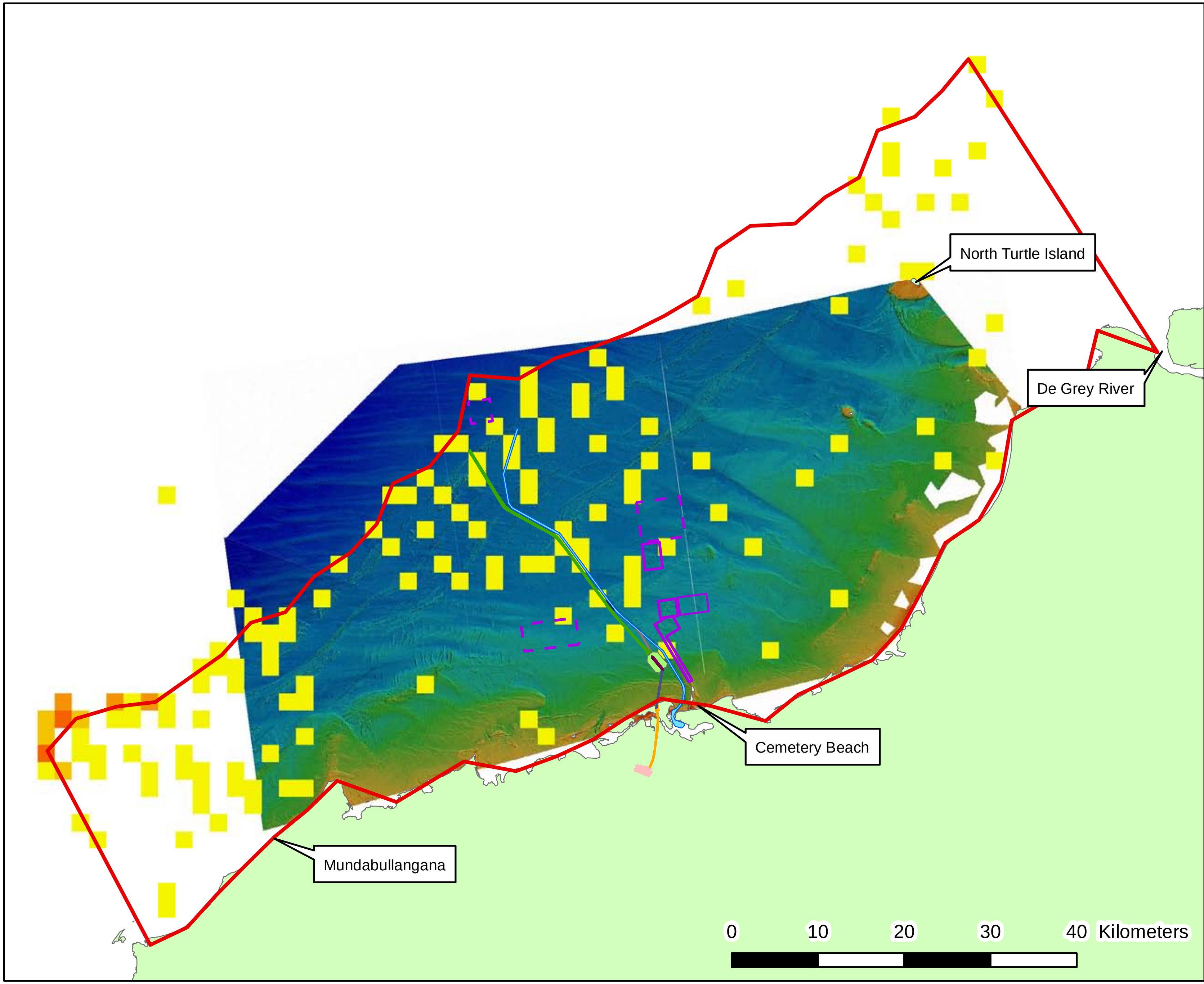
Table 8: Mean percentage of dives spent at the seabed floor for internesting flatback turtles at Cemetery Beach.

Internesting Period	Mean	Std Dev	Range	N	SE
52895_1	30.4	22.0	1-78	25	4.4
52895_2	27.2	32.2	0-100	20	7.2
52895_3	44.7	32.3	1-91	18	7.6
52896_1	19.1	23.5	0-78	19	5.4
52896_2	40.9	31.7	4-96	17	7.7
52897_1	44.9	34.7	0-100	37	5.7
52900_1	34.1	22.8	3.6-86.4	32	4.0
52903_1	36.1	24.4	0-85	39	3.9
52903_2	20.5	27.3	1-84	22	5.8
52909_1	45.9	27.4	0-100	35	4.6
Overall	**34.4**	**9.9**	**19.1-45.9**	**264**	**3.1**

3.5 Aerial Survey Results

A total of 709 turtles were sighted within the transect area (424.56 km^2) during the aerial survey in January 2010 (**Figure 17**). Approximately 20 of these turtles (~3 %) were sighted within the proposed development footprint or very close to (within 50 m). The conversion factor based on the time depth data was calculated to be 1.518. This was a conservative estimate as it was based on the minimum time spent diving. Using the conversion factor the number of turtles present within the transect area was 1076 turtles. This number was then extrapolated to the whole survey area of 4655km^2, which results in 11,800 turtles and a density of 2.5 turtles per km^2 within the area stretching from the De Grey River to Mundabullangana out to the 20 m depth contour.

Figure 18 depicts the results from the two summer aerial surveys that have been conducted (December 2008 and January 2010). Generally, turtles tended to be sighted away from the coast out towards the 20 m depth contour (**Figure 18**). The highest concentration of turtles was off the coast at Mundabullangana at the 20 m depth contour. Turtles were also found in high numbers close to, and north of, North Turtle Island (**Figure 18**).



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Project
J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title
Figure 17: Distribution of turtles sighted within the aerial transect survey area - January 2010

Legend
- Aerial transect survey area

Number of turtles sighted (2 km x 2 km grid)
- 1 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 121

Existing and Proposed Infrastructure
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

N

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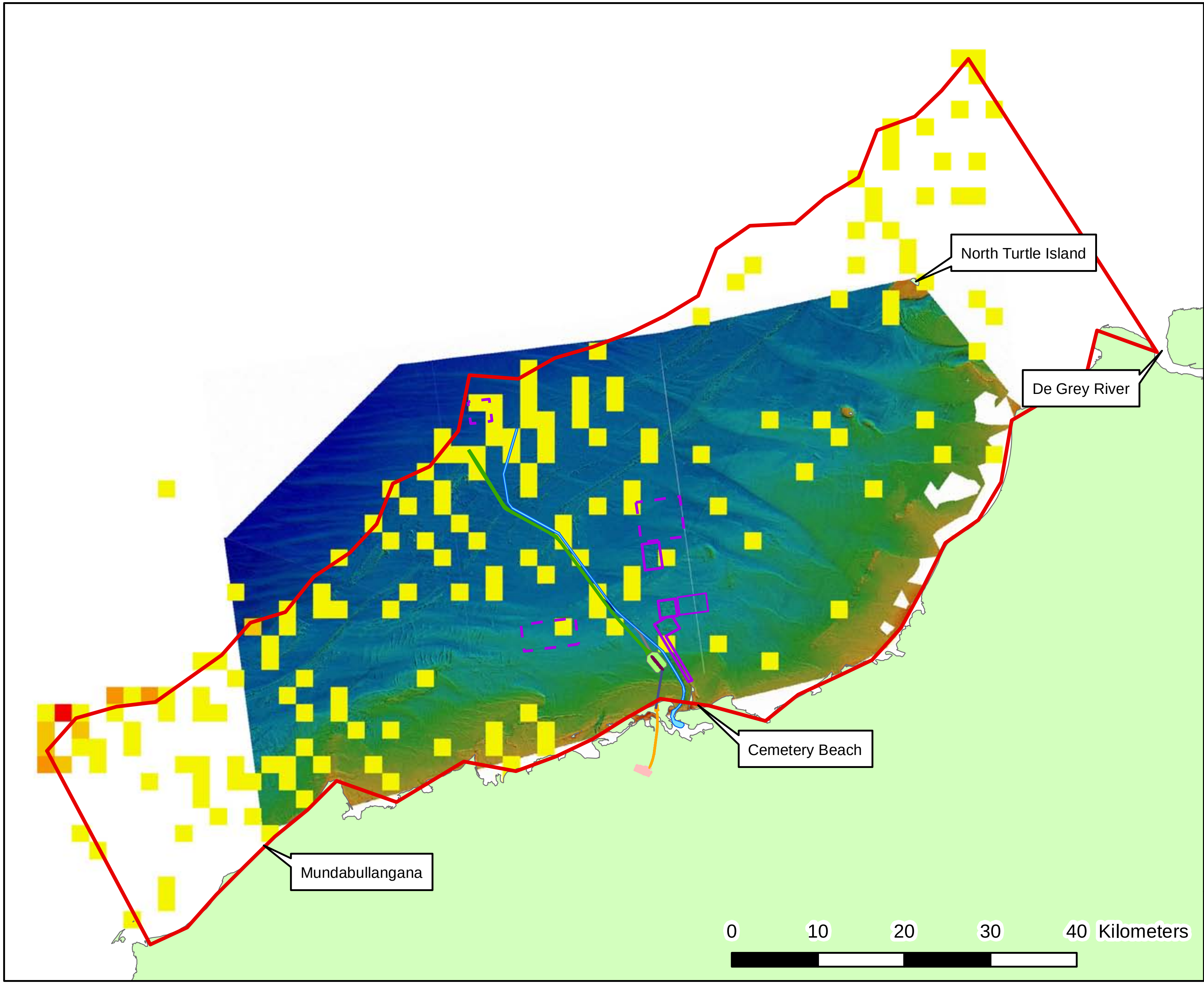

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Project
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Title
Figure 18: Distribution of turtles sighted within the aerial transect survey area - December 2008 & January 2010

Legend
Aerial transect survey area
Number of turtles sighted (2 km x 2 km grid)
1 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 121
Existing and Proposed Infrastructure
Proposed Jetty
Proposed Wharf
Proposed Infrastructure Corridor
Proposed Stockyards
Spoil Ground (Existing)
Spoil Ground (Proposed)
Tug access channel
Proposed Departure Channel
Proposed Berth Pockets and Swing Basins
Proposed Link Channel
Proposed Crossover Channel
Existing Shipping Channel

N

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4 DISCUSSION

A total of ten internesting periods were tracked from six flatback turtles between the 10th December 2009 and 16th January 2010, with the remaining four turtles departing from Port Hedlandwithout nesting again providing no further internesting data. The six turtles tracked during internesting displayed notable consistency in direction of movement with all but one internesting period migration track remaining within 50 km of Cemetery Beach in a north or north-east direction. The exception to this was internesting track 52897_1 which passed through the existing shipping channel and headed west to nest at Mundabullangana, 50 km away. The mean home range area was 143.2 km^2 (95 % UD) and core activity area (50 % UD) was 14.8 km^2 for the internesting flatback turtles, however there was variation in home range size for each individual turtle.

Flatback turtles exhibited relatively short dives where 75 % of dives recorded were less than 15 min and the majority of dives were less than 5 min in duration. The flatback turtles recorded shallow dives, with 85 % of their dive time spent at 20 m or less, with most time spent between 5 – 10 m. The maximum dive depth for the internesting flatback turtles showed a very similar pattern to the time spent at depth, indicating that when turtles dived they generally dive to their maximum depth and remain there for the duration of the dive. The average percentage of time spent at the surface was 31.5 %, with 68.5 % of time spent diving.

None of the Argos positions or the core activity areas of the internesting flatback turtles overlapped with the proposed development footprint. However, turtles are known to occur within the proposed development footprint, as shown by one of the flatback turtles tracked in 2008/09 (Pendoley Environmental, 2009). The aerial survey results also showed that approximately 3 % of the turtles sighted were within the proposed development footprint.

In addition, turtles were found to spend 34 % of their time on the seabed floor, where they are more at risk from dredge entrainment. Therefore, dredging is a potential risk to marine turtles and should be adequately addressed and specific mitigation measures implemented.

4.1 Internesting

The mean number of attempts prior to a successful nesting event (1.5 attempts per nest) for satellite tagged turtles at Cemetery Beach was less than that observed for the overall Cemetery Beach population recorded during the concurrent tagging program (2.27 attempts per nest; Pendoley Environmental, 2010). The mean internesting interval of 13.0 days for the satellite tagged turtles at Cemetery Beach was also similar to that of 13.3 days recorded for the overall Cemetery Beach population. These results indicate that the satellite transmitters were not adversely affecting the turtles' ability to successfully nest and their behaviour during the internesting period.

4.1.1 Internesting Migration

The internesting migration behaviour of flatback turtles is hypothesised to be driven by the need to optimise energy reserves in a manner most suited to the localised conditions and to the processes associated with nesting. Indeed, during this time the tracked flatback turtles experienced an array of physiological changes associated with ovulation, fertilisation, deposition and calcification of large quantities of eggs for oviposition (Houghton *et al*. 2002). In most species, internesting grounds are located close to shore. According to Plotkin (2003) internesting flatbacks presumably remain near shore during the internesting period and return to foraging grounds after the last clutch of eggs has been oviposited, however, no published data exists to support this presumption. It should also be noted that since female turtles store sperm after mating at the start of the nesting season (Lee, 2008), it is unlikely that the internesting movements reflect a search for males.

Generally, most of the flatback turtles showed a high level of site fidelity to the near shore environment immediately off Cemetery Beach or close inshore within 50 km to the east of Cemetery Beach, similar to the results for flatback turtles tracked from Cemetery Beach in 2008/09 (Pendoley Environmental 2009). An exception to this was the internesting migration of 52903_1, which travelled away from the coast to between North Turtle and Little Turtle Islands, approximately 40 - 50 km offshore. This turtle travelled a total distance of 159.5 km and was a maximum straight line distance of 49.2 km away from its nesting beach. Another turtle (52897) travelled east along the coast after nesting before it turned around and travelled west past its previous nesting site (Cemetery Beach) to nest at Mundabullangana, approximately 50 km away from Cemetery Beach. This turtle travelled the longest total distance of 206.8 km and had a maximum straight line distance of 56.8 km from Cemetery Beach. Previous satellite tracking studies in the Pilbara region have also shown that flatback turtles can undergo internesting migration routes of approximately 50 km from the nesting beach (Pendoley Environmental 2009; Chevron Australia 2009) and this has not been previously reported in flatback turtles elsewhere in Australia. Our results for flatback turtles show that they generally maintain nesting site fidelity, similar to results shown previously for olive ridley (*Lepidochelys olivacea)* turtles (Hamel *et al.* 2008) and leatherback (*Dermochelys coriacea*) turtles (Georges *et al*. 2007). However, one satellite tracked flatback turtle did nest at different nesting sites approximately 50 km apart (between Cemetery Beach and Mundabullangana) within the season and this was also recorded multiple times during the concurrent tagging program on Cemetery Beach (Pendoley Environmental, 2010), indicating turtles do not maintain fidelity to a restricted internesting home range and are capable of moving nesting sites.

Except for the one turtle that nested at Mundabullangana, all turtles spent their internesting period to the north-east of Cemetery Beach. Approximately 6 km to the west of Cemetery Beach is the operating Port Hedland port. It is unknown whether this port and associated activities has resulted in turtles not internesting to the west of Cemetery Beach or if they naturally interest to the north-east of their nesting beach. Previous satellite tracking results from Cemetery Beach in 2008/09 did show that two flatback turtles spent part of their time within or very close to the existing shipping channel at Port Hedland (Pendoley Environmental 2009).

The flatback turtles also displayed notable consistency in their habitat selection during internesting, with most turtles selecting bare sediment habitat. One exception to this is internesting migration track 52903_1, which was located between North Turtle and Little Turtle Islands on a combination of sediment and hard substrate/sediment with Benthic Primary Producer (BPP) habitat. Previous tracking studies on flatback turtles investigating post-nesting migrations (Pendoley, unpublished data; www.seaturtle.org) have identified foraging grounds close to North Turtle Island and it is possible that this turtle is foraging in this location during internesting. A number of studies have shown that some green turtles will forage during the internesting period (Balazs 1980; Tucker & Read 2001; Delcroix *et al.* 2009). This cannot be confirmed from just looking at the internesting migration routes alone, and a combination of techniques involving additional tracking technology is required to determine foraging behaviour.

4.1.2 Home Range

The use of two datasets in identifying home range areas provided a method to investigate how the size of home range area was impacted by the number of locations in the dataset and aided this study in identifying which dataset was most suitable for future tracking studies.

The average size of MCP and FKD areas for all tracked turtles were similar for both the 95% UD and 50% UD for the temporally restricted dataset based on the Argos positions, however there was substantial variation in home range size for each individual turtle between both home range analysis techniques. The temporally restricted dataset is a better measure of home range area as it removes the bias from using all Argos positions and provides an assurance that artifacts caused by differing data volumes were not being generated when estimating home range areas. It is therefore recommended that the temporally restricted dataset be used for future tracking studies.

The FKD home range areas (based on the temporally restricted dataset) were used to describe the flatback turtle internesting home range areas. While the MCP analysis has been the most commonly applied home range analysis method (Mendonca 1983; Renaud & Carpenter 1994; Renaud *et al*. 1995; Whiting & Miller 1998) novel non-parametric methods such as FKD analysis are now being commonly used. Using FKDs has a number of features that make it useful for home range analysis. FKDs work well with small amounts of data, they are robust to autocorrelation, they are non-parametric, they allow multiple centres of activity and they result in a utilization distribution rather than a simple home range outline similar to what an MCP analysis produces (Kernohan *et al*. 2001). FKD home range analysis also reveal areas of disproportionately high use (i.e. multiple core areas of activity) for each internesting interval while appropriately weighing outlier observations, in contrast the MCP home range analysis strongly relates to the distribution of the outermost points and was constrained by its inability to identify fine scale spatial use patterns by only revealing one area of activity for each internesting interval. Worton (1987) and White & Garrot (1990) found that MCP analysis was prone to incorporating areas of non-use that separated patches of highly used habitat. Seaman & Powell (1996) also evaluated the FKD analysis and suggested this approach is the most accurate compared to MCP analysis.

The core activity areas (FKD 50 % UD, based on temporally restricted dataset) were situated within 10 km of Cemetery Beach (the nesting site) and reflect the majority of internesting flatbacks using this area for their internesting. The one exception to this is the internesting migration of 52903_1, with its core activity area being situated between Little and North Turtle Islands. Analysis of the six flatback turtles tracked from Cemetery Beach in 2008/09 showed that the turtles occupied similar core activity areas to those in this study (**Figure 19**). There was no direct correlation between the overall distance travelled during the internesting migration and FKD home range area for 50% UD (based on temporally restricted dataset). This implies that there are two direct behaviour patterns exhibited during the internesting interval. The first is a migration away from the nesting site (up to 50 km), the second is the activity spent in their core area of activity is assumed to be resting. The lack of correlation confirms that the migration distance travelled during this first behaviour activity does not influence the size of the core home range area.

There are no published studies on home range estimates for internesting flatback turtles so direct comparisons with other data cannot be undertaken. There are also no published studies on home range estimates for post-nesting flatback turtles, as well as summer/winter home range estimates of both adult and juvenile flatback turtles. Direct comparison with home range estimates of other marine turtle species was not undertaken due to huge variances documented in home range size of other marine turtle species (i.e. in green turtles (*Chelonia mydas*); Mendonca 1983; Renaud *et al*. 1995; Whiting & Miller,1998; Seminoff *et al*. 2002). Seminoff *et al*. (2002) explains that these differences are related to individual sizes, and/or marine zones inhabited by different marine turtles, further confirming that direct comparison is not relevant for this project.

4.2 Dive Behaviour

The mean minimum percentage of time spent at the surface (<2 m depth) during each internesting period was 31.5% with 68.5% of time spent diving. The percentage time spent diving is likely to be higher as only the minimum range value of the bin values could be calculated. No direct comparison of these percentages can be made as no published data exists on dive/surface duration percentages for internesting flatback turtles, however, internesting flatback turtles are very rarely observed at the surface (J. Oates, pers. obs.) which would confirm these percentage values. Values for surface duration may also be biased as the bathymetric depth in the near shore intertidal zone near Cemetery Beach is often less than 2 m resulting in the flatback turtle being recorded at the surface because the bathymetric depth restricts the flatback turtle from reaching a deeper depth to trigger the start of a dive. Additionally, it cannot be ruled out that the positive buoyancy of the satellite units had an effect on the dive behaviour such as suppressing the desire to dive and a reduction of the dive duration (Nagelkerken *et al*. 2003).

The dive duration recorded for internesting flatback turtles at Cemetery Beach was relatively short; 75 % of recorded dives were less than 15 minutes and 42.5 % of dives were less than 5 minutes. All recorded dives during the internesting period were less than 60 min in duration. Other marine turtle species have recorded longer dive duration of 00:31:12 (hh:mm:ss) observed in hawksbill turtles (Bell & Parmenter 2008), and between 00:27:48 – 00:37:24 (hh:mm:ss) for leatherback turtles (Eckert *et al*., 1986). Longer duration dives did occur in this study with 8% of dives recorded between 30 and 45 minutes in duration. Sperling *et al*. (2007) found that flatback turtles showed a blood oxygen carrying capacity in the high end of the range for diving reptiles suggesting the flatback turtle's ability for longer dives is high compared to other marine turtle species. Comparisons of internesting dive behaviour with post-nesting dive behaviour is required to confirm if this observed dive behaviour during the internesting period is unique to the flatback turtle's internesting life stage, as opposed to dive behaviour observed in post-nesting flatback turtles.

Internesting flatback turtles exhibited relatively shallow dives, with 85 % of the time spent at less than 20 m and most time was spent between 5 – 10 m (27 %). All recorded dives were less than 30 m in depth during the internesting period. This coincides with Limpus *et al*. (1983) who describes flatback turtles as "shallow divers who feed in turbid nearshore waters", but disagrees with Walker's (1991) observations of flatback turtles being commonly found in waters down to a depth of between 40 - 45 m (although no bathymetry of this depth was experienced along the routes of any of the internesting migration routes). The maximum dive depth for the internesting flatback turtles showed a very similar pattern to the time spent at depth, indicating that when turtles dived they generally dive to their maximum depth and remain there for the duration of the dive.

4.3 Aerial Survey

Using the conversion factor a density of 2.5 turtles per km^2 was recorded within the area stretching from the De Grey River to Mundabullangana out to the 20 m depth contour. The highest concentration of turtles was off the coast at Mundabullangana at the 20 m depth contour, which probably reflects internesting habitat used by flatback turtles from Mundabullangana. Turtles were also found in high numbers close to, and north of, North Turtle Island and this is probably reflecting foraging habitat used by juvenile and adult green turtles, rather than internesting habitat, given the results of ground-truthing surveys in 2008/09 (Pendoley Environmental 2009) and the lack of satellite data showing turtles internesting in this area. The extrapolation of the number of turtles using a conversion factor based on the time depth data from internesting flatback turtles should be used with caution due to the limitations, e.g. the dive data was from internesting turtles and foraging turtles may differ in their dive behaviour.

4.4 Construction Impacts

All estimates of interaction due to proposed construction activities should be taken as a conservative estimate as this report has only considered the areas directly impacted by dredging. It is likely that further interaction with activities outside of these areas, including impacts from sedimentation and turbidity from the dredge plumes and increased ship movement, may occur.

Home range analysis is a very effective method for both an understanding of use of habitat and the establishment of conservation measures for marine turtles (Yasuda & Arai 2005), in this case identifying the interaction of internesting flatback turtles with dredging and related construction activities. None of the Argos positions for the internesting flatback turtles were located within the proposed development footprint area, including areas proposed to be dredged and proposed spoil disposal grounds. Approximately 2 % of the temporally restricted Argos positions were located within existing spoil grounds. Similarly, the core activity areas for the internesting turtles (FKD 50% UD based on temporally restricted dataset) do not overlap with the proposed development footprint. A very small percentage (0.18 ± 0.18 %) of the core activity area lies within existing spoil grounds. This indicates that the internesting flatback turtles are not internesting within this area and may be actively avoiding the area due to shipping activities, etc associated with the operating Port Hedland Harbour. The aerial surveys also showed that only a small proportion (~3 %) of the turtles sighted were within or very close to (within 50 m) the proposed development footprint.

Caution should be made in making conclusions regarding potential impacts due to construction activities from monitoring ten internesting periods. The results of the aerial surveys indicated that turtles were not observed in the proposed development footprint, but whether these are internesting turtles is unknown, as resident foraging turtles are present all year round. One of the flatback turtles tracked in 2008/09 from Cemetery Beach also revealed that 12 % of its core activity area overlapped with the proposed development footprint (**Figure 19**). These results illustrate the need for further studies over multiple seasons for a more robust analysis of potential impacts on internesting flatback turtles in the area.

An attempt was made in this study to identify the percentage of the dive duration of each tracked flatback turtle that occurred close to the seabed floor, where presumably the flatback turtle was resting. Identifying this percentage would demonstrate the likely interaction between diving internesting flatback turtles on the sea bed floor and the potential construction impacts associated with the proposed Outer Harbour Development, particularly during dredging when resting flatback turtles are more at risk of being entrained. The results indicated that internesting flatback turtles spent an average of 34.4 % of their dive time on the seabed floor. This is an estimate as there were limitations with the type of data collected by the satellite units (lack of individual dive profiles and the use of bin values) as well as the interpolation of bathymetric depth contours.

The difference between the time spent on the seabed floor during daylight and night time hours was compared to determine if internesting flatback turtles may be potentially more at risk from dredging during a certain time period, however, no difference was observed.

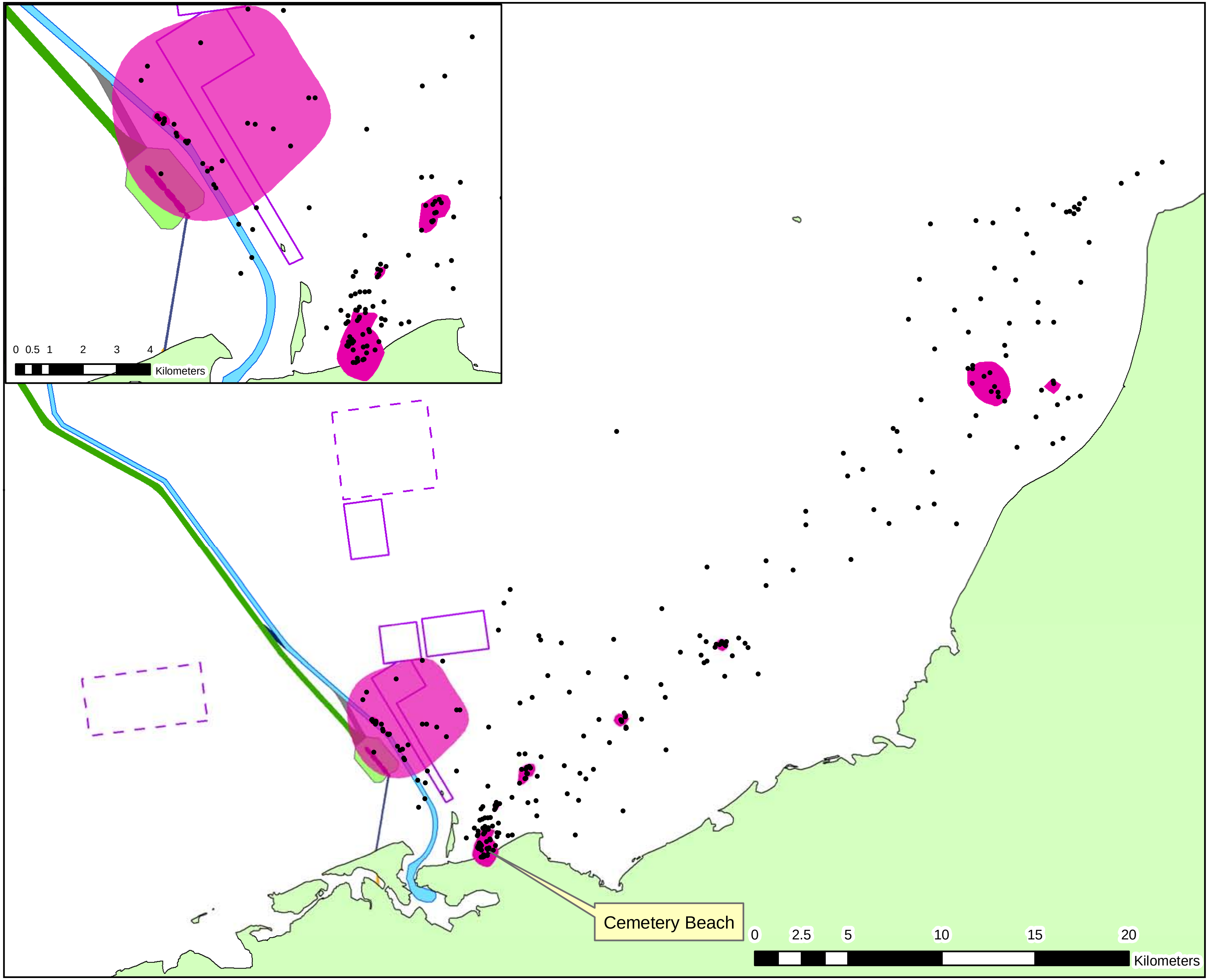
4.5 Conclusions and Recommendations

The results of this study indicate that internesting flatback turtles nesting at Cemetery Beach internest either just off Cemetery Beach or to the north-east of Cemetery Beach up to 50 km away. It appears that internesting flatback turtles tend to avoid the area to the west of their nesting beach, but whether this is natural or due to the existing shipping channel and associated port and shipping activities is not known. These results suggest that the potential risk to these turtles from dredging activities associated with the proposed Outer Harbour Development may be less than previously thought. However, turtles are known to occur within the proposed development footprint, as shown by one of the flatback turtles tracked in 2008/09 and the aerial surveys. In addition, turtles were found to spend 34 % of their time on the seabed floor, where they are more at risk from dredge entrainment. Therefore, dredging is still a potential risk to marine turtles and should therefore be adequately addressed and specific mitigation measures implemented.

The results of the aerial survey showed that turtles occurred within the proposed development footprint, however, it is unknown whether these were internesting flatback turtles that are present during the summer or resident foraging turtles that are present all year round. It is likely that some of these turtles are resident foraging turtles and it is highly recommended to conduct satellite tracking of these foraging turtles to determine their movements and behavior within the dredging and spoil disposal areas.

Each Mk-10A satellite tag transmitted only Argos LC (Doppler shift) positions. Another data type that can be transmitted is Fastloc® GPS, which is considered to provide a greatly enhanced location accuracy relative to the Argos positional data, particularly for fine scale movements (Hazel 2009; Costa *et al*. 2010). There are however advantages to using satellite units without the Fastloc® function including increased battery life, reduced costs, and near real time display of Argos locations (Fastloc® positions have a 24 hour delay due to processing). Argos-derived positions perform well for large scale movements, such as migration in turtles, especially as filtering becomes more effective (Witt *et al.* in press). The advantages and disadvantages of each tag type, including using both data types should be considered for future tracking studies and the survey objectives.

Further studies involving the use of recoverable TDR units on internesting flatbacks, and hence having access to individual dive profiles, is recommended to confirm the exact dive behaviour of internesting flatback turtles at Cemetery Beach. Analysis of individual dive profiles will enable a more accurate assessment of the time spent on the seabed floor. The different types of TDR units available should be investigated to determine the best type depending on what kind of data are trying to be collected. For example, are there TDR units that provide more accurate higher resolution depth measurements where data are not binned, however, these types of units require retrieval.



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Project

J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Figure 19: Fixed Kernel Density core activity areas for internesting flatback turtles tracked from Cemetery Beach in 2008/09 (based on temporally restricted dataset)

Legend

- Internesting location
- FKD 50% UD (based on restricted dataset)

Existing and Proposed Infrastructure

- **Proposed Jetty**
- **Proposed Wharf**
- **Proposed Infrastructure Corridor**
- **Proposed Stockyards**
- **Spoil Ground (Existing)**
- **Spoil Ground (Proposed)**
- **Tug access channel**
- **Proposed Departure Channel**
- **Proposed Berth Pockets and Swing Basins**
- **Proposed Link Channel**
- **Proposed Crossover Channel**
- **Existing Shipping Channel**

Drawn	JEO	Date	21/05/10	Scale
Checked	PAW	Date	21/05/10	As shown
Approved	KLP	Date	21/05/10	
Drawing File Ref:	PENV-J22008-144-A			Rev. No. A

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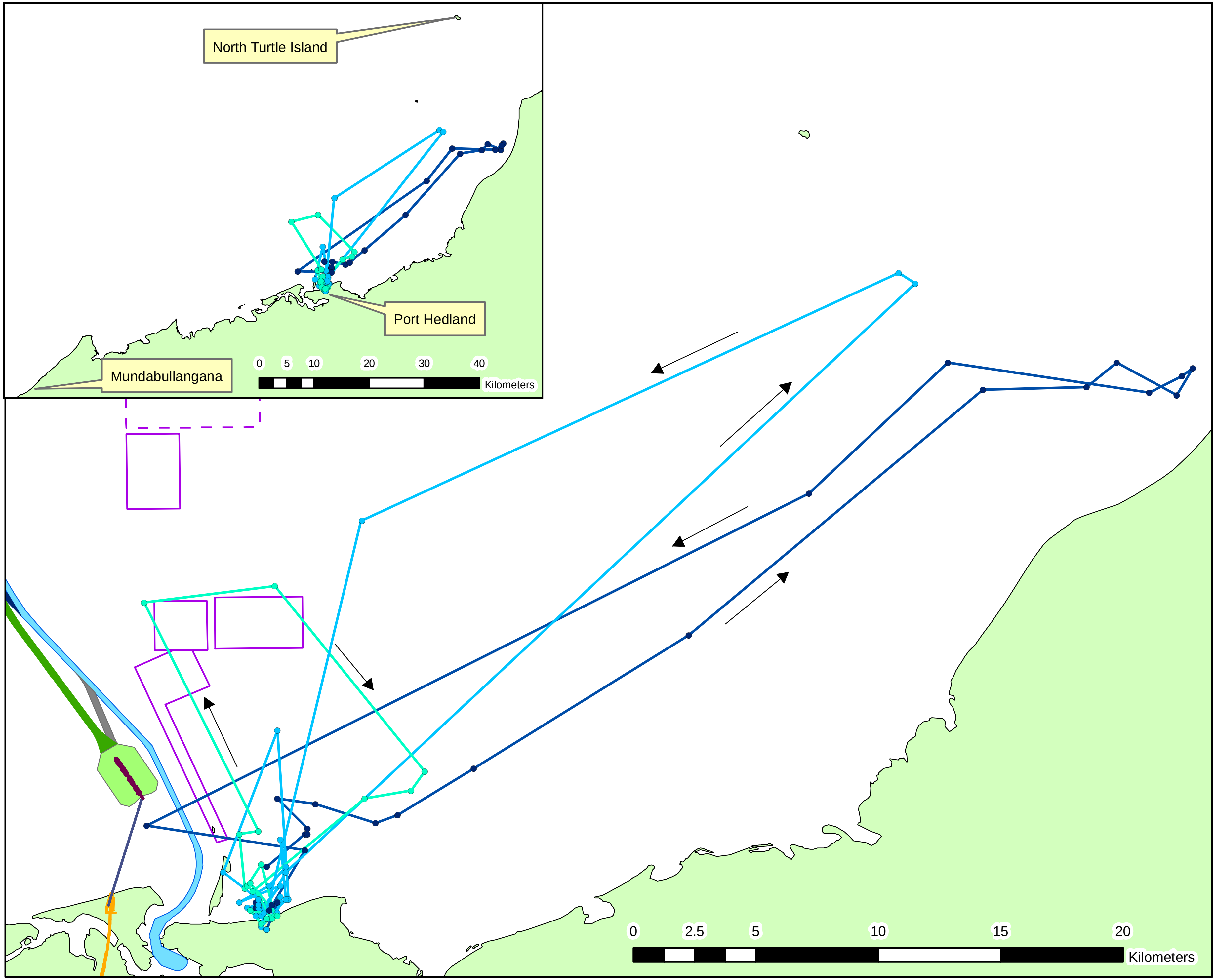
Appendix A: Summary of observations of internesting flatback turtles recorded during the tagging program at Cemetery Beach

PTT Number	Date (night of)	Satellite Tag Applied	Beach	Nest or Attempt	Tagging Team Observations			Was beach monitored at the time?	GPS Coordinates	
					Observed by tagging team?	Time of Observation	Activity		Lat.	Long.
52895	12/12/2009	Yes	Cemetery Beach	Nest	Yes	19:45	Laying eggs	Yes	-20.30746	118.60931
52895	2/01/2010	No	Cemetery Beach	Attempt	Yes	22:36	Digging body pit	Yes	-20.30719	118.61154
52895	3/01/2010	No	Cemetery Beach	Nest	Yes	1:24	Laying eggs	Yes	-20.30685	118.61286
52896	9/12/2009	Yes	Cemetery Beach	Nest	Yes	4:26	Laying eggs	Yes	-20.30702	118.61219
52896	4/01/2010	No	Cemetery Beach	Unknown	Yes	23:55	Digging body pit	Yes	-20.30683	118.61319
52897	30/11/2009	No	Cemetery Beach	Nest	Yes	23:53	Laying eggs	Yes	-20.30687	118.61266
52897	12/12/2009	Yes	Cemetery Beach	Attempt	Yes	18:09	Digging body pit	Yes	-20.30734	118.60995
52897	12/12/2009	No	Cemetery Beach	Nest	Yes	19:42	Laying eggs	Yes	-20.30736	118.60967
52900	10/12/2009	Yes	Cemetery Beach	Nest	Yes	19:01	Filling in egg chamber	Yes	-20.30758	118.60778
52901	28/11/2009	No	Cemetery Beach	Nest	Yes	19:45	Laying eggs	Yes	-20.30667	118.60341
52901	11/12/2009	Yes	Cemetery Beach	Unknown	Yes	19:17	Returning to water	Yes	-20.30729	118.60986
52903	30/11/2009	No	Cemetery Beach	Nest	Yes	22:37	Laying eggs	Yes	-20.30727	118.61063
52903	12/12/2009	Yes	Cemetery Beach	Nest	Yes	20:04	Laying eggs	Yes	-20.30750	118.30878
52904	28/11/2009	No	Cemetery Beach	Unknown	Yes	22:39	Returning to water	Yes	-20.30716	118.60941
52904	11/12/2009	Yes	Cemetery Beach	Attempt	Yes	17:00	Not recorded in field	Yes	-20.30726	118.60987
52904	13/12/2009	No	Cemetery Beach	Unknown	Yes	22:49	Excavating egg chamber	Yes	-20.30678	118.6128
52907	28/11/2009	No	Cemetery Beach	Nest	Yes	21:35	Filling in egg chamber	Yes	-20.30687	118.61269
52907	8/12/2009	No	Cemetery Beach	Attempt	Yes	2:50	Returning to water	Yes	-	-
52907	9/12/2009	No	Cemetery Beach	Attempt	Yes	4:09	Not recorded in field	Yes	-20.30698	118.61228
52907	12/12/2009	Yes	Cemetery Beach	Attempt	Yes	21:43	Returning to water	Yes	-20.30746	118.60916
52907	13/12/2009	No	Cemetery Beach	Attempt	Yes	22:05	Returning to water	Yes	-20.30773	118.61353
52907	14/12/2009	No	Cemetery Beach	Unknown	Yes	5:00	Returning to water	Yes	-20.30705	118.61257
52909	11/12/2009	Yes	Cemetery Beach	Attempt	Yes	19:37	Returning to water	Yes	-20.30729	118.60988
52909	12/12/2009	No	Cemetery Beach	Unknown	Yes	17:40	Returning to water	Yes	-20.30740	118.60861
52911	30/11/2009	No	Cemetery Beach	Nest	Yes	21:02	Laying eggs	Yes	-20.30689	118.61261

PTT Number	Date (night of)	Satellite Tag Applied	Beach	Nest or Attempt	Tagging Team Observations			Was beach monitored at the time?	GPS Coordinates	
					Observed by tagging team?	Time of Observation	Activity		Lat.	Long.
52911	11/12/2009	Yes	Cemetery Beach	Nest	Yes	19:50	Laying eggs	Yes	-20.30710	118.61142
52911	11/12/2009	No	Cemetery Beach	Same nest	Yes	20:11	Returning to water	Yes	-20.30702	118.61141

Appendix B: Internesting period locations for the nine individual flatback turtles tracked from Cemetery Beach



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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map B1: Internesting period tracks for flatback turtle 52895

Legend

- 52895_1 internesting locations
- 52895_2 internesting locations
- 52895_3 internesting locations

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale: As shown
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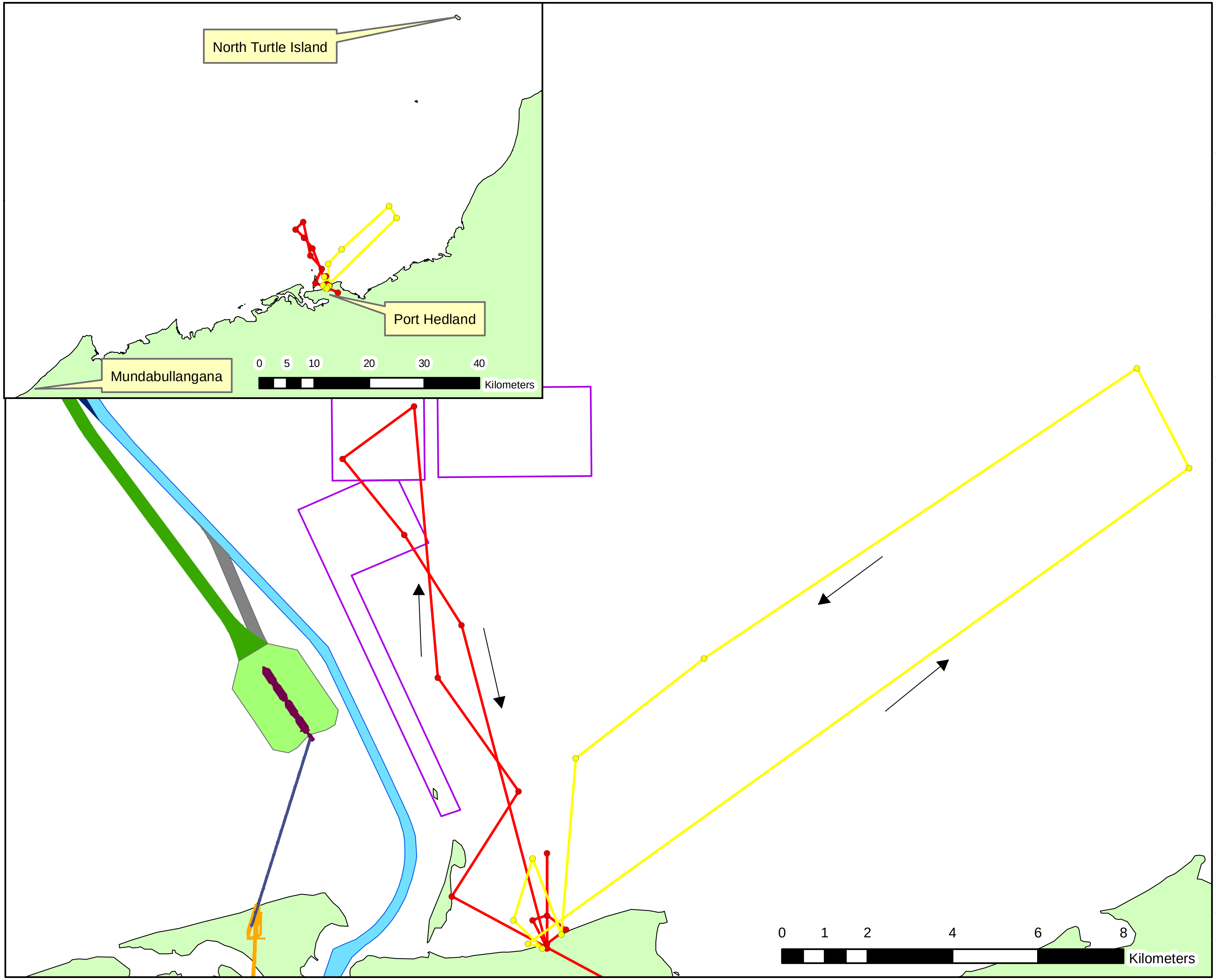
Approved	KLP	Date	25/05/10	
Drawing File Ref: PENV-J22008-107-A				Rev. No. A



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Title

Map B2: Internesting period tracks for flatback turtle 52896

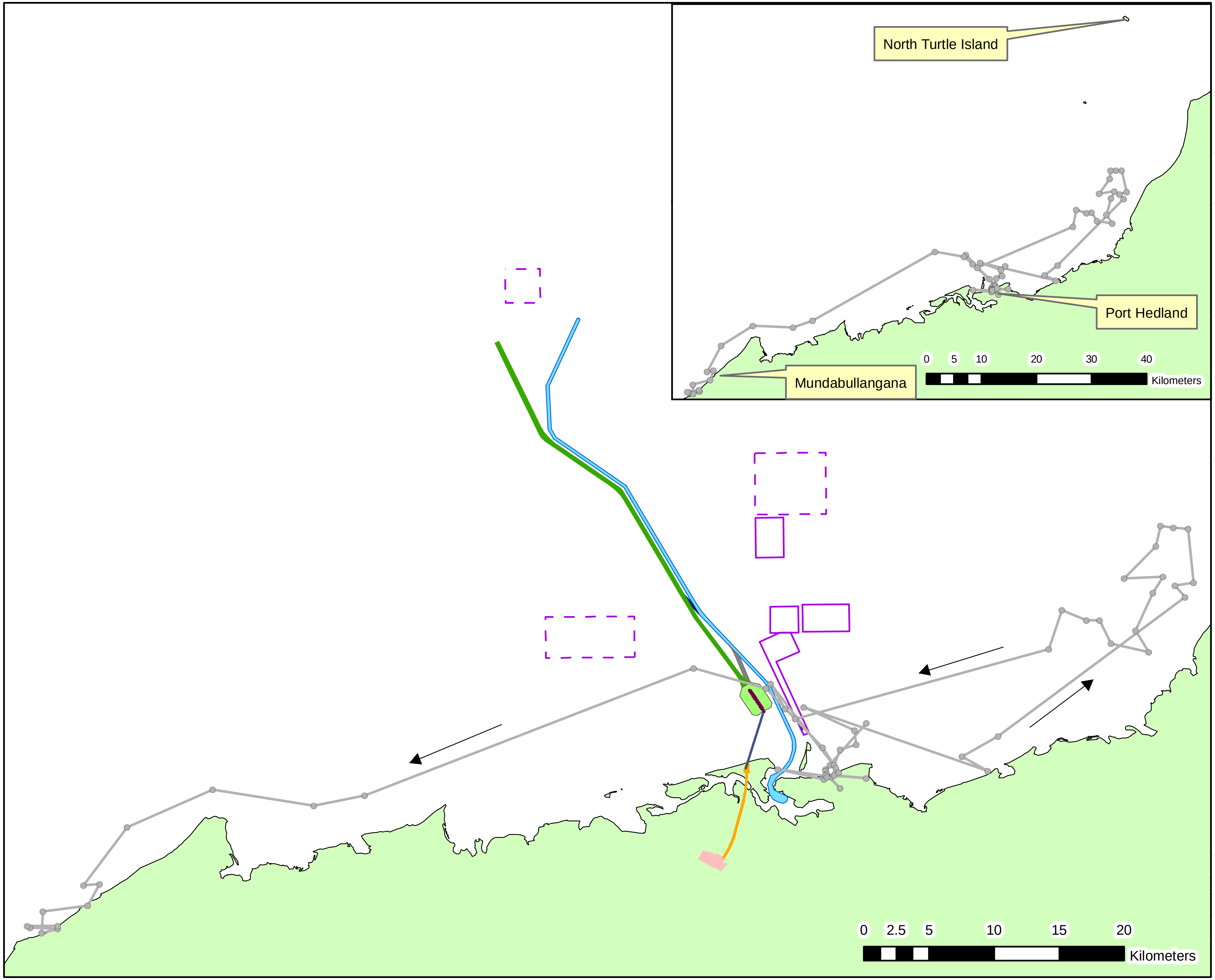
Legend

- 52896_1 internesting locations
- 52896_2 internesting locations

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-108-A			Rev. No. A



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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

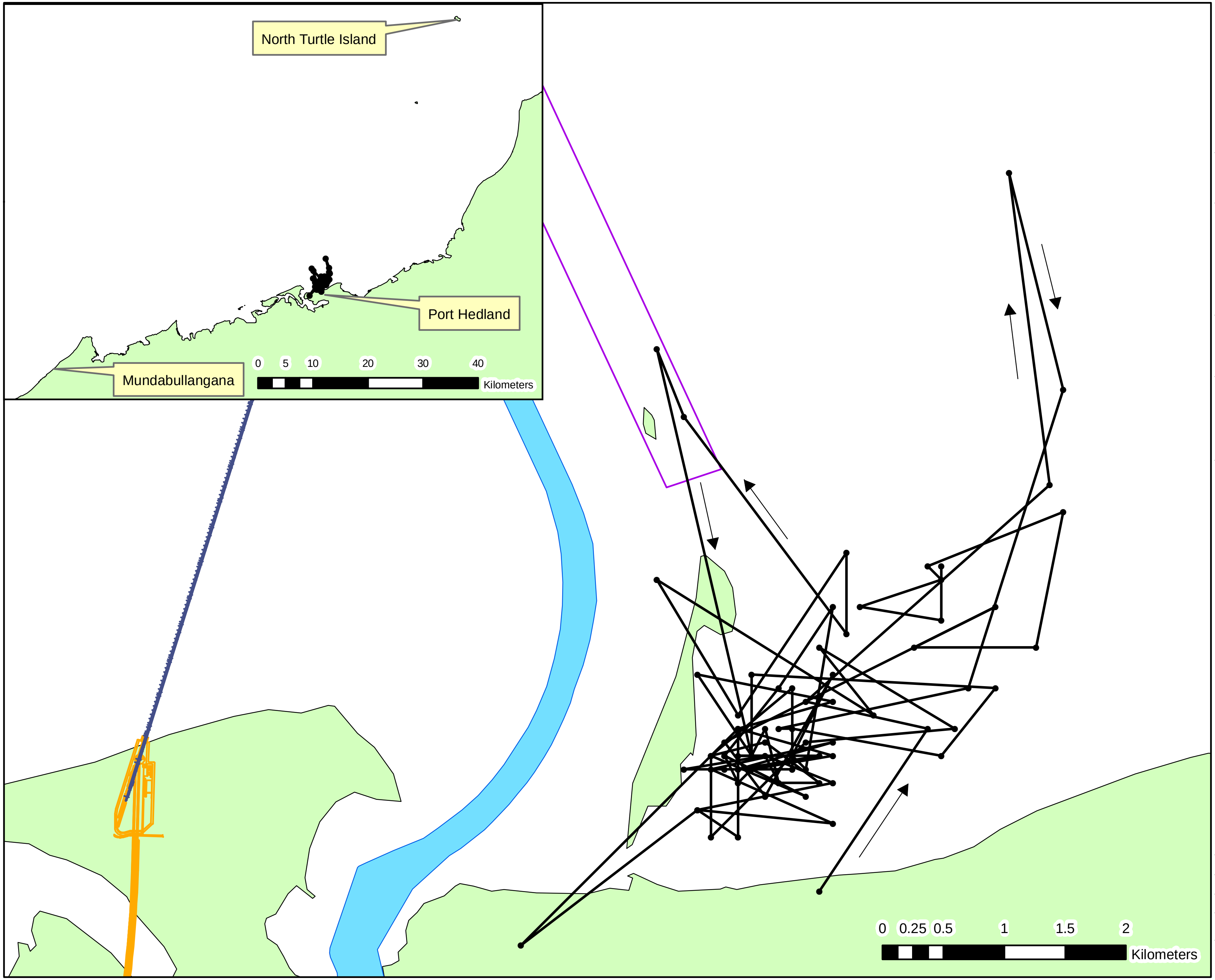
Title

Map B3: Internesting period tracks for flatback turtle 52897

Legend

- 52897_1 internesting locations
- Existing and Proposed Infrastructure
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-109-A			Rev. No. A



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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map B4: Internesting period tracks for flatback turtle 52900

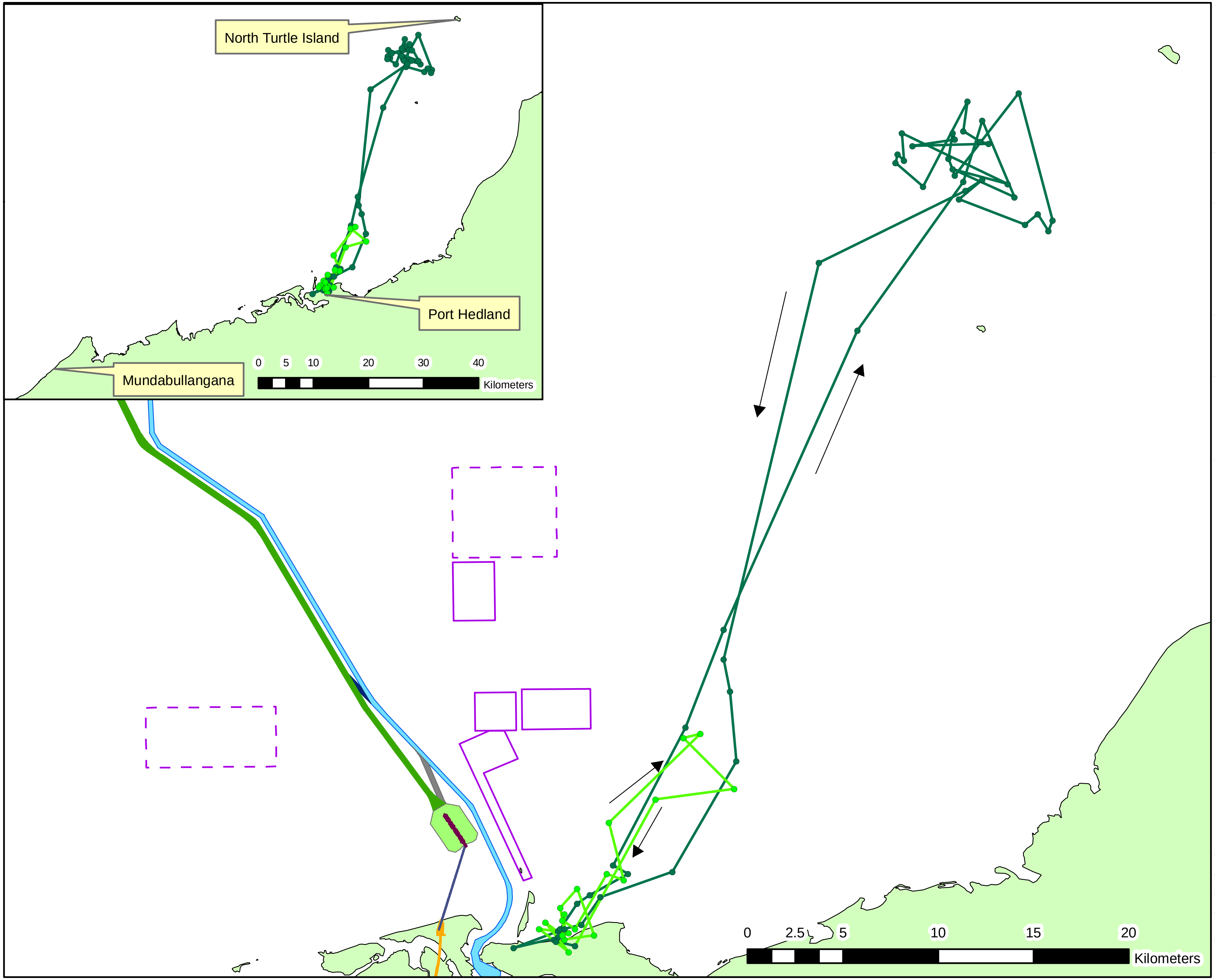
Legend

- 52900_1 internesting locations

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-110-A			Rev. No. A



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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map B5: Internesting period tracks for flatback turtle 52903

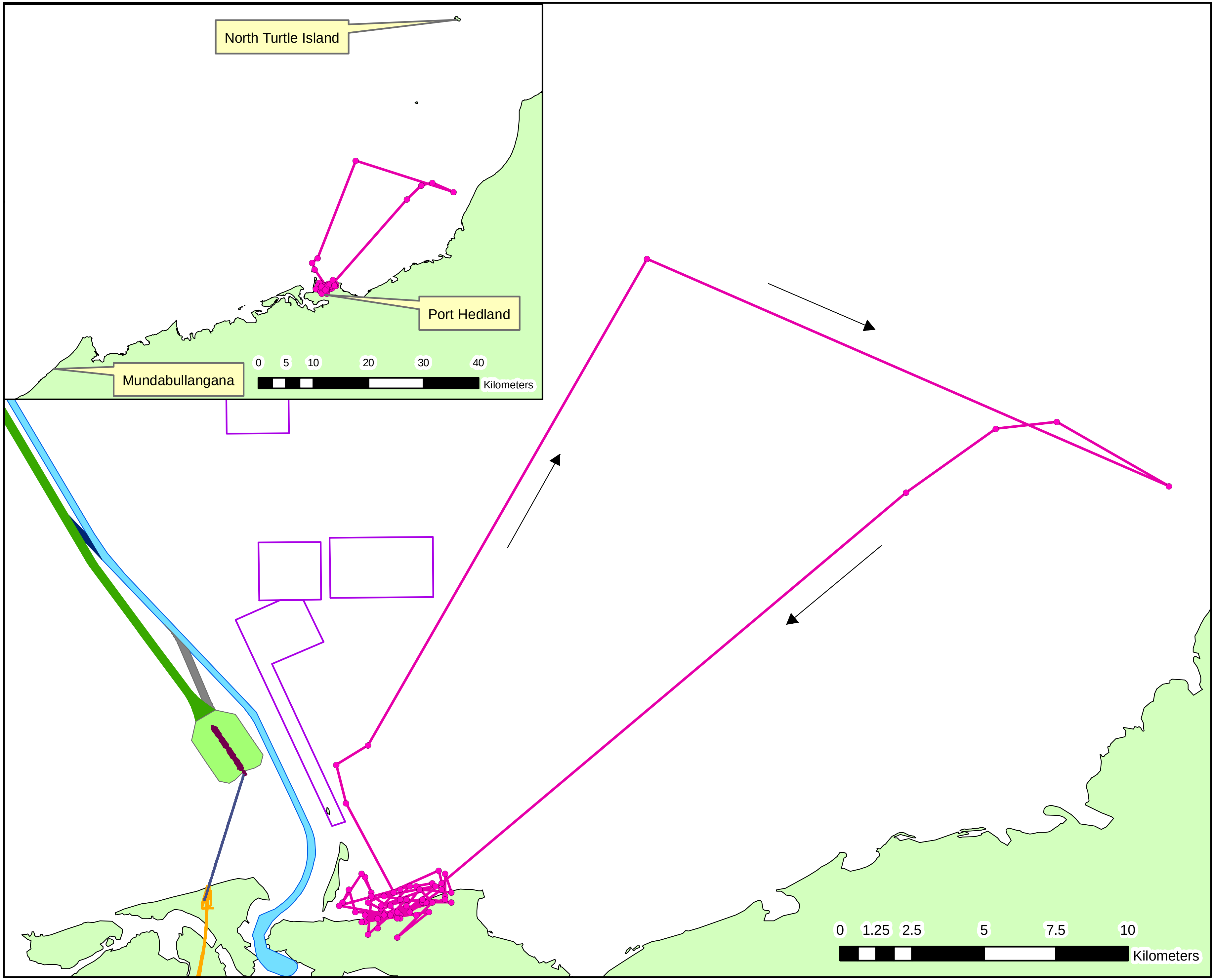
Legend

- 52903_1 internesting locations
- 52903_2 internesting locations

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale
Checked	PAW	Date	25/05/10	As shown
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-111-A			Rev. No. A



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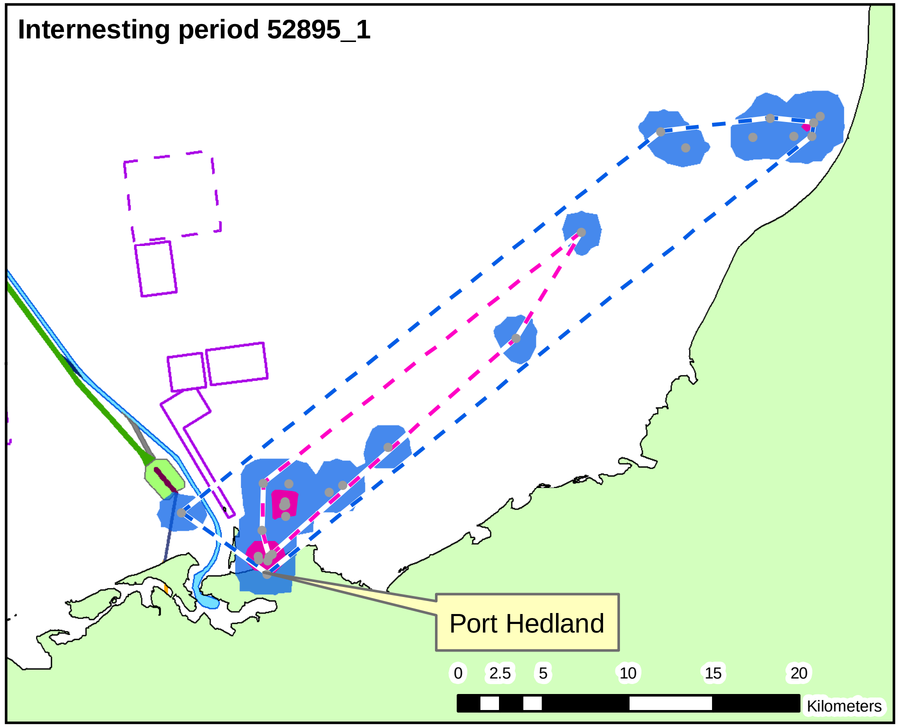
Project
J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

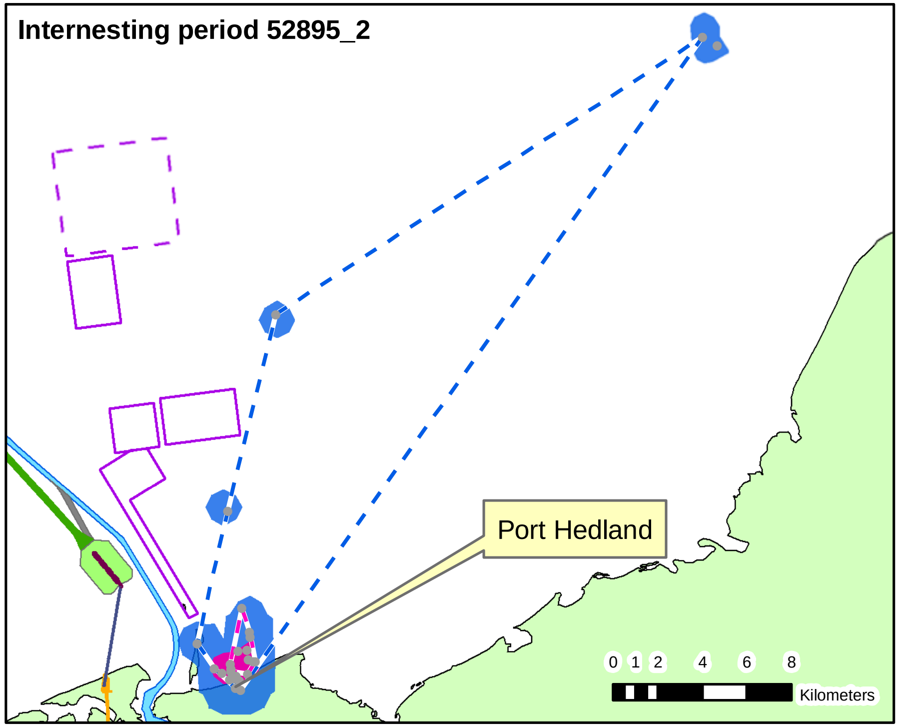
Title
Map B6: Internesting period tracks for flatback turtle 52909

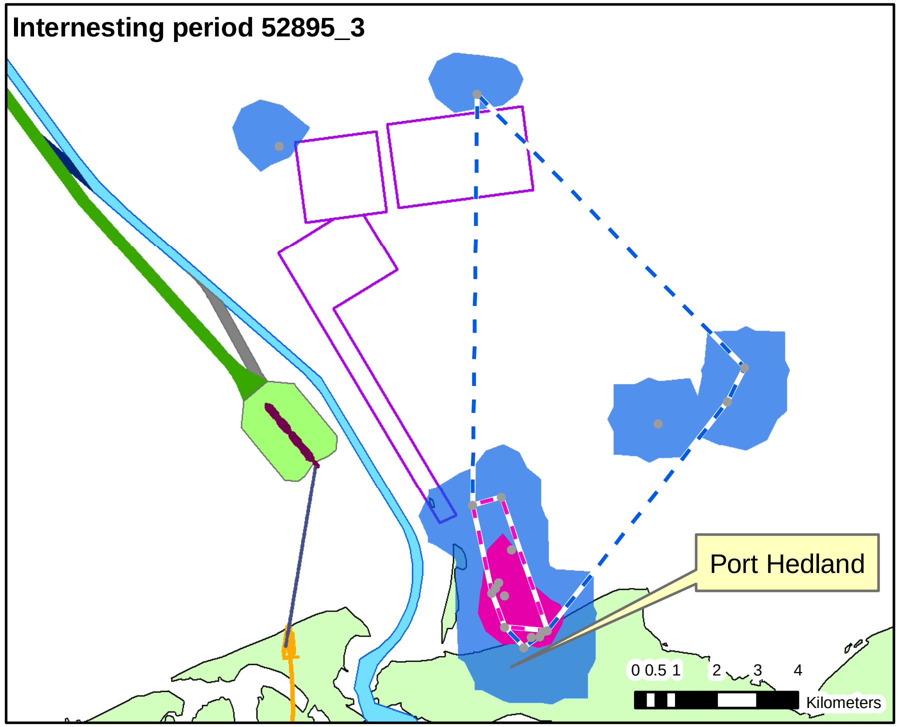
Legend
52909_1 internesting locations
Existing and Proposed Infrastructure
Proposed Jetty
Proposed Wharf
Proposed Infrastructure Corridor
Proposed Stockyards
Spoil Ground (Existing)
Spoil Ground (Proposed)
Tug access channel
Proposed Departure Channel
Proposed Berth Pockets and Swing Basins
Proposed Link Channel
Proposed Crossover Channel
Existing Shipping Channel

Drawn JEO	Date 25/05/10	Scale	As shown
Checked PAW	Date 25/05/10		
Approved KLP	Date 25/05/10		
Drawing File Ref: PENV-J22008-112-A		Rev. No.	A

Appendix C: Minimum Convex Polygon and Fixed Kernel Density home range are for flatback turtles during internesting (based on unrestricted dataset)







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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map C1: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52895 (based on unrestricted dataset)

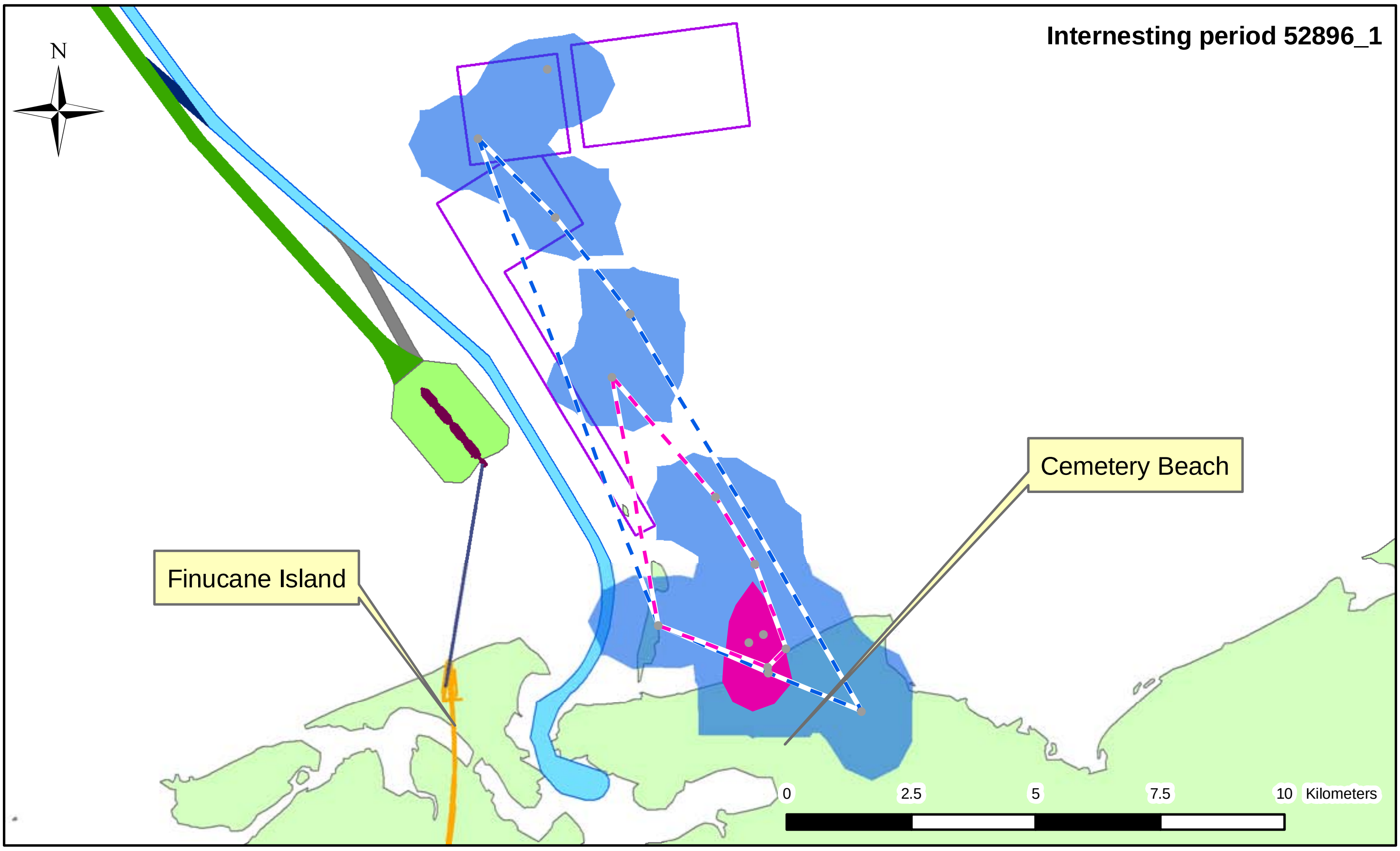
Legend

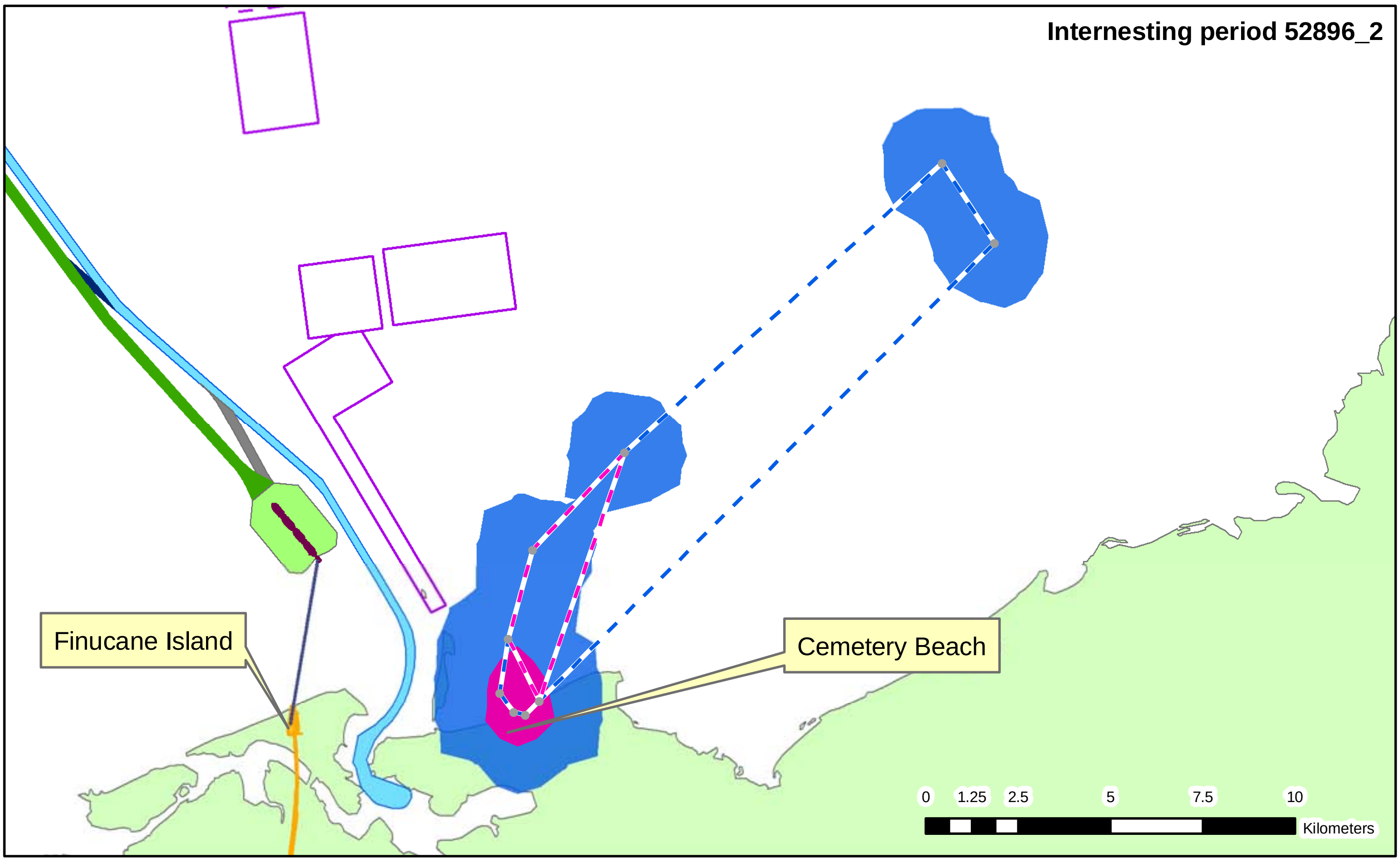
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD
- Internesting locations

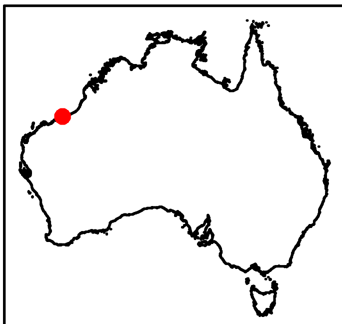
Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-114-A			Rev. No. A







Project
J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title
Map C2: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52896 (based on unrestricted dataset)

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref: PENV-J22008-115-A				Rev. No. A

Legend

- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel
- Tug access channel
- Spoil Ground One
- Spoil Ground (Existing)
- Spoil Ground (Proposed)

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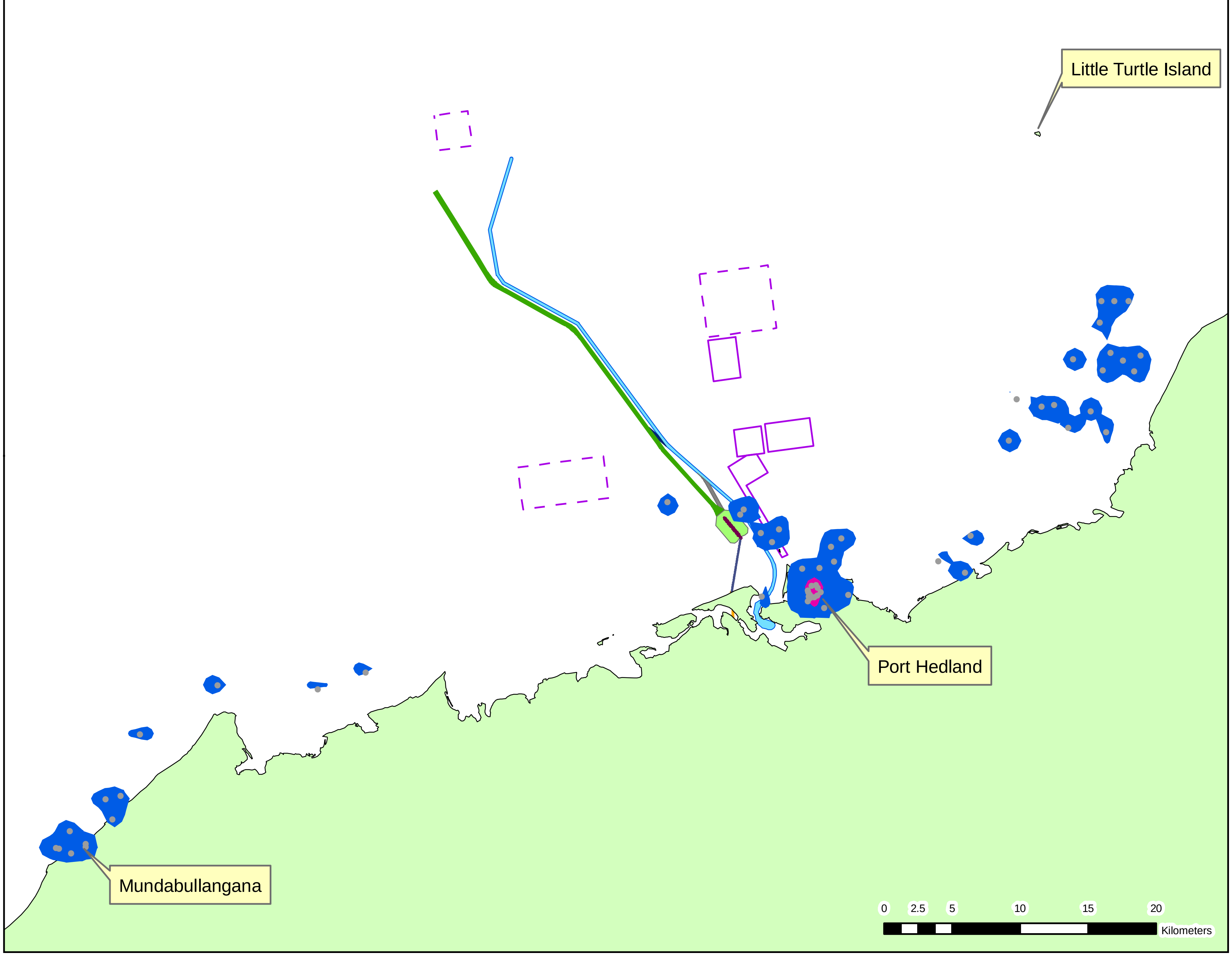
Internesting period 52897_1



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J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map C3: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52897 (based on unrestricted dataset)

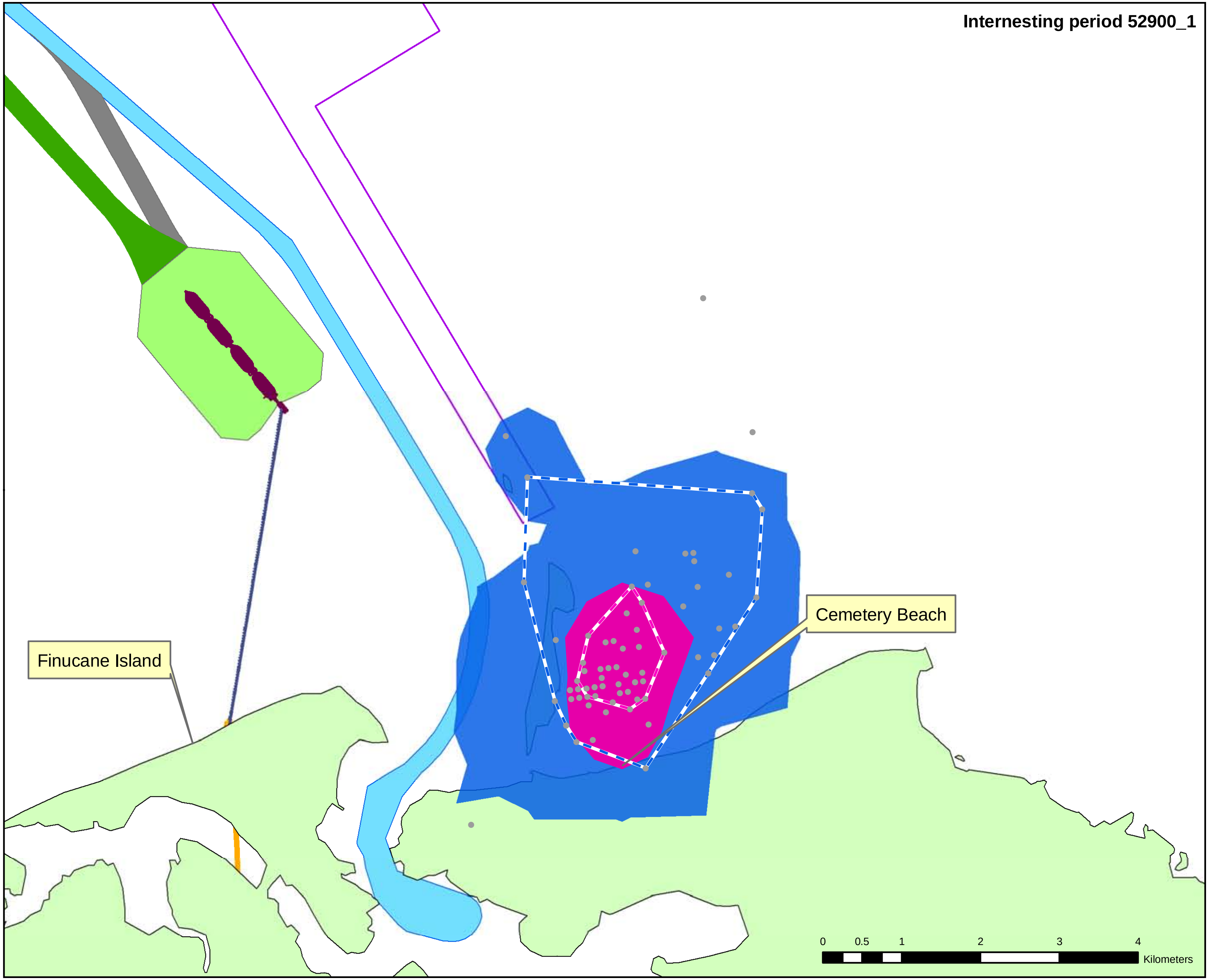
Legend

- Internesting locations
- FKD 50% UD
- FKD 95% UD
- MCP 50% UD
- MCP 95% UD

Existing and Proposed Infrastructure

- **Proposed Jetty**
- **Proposed Wharf**
- **Proposed Infrastructure Corridor**
- **Proposed Stockyards**
- **Spoil Ground (Existing)**
- **Spoil Ground (Proposed)**
- **Tug access channel**
- **Proposed Departure Channel**
- **Proposed Berth Pockets and Swing Basins**
- **Proposed Link Channel**
- **Proposed Crossover Channel**
- **Existing Shipping Channel**

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-116-A			Rev. No.: A



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Project

J22008 Outer Harbour Development Port Hedland Satellite/TDR Study

Title

Map C4: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52900 (based on unrestricted dataset)

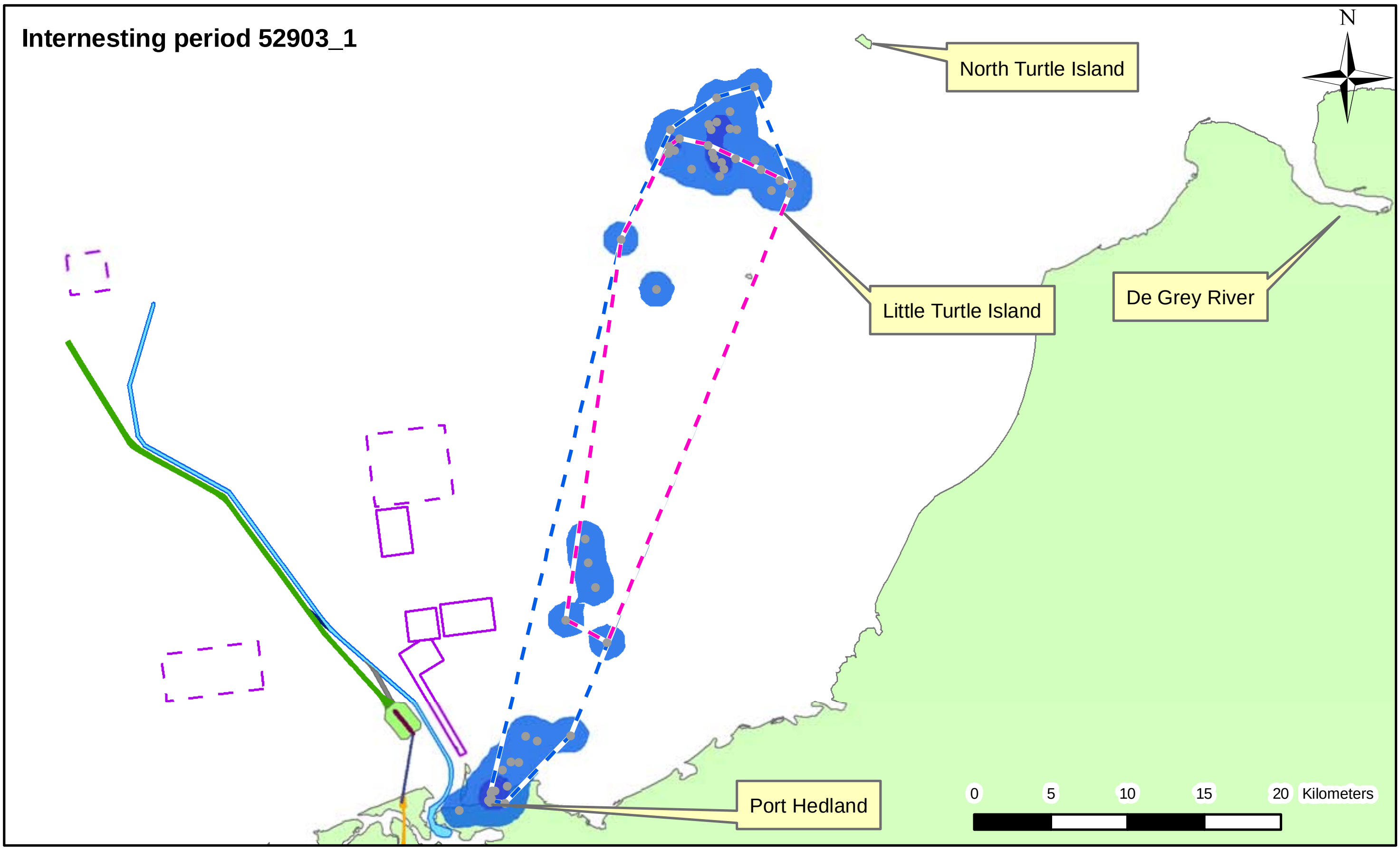
Legend

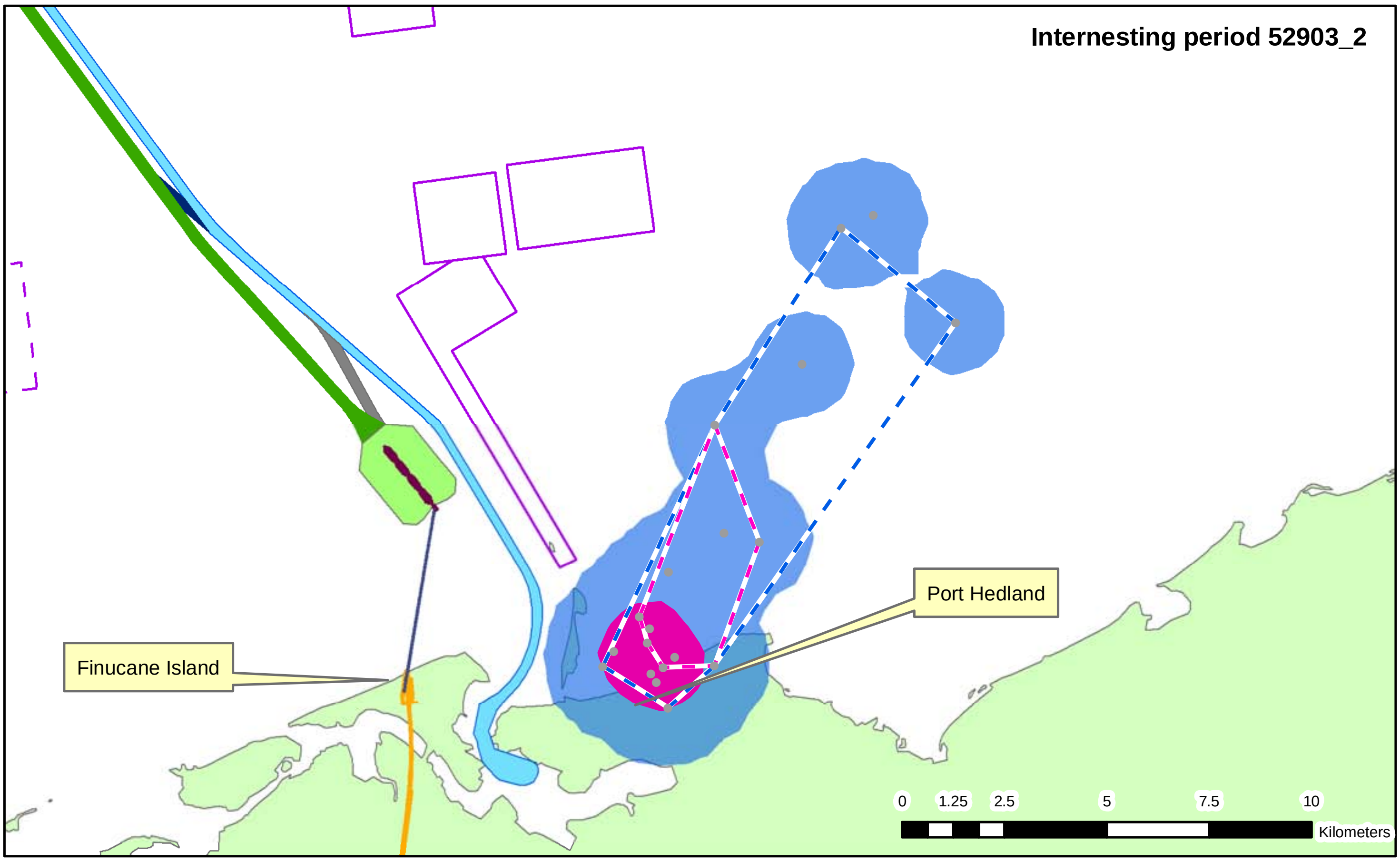
- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD

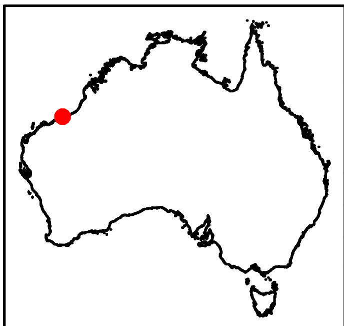
Existing and Proposed Infrastructure

- **Proposed Jetty**
- **Proposed Wharf**
- **Proposed Infrastructure Corridor**
- **Proposed Stockyards**
- **Spoil Ground (Existing)**
- **Spoil Ground (Proposed)**
- **Tug access channel**
- **Proposed Departure Channel**
- **Proposed Berth Pockets and Swing Basins**
- **Proposed Link Channel**
- **Proposed Crossover Channel**
- **Existing Shipping Channel**

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref: PENV-J22008-117-A				Rev. No. A







Project	J22008 Outer Harbour Development Port Hedland Satellite/TDR Study	
Title	Map C5: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52903 (based on unrestricted dataset)	
Drawn JEO	Date 25/05/10	Scale As shown
Checked PAW	Date 25/05/10	
Approved KLP	Date 25/05/10	
Drawing File Ref: PENV-J22008-118-A		Rev. No. A

Legend

- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD

Existing and Proposed Infrastructure

- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Tug access channel
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Proposed Crossover Channel
- Existing Shipping Channel

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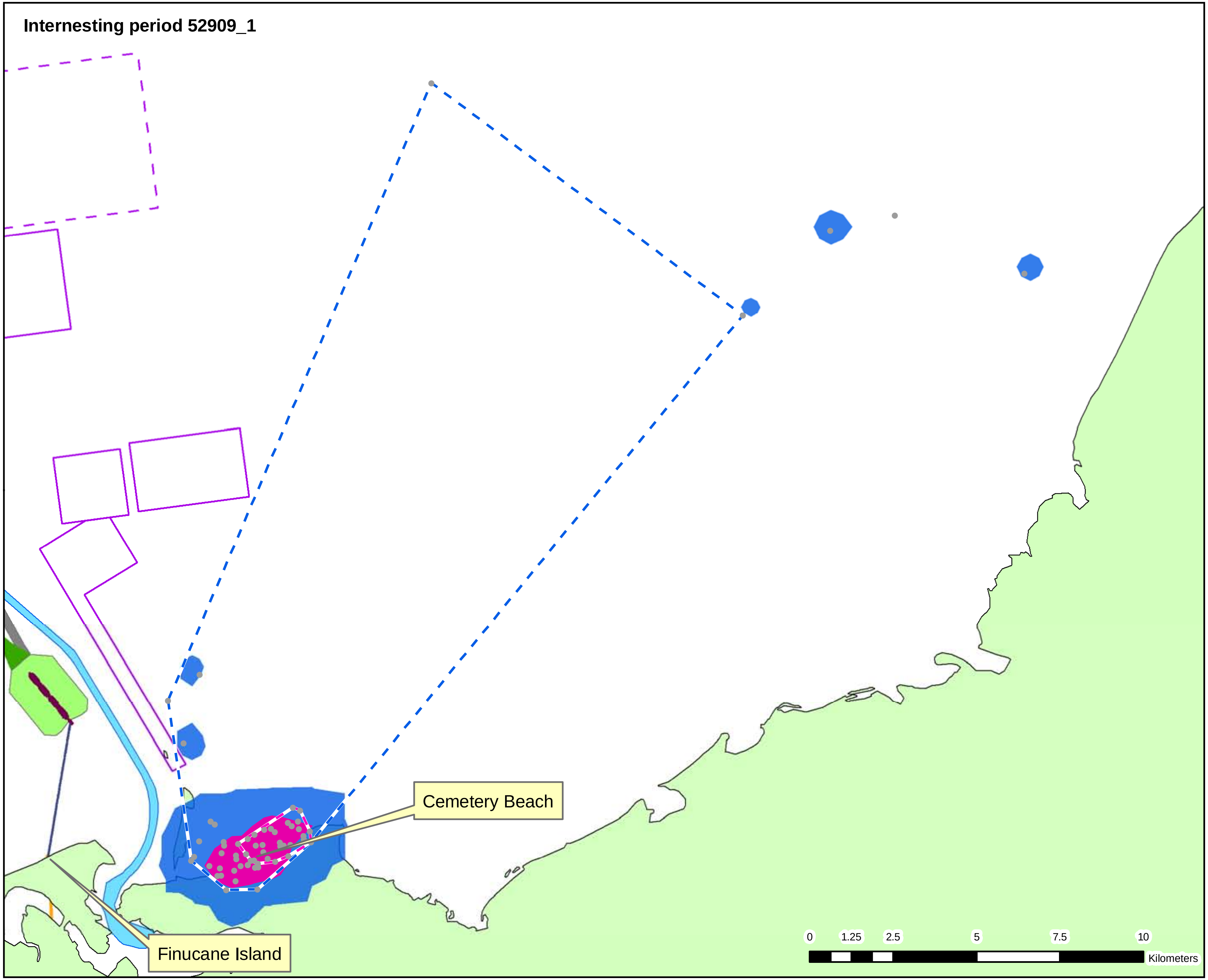

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Project
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Title
Map C6: Minimum Convex Polygon and Fixed Kernel Density home range areas for flatback turtle 52909 (based on unrestricted dataset)

Legend
- Internesting locations
- MCP 50% UD
- MCP 95% UD
- FKD 50% UD
- FKD 95% UD

Existing and Proposed Infrastructure
- **Proposed Jetty**
- **Proposed Wharf**
- **Proposed Infrastructure Corridor**
- **Proposed Stockyards**
- **Spoil Ground (Existing)**
- **Spoil Ground (Proposed)**
- **Tug access channel**
- **Proposed Departure Channel**
- **Proposed Berth Pockets and Swing Basins**
- **Proposed Link Channel**
- **Proposed Crossover Channel**
- **Existing Shipping Channel**

Drawn	JEO	Date	25/05/10	Scale: As shown
Checked	PAW	Date	25/05/10	
Approved	KLP	Date	25/05/10	
Drawing File Ref:	PENV-J22008-119-A			Rev. No. A

Appendix D: Dive depth histogram profiles for individual flatback turtles during internesting

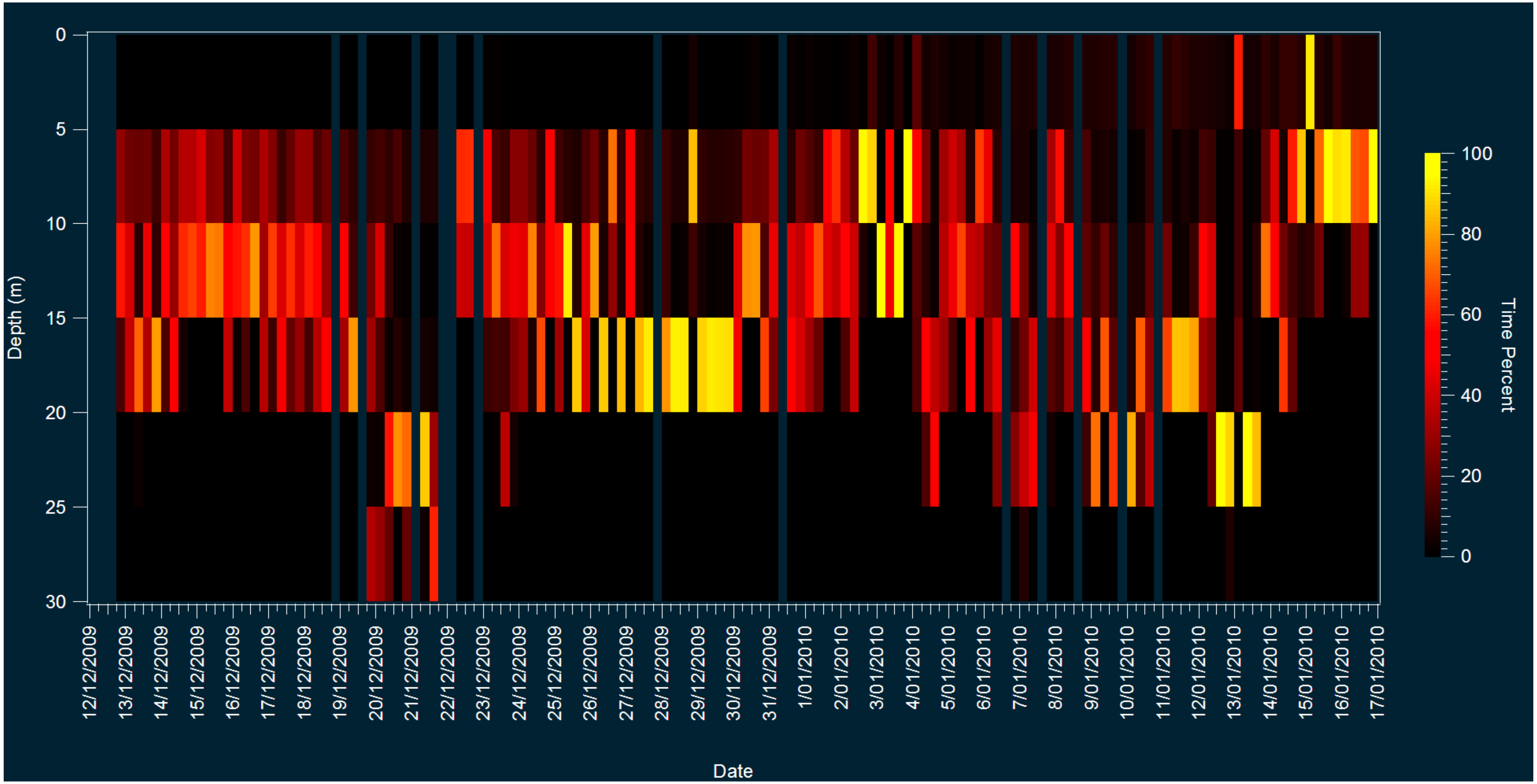

Figure D1: Dive depth histogram profile for flatback turtle 52895 during internesting.

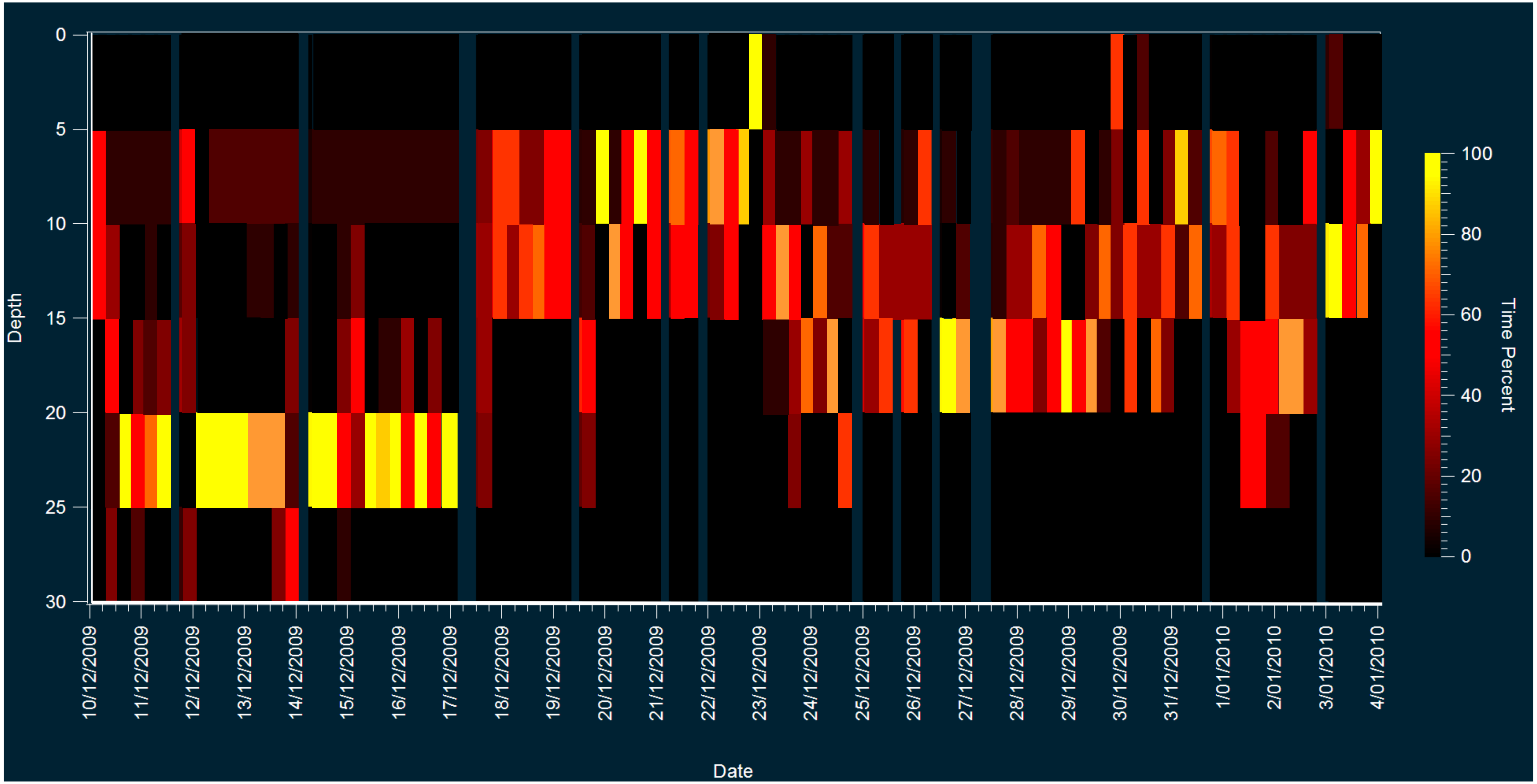

Figure D2: Dive depth histogram profile for flatback turtle 52896 during internesting.

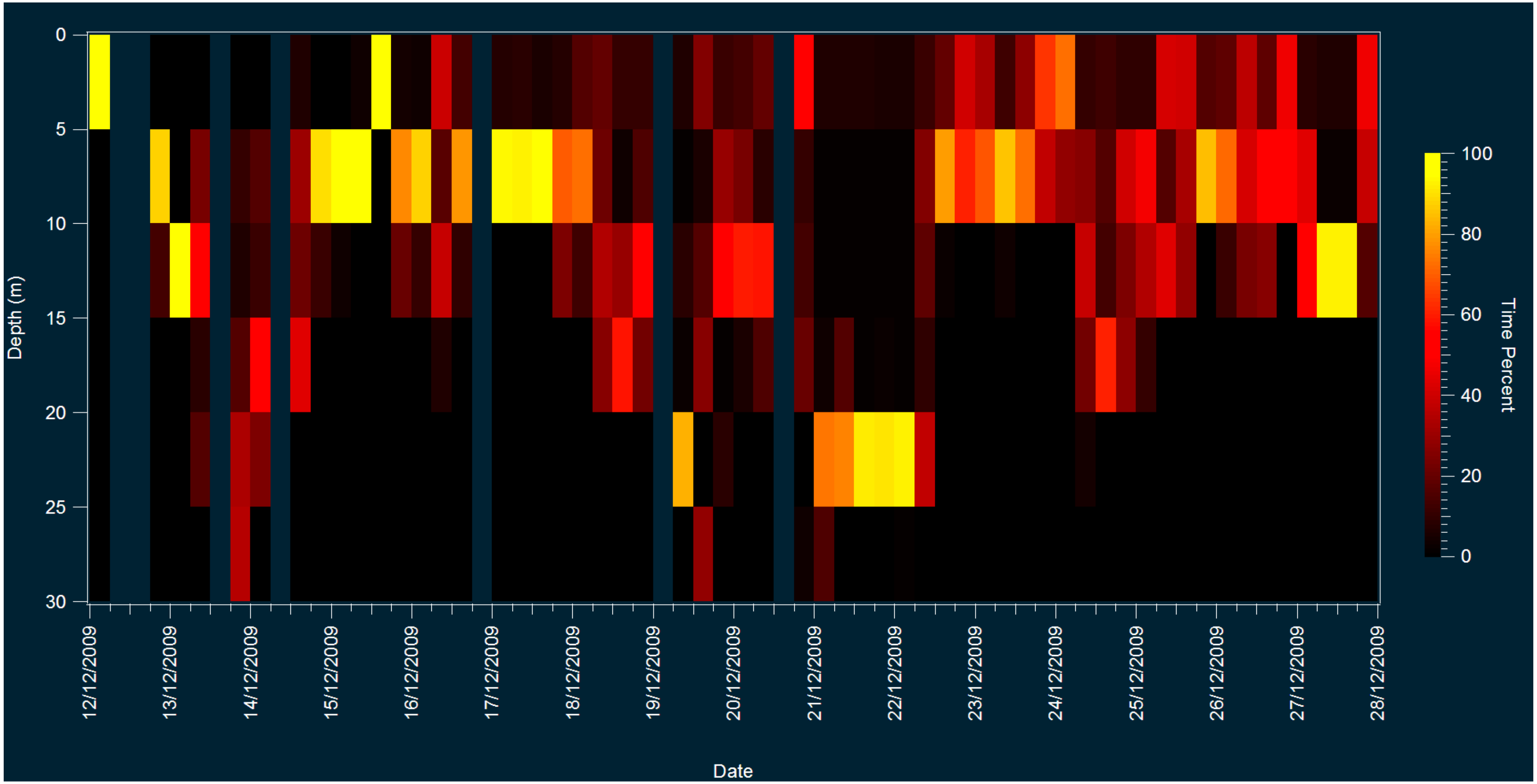

Figure D3: Dive depth histogram profile for flatback turtle 52897 during internesting.

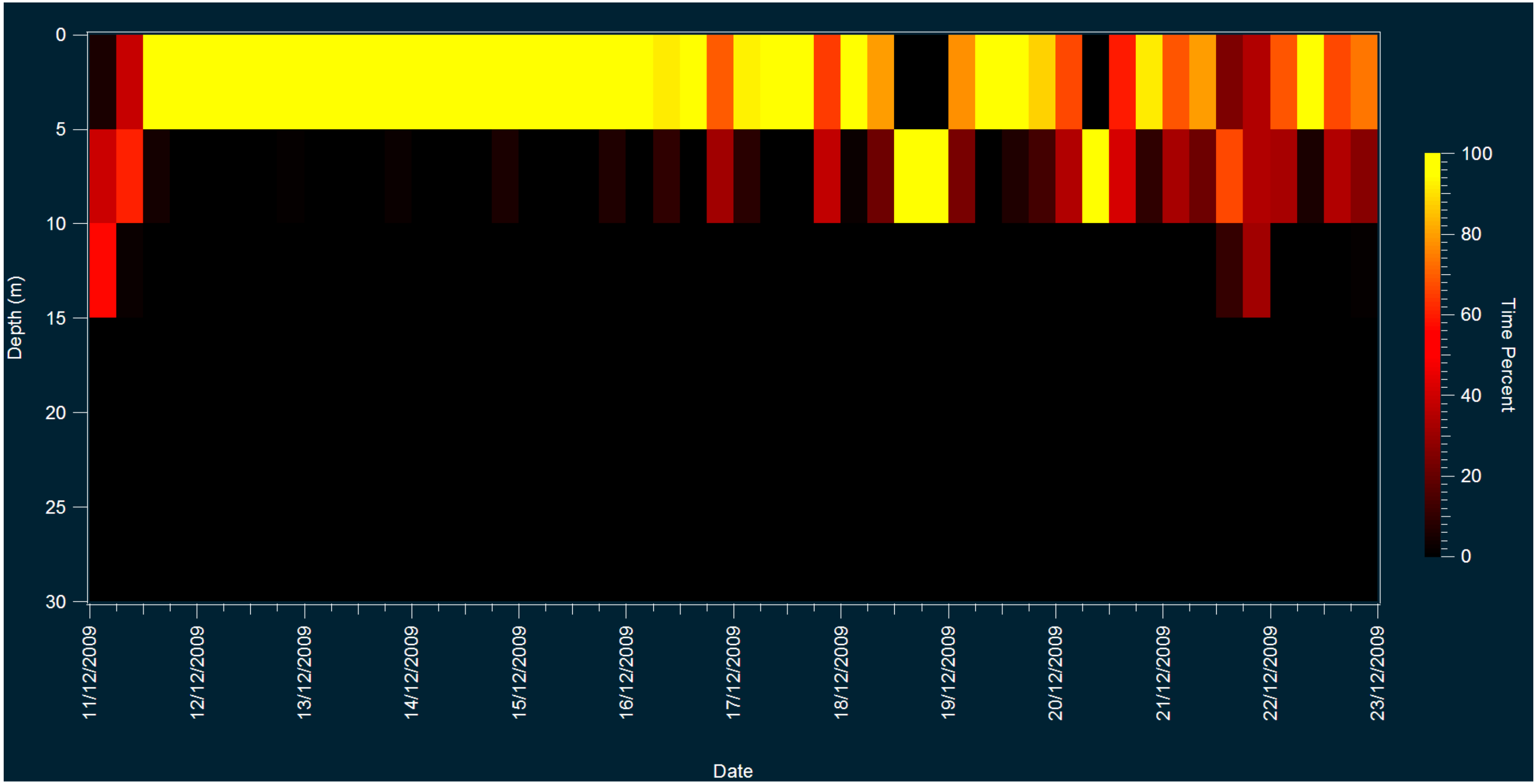

Figure D4: Dive depth histogram profile for flatback turtle 52900 during internesting.

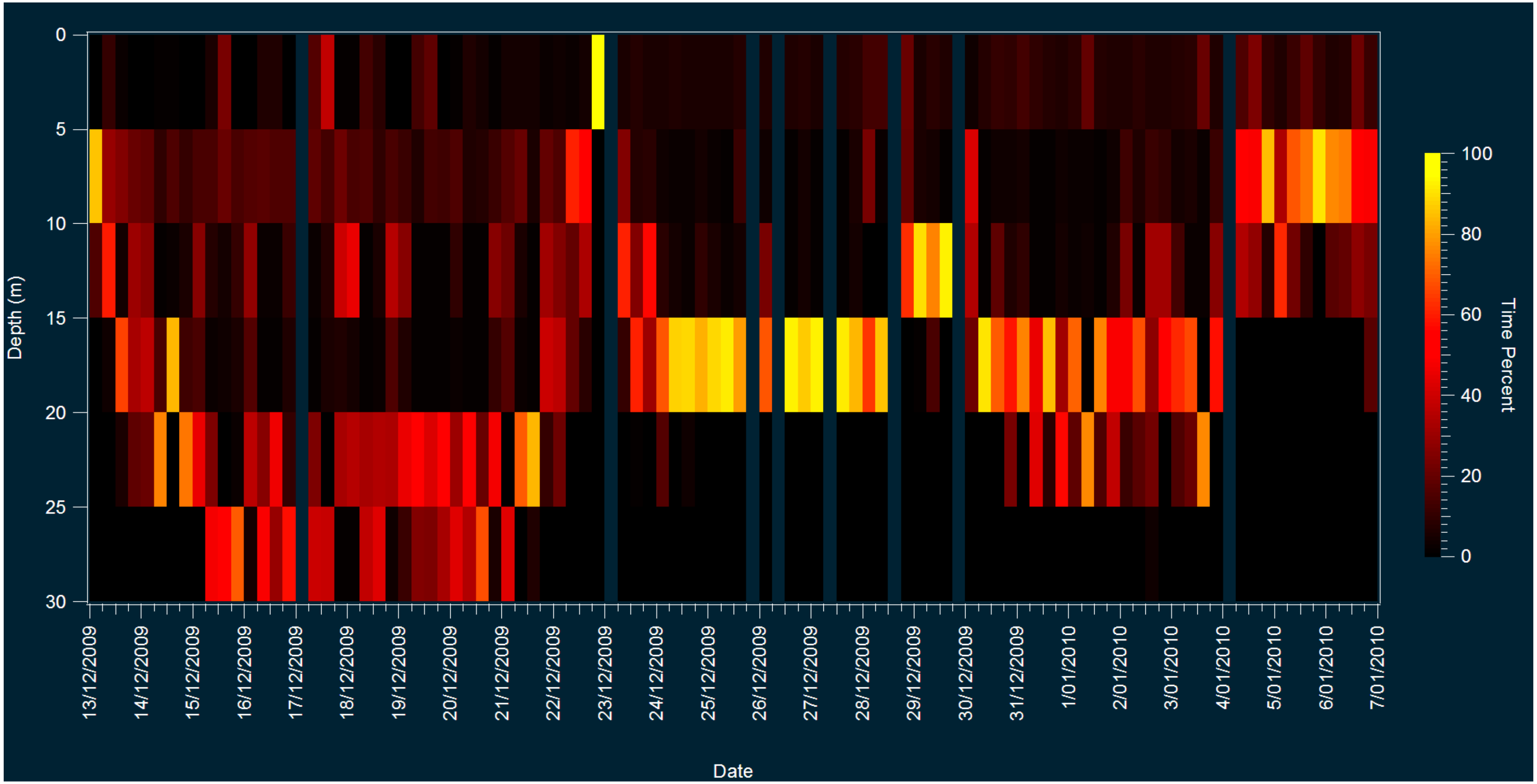

Figure D5: Dive depth histogram profile for flatback turtle 52903 during internesting.

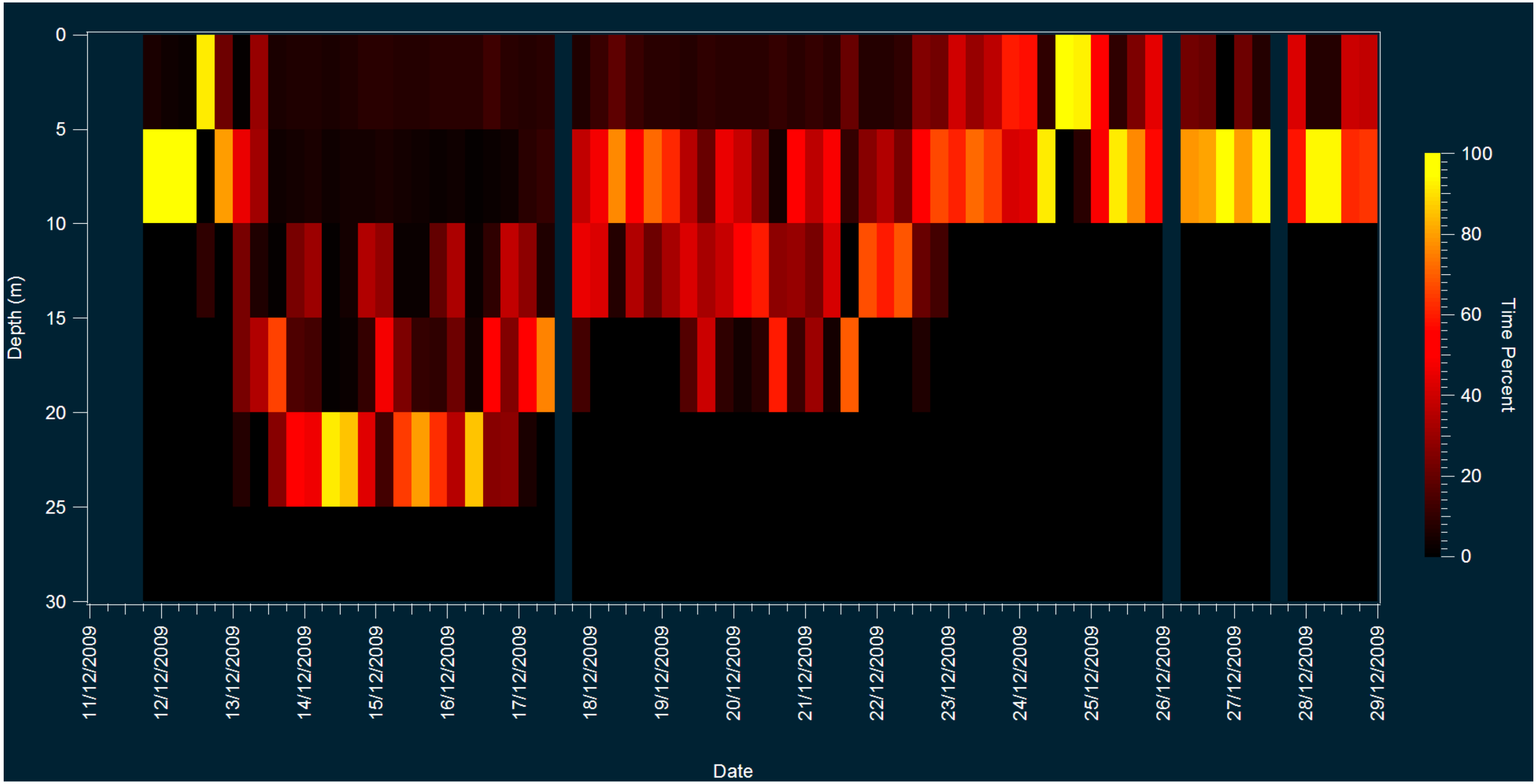

Figure D6: Dive depth histogram profile for flatback turtle 52909 during internesting.