RTA WEIPA PTY LTD

AMRUN PROJECT: MARINE TURTLE NEST MONITORING SURVEY SEPTEMBER 2019

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For

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7 August 2020

DOCUMENT CONTROL INFORMATION

TITLE: AMRUN PROJECT: MARINE TURTLE NEST MONITORING SURVEY SEPTEMBER 2019

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Document History

Revision	Description	Date received	Date issued	Personnel
	Report Draft		10/02/2020	P. Whittock
Draft	Internal Review	11/02/2020	19/02/2020	K. Pendoley
Rev A	Client review	19/02/2020	24/02/2020	L. Wells
Rev B	Address Client Comments	24/02/2020	28/05/2020	P. Whittock
Rev 0	Finalised	07/08/2020		P. Whittock

Printed:	7 August 2020
Last saved:	7 August 2020 01:07 PM
File name:	P:\06 Projects\J51 Rio\2019 Amrun\05 Programs\J51004 Amrun Turtle Monitoring\02 Technical Reports\J51004 Amrun Marine Turtle Nesting Surveys 2019_Rev0.docx
Author:	Paul Whittock
Project manager:	Paul Whittock
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Amrun Project Marine Turtle Nesting Surveys
Client	RTA Weipa Pty Ltd
Client representative:	Linda Wells
Report number:	J51004
Cover photos:	Measuring track/plastron width (credit: P. Whittock)

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Acronyms and Abbreviations

AEC	Animal Ethics Committee
DAF	Queensland Department of Agriculture and Fisheries
DEHP	Department of Environment and Heritage Protection
EPBC	Environmental Protection and Biodiversity Conservation Act
FCA	False-crawl attempt
FCU	False-crawl U-turn
HSEQ	Health, Safety, Environment and Quality
JSA	Job Safety Analysis
LSMP	Land and Sea Management Program
PALM	Permits and Licensing Management (Queensland)
PENV	Pendoley Environmental Pty Ltd
QTRP	Queensland Turtle Research Project
RTAW	RTA Weipa Pty Ltd
SOP	Standard Operating Procedure
TO	Traditional Owner

1 SURVEY BACKGROUND, OBJECTIVES AND METHODS

1.1 Survey Background and Objectives

This survey has been designed to address marine turtle nest monitoring commitments within the RTA Weipa Pty Ltd (RTAW) Marine Turtle Offset Plan (referred to herein as the 'Plan') and a Feral Pig Management Offset Strategy (referred to herein as the 'Strategy'). The commitments within the Plan and Strategy are in accordance with Condition (J42) (b) of the RTAW Environmental Authority (EA) No. EPML00725113, and Condition 45 of the RTAW Environmental Protection and Biodiversity Conservation Act (EPBC Act) Approval (EPBC 2010/5642), respectively. The execution of the survey was in alignment with EA Condition (J43) and EPBC Act Approval Condition 44, which requires that the Plan, and the Strategy, are implemented.

The Plan and Strategy were designed to reduce feral pig predation on marine turtle nests, thereby increasing hatchling survivorship. Both the Plan and the Strategy therefore commit to annual monitoring of marine turtle nests to detect variation in nest predation rates by feral pigs.

The primary objective of this marine turtle nesting survey was therefore to obtain sufficient data to detect long-term trends in nest predation rates by feral pigs.

1.2 Survey Design and Methods: Marine Turtle Nesting

To ensure the objective was met and for consistency with the baseline survey, survey design was per Guinea (2014). Survey approach was based on the relevant Pendoley Environmental (PENV) Standard Operating Procedures (SOP; Pendoley Environmental 2016, 2016a, 2016b, 2016c, 2017). Variation from methods detailed in the SOPs and those detailed herein were allowed to facilitate collection of additional data to meet specific scope requirements and to aid comparison with previous seasons. Further modifications were incorporated to ensure data collection methods and data recording aligned with those of the Department of Environment and Heritage (DEHP) Queensland Turtle Research Project (QTRP). Modifications since 2016 have been limited to only those that would substantially enhance either data quality or collection efficiency, or both.

1.2.1 Survey Area

In each survey season, all known marine turtle nesting habitat in proximity to the Amrun project was assessed (Guinea 2014). The survey area was divided into seven discrete survey beach sections and included all accessible nesting beaches between Winda Winda Creek in the north and Ina Creek to the south. The survey area is shown in **Figure 1** with detail on each surveyed beach section provided in **Table 1**. For a detailed description of the natural features and conditions at each survey beach section, see Guinea (2014).

The sections surveyed were consistent in all seasons, except for one section (Southern) that could not be accessed in 2019 due to a cultural area closure. The frequency of surveys on each section has also varied among seasons.

Figure 1: Survey area.
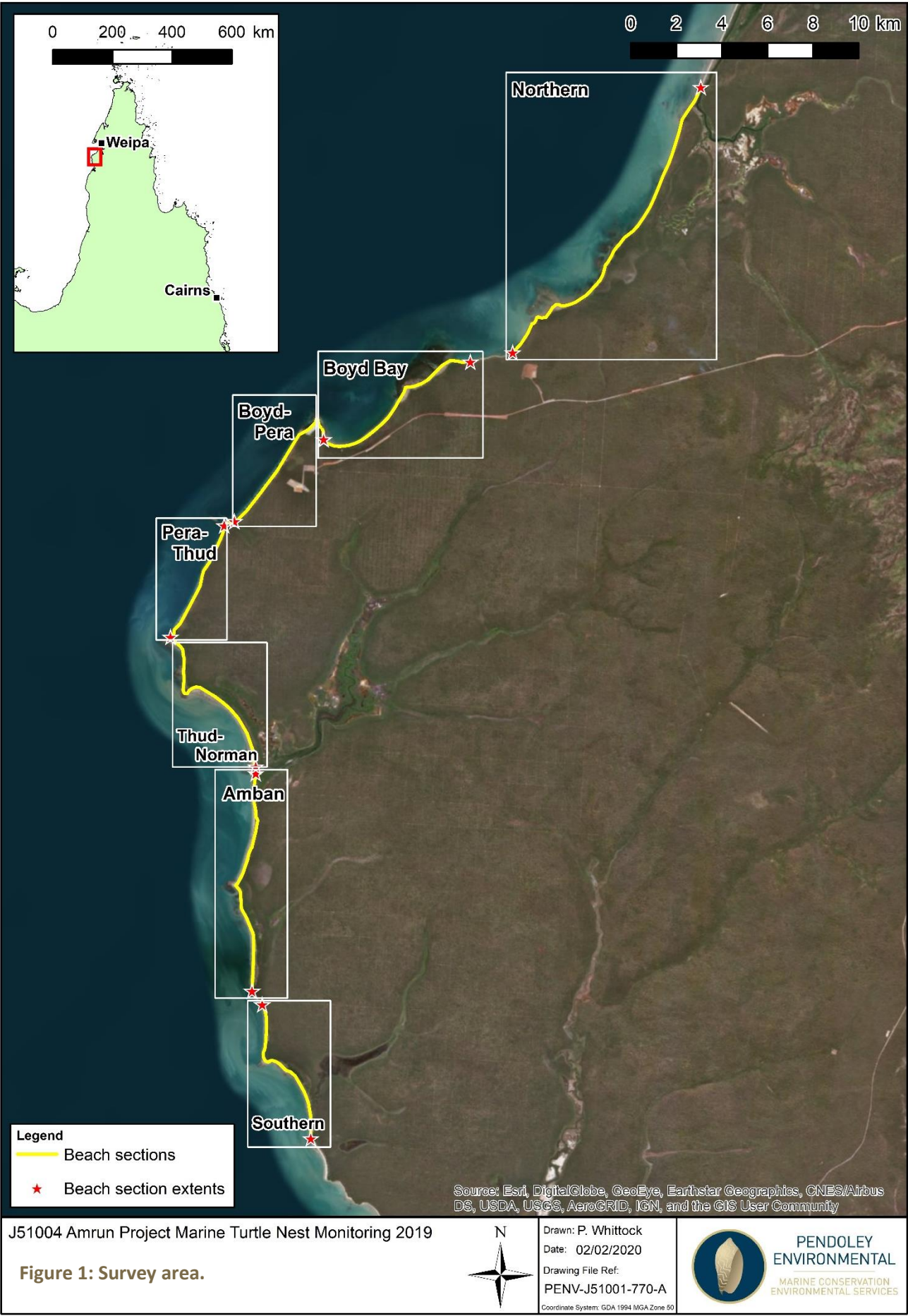
Table 1: Surveyed beach sections in September 2019. Notes: TO required: permission to access to this area only if a Traditional Owner (TO) is present; *high tide restricts access to the northern end of this section.

Beach Section		Section Access	
Name	Length (km)	Tidal Phase	Permission
Northern	14.5	Low-tide *	None required
Boyd Bay	9.2	Not restricted	TO required
Boyd – Pera	6.5	Not restricted	TO required
Pera – Thud	6.0	Not restricted	TO required
Thud – Norman	7.3	Not restricted	None required
Amban	9.5	Low-tide	None required
Southern	5.1	Low-tide	None required

1.2.1   Species Identification

Species identification was primarily via assessment of track and nest morphology. Track width (mm) and plastron width (mm) were measured using a straight ruler (Lufkin 1000 mm). Each event was assigned to species using a combination of information supplied in the Queensland Government Environmental Protection Agency/Queensland Parks and Wildlife Service 'Turtle Species Identification' and 'Adult Marine Turtle Track Identification' guides. In addition to this, field staff experienced in assessing track width and gait, position of the activity on the beach and where possible, assessment of nest morphology, was utilised.

1.2.2   Nesting Activity

During daytime track surveys, all observed nesting activity was recorded and where possible, assigned to species.

The position of each activity relative to the beach profile was recorded as per the QTRP, as either:

- dune;
- slope;
- below slope (beach flat); or
- below mean high water mark.

Nesting activity was categorised as either:

- 'nest' including both nests and potential nests; or
- 'attempt', including:
    - 'false-crawl u-turn' (FCU) track only, no nesting attempt made; and
    - 'false-crawl attempt' (FCA) tracks associated with attempted nesting i.e. digging, but no nest mound or other signs of covering.

The proportion of all recorded nesting events (i.e. nests and attempts) that resulted in a successful nesting event (nest) is termed the 'nesting success rate'.

The specific location of each activity was recorded by documentation of GPS position. GPS of each activity was recorded at either:

- Nest: Taken at the nest site;

- FCA: Taken at the position of the first nesting attempt; or
- FCU: Taken at the highest point of the track on the beach i.e. greatest distance from the mean high-water mark in the direction of the dunes.

The presence of a clutch of eggs within a nest can only be confirmed by sighting the eggs. In these surveys, eggs were sighted and nesting confirmed when either:

- the turtle was observed laying; or
- egg shells were seen scattered at the sand surface.

Where the turtle was not observed laying and no egg shells were seen at the surface of the sand (due to predation or turtle disturbance), the disturbed area was carefully assessed to infer behaviour. Where it was concluded that the turtle had most likely laid, a 'potential nest' was recorded. For the purpose of analysis, once categorised, a potential nest was treated in the same group as a nest, but for accuracy, could not be recorded as a confirmed nest.

1.3   Survey Design and Methods: Predator Activity and Predation

Predator species were identified by careful study of tracks and traces left in the sand, at and around the nest area. Where field cameras were installed at the nest site and captured images of a predation event, species was identified from review of images. Where activity could not be assigned to species, the event was assigned to the category 'unidentified'.

1.3.1   Daytime Beach Surveys

During daytime beach surveys, observations of predator behaviour were derived from observed indicators of predator activity. Indicators included tracks and traces of predator species that overlapped with signs of turtle activity and observations of egg shells scattered on the surface of the sand. Each indicator was then assigned to one of three predator behaviour categories:

- Indicator: Tracks; behaviour: predator activity ('tracks');
- Indicator: Digging; behaviour: predation or attempted predation ('digging'); and
- Indicator: Shells/remains; behaviour: confirmed predation, egg shells are scattered at the surface of the sand ('shells', 'remains').

The location of each indicator ('tracks' and/or 'digging') was recorded relative to the position of the turtle nesting activity and was categorised as either:

- Nest: On or over the turtle nest;
- Tracks: Along the turtle tracks; or
- Nearby: In the area but not associated with the turtle nesting activity.

1.3.1.1   Hatched nests

Hatched nests were identified by either a small cone-shaped depression in the sand or observation of hatchling tracks which were followed to locate the emergence point, or clutch location.

1.3.1.2   Incubation success

Where the clutch of a hatched nest could be located, the area was excavated and the clutch contents assessed to identify the nesting species, gather hatchling morphometric data (Straight Carapace Length (SCL): +/- 1.0 mm; mass: +/- 0.1 g) and determine hatch and emergence success (%) rates (Pendoley Environmental 2016c).

1.3.1.3   Hatchling orientation

Where hatchling tracks were visible, hatchling sea-finding orientation was recorded to measure hatchling dispersal patterns on the beach immediately following emergence from the clutch as hatchlings orient toward the ocean (Pendoley Environmental 2016a). Hatchling tracks are not persistent in sand over time and detection was limited to hatching events that occurred during the night preceding the survey.

1.3.2   24-hour Monitoring: Field Cameras

To monitor for predation and predator activity, motion sensitive field cameras (Reconyx PC900) were deployed at either a. freshly laid 'potential' nests where no previous predation or predator activity was observed or b. confirmed nests where laying was observed and eggs were sighted.

Field cameras were positioned approximately one meter behind the known or estimated location of the clutch. A 'clutch' being the term for the group of eggs, which are located within the nest mound, which is substantially larger and is comprised of sand. Where nesting was not observed, the estimated clutch location was determined by examination of track/nest morphology and inferred nesting behaviour.

Field cameras were mounted on plastic poles approximately one meter above the sand surface using cable ties/bungee straps. Detection range was tested using the camera's 'Walk Test' function to ensure capture of activity within a 40° field of view and up to 30 m from the camera's location. Predator activity was captured when the motion sensor was triggered using either daylight or infra-red technology (at night).

The motion sensor function was set at high sensitivity, and camera function set to 'HyperFire' which recorded ten images each time the motion sensor was triggered, at a minimum rate of one image per second, with 'no delay' between triggers. Field cameras recorded the date, time, temperature, moon phase, and the number of the image/motion in the sequence (e.g. M1 – M10) each time the sensor was triggered.

At each deployment location, the survey team recorded the date, time, beach, GPS position (of the field camera and the clutch), beach position, distance of camera from clutch, position of camera in relation to the clutch, and nesting turtle species (Pendoley Environmental 2017).

Upon retrieval, where possible, the following information was extracted from images:

Predator activity:

- predator species identification;
- predator abundance (*n*);

- clutch location method (e.g. olfactory – sniffed out, other predator seen at nest site, turtle seen nesting, nest seen hatching);
- time of approach; and
- activity (predation attempt: scratch, sniff; predation success: dig, extract).

Predation:

- time first dig start/end;
- duration of predation event; and
- confirmed predation (i.e. number of eggs extracted and/or consumed).

1.3.3 Night-time Tagging Surveys

Nesting turtles were approached only when they had finished laying. One titanium flipper tag was attached to each of the front flippers (axial scale, closest to the body) as per Limpus (1971), Limpus et al. (1983), Pendoley Environmental (2016b) and with reference to the DEHP guidelines for Tagging and Measuring Turtles. Curved carapace length (CCL) were measured (+/- 1.0 mm) with a flexible fiberglass tape. All data were recorded as per Pendoley Environmental (2016b) and in compliance with the DEHP Queensland Turtle Research Project (QTRP) requirements (Limpus 2013). If the turtle nested, a sample of up to 10 eggs from each clutch were weighed (mass: +/- 0.1 g) and measured (diameter: +/- 0.1 mm).

1.3.4 Traditional Owner Engagement

Traditional Owners (TOs) from the Land and Sea Management Program (LSMP) accompanied the survey team, fulfilling support roles and receiving training pre-departure for the field and on-the-job training during daily surveys with PENV field staff. Following the demobilisation of the PENV field staff on 26th September, TOs continued monitoring beach sections for an additional five days to ensure the required field survey duration was met (i.e. 10 – 12 days).

1.4 Data Handling and Presentation

For meaningful comparison of findings among seasons, all data were collected and analysed in alignment with the approach detailed in the previous (baseline) survey report (Guinea 2014). All summary statistics presented within are given as mean ± standard deviation (StDev), (range, *n*). For a limited number of monitored parameters, a single tailed t-test was used to determine statistically significant variation among surveys.

1.4.1 Nesting Activity and Density

Total nesting activity includes both categories described in **Section 1.2.2.** i.e. 'nests' and 'attempts'.

On the initial survey days, assessment of all visible nesting activity provides a 'snapshot' of activity on the beach up to approximately two weeks prior to the survey. For accuracy and consistency with the baseline survey, the 'snapshot' data were excluded from analysis of nesting density. Nesting density, excluding the initial 'snapshot' days is referred to as overnight nesting density.

Consistent with the baseline survey, overnight nesting density was calculated by conversion of the number of overnight nests per km of surveyed beach over the duration of the survey. Survey duration

is defined as the number of nights between the first and last survey to assess overnight nesting activity on each beach section (inclusive) and is presented within as 'nests/km/night'. A single tailed t-test was used to determine significant variation in nesting density on all surveyed beach sections between baseline (2013), previous (2016, 2017,2018) and current (2019) surveys.

1.4.2   Species-specific Morphological Measurements

Individual turtle and track morphological measurements are given as mean ± StDev (range, *n*) for each parameter given.

1.4.3   Predation and Predator Activity

Rate of predation was analysed to determine the influence of three primary covariates: beach section, nesting turtle species, and predator species. The rate of predation is given as the proportion of all recorded nesting events (nests and potential nests) where predation was observed and included observations of previous (snapshot) and overnight nesting events. Observations that could not be assigned to species were included in estimates of predation rates.

1.5   Ethics Approval and Permit to Conduct Works

All works were conducted under, and in accordance with, the appropriate licenses issued by the DEHP, Permits and Licensing Management (PALM) Department License No. WA0001415 and with the approval of the relevant Animals Ethics Committee (AEC) (Department of Agriculture and Fisheries; DAF), Registered User No. 505, Approval Reference No. CA2016/08/996.

1.6   Survey Schedule

Survey scheduling was successfully planned around a number of variables influencing survey timing, frequency and duration (including the impact of lunar phase and predicted tidal cycles on nesting activity and beach access), resource availability, and other logistical factors such as training and inductions. These variables were accounted for and did not impact survey success.

All factors with the potential to influence survey execution were broadly grouped into three categories:

Timing and duration:

- lunar phase;
- sunset and sunrise times;
- beach length;
- travel time to each beach section; and
- level of activity at each beach section.

Accessibility:

- natural hazards (e.g. bushfire);
- cultural closures;
- access points and access tracks; and
- availability of traditional owners.

Available resources and safety considerations:

- logistical, resource and personnel requirements;
- safety at night; and
- fatigue management requirements.

1.7   Limitations

On occasion, the following limitations to data collection were noted:

- marine turtle and predator abundance and species identification were constrained by high winds and/or rain erasing tracks; and/ or
- marine turtle abundance and species identification was constrained by predator activity or predation, which obliterated the required detail.

2 RESULTS

2.1 Survey Timing, Schedule and Effort

Survey timing (13th – 30th September 2019) fell within the peak nesting period for this region (August/September; Guinea 2014).

2.1.1 Daytime Beach Surveys

Due to limited vehicle availability, the survey team was delayed in completing the initial snapshot survey of each beach section (completed between the 13th and 19th September). Therefore, to ensure a 10 – 12 day survey duration at each beach section, the survey was extended from the 26th to 30th September. Overnight nesting was assessed on each visit to each beach section on each census day.

It was not possible to survey all beach sections on each survey day (see **Section 1.6**). Furthermore, in this 2019 survey, Southern beach section was not accessible for the duration of the survey due to a cultural areas closure and was therefore not monitored. Survey duration varied among beach sections from 0 (Southern) to 14 (Boyd-Pera) days (**Table 2**). Mean survey duration (all sections) was 10.1 days. Mean survey duration (excluding Southern) was 11.8 days.

2.1.2 Night-time Tagging Surveys

The night-time tagging survey focused on nesting habitat from Boyd Point to Pera Head (Boyd – Pera) consistent with all previous (baseline (2013), 2016, 2017, and 2018) surveys (**Figure 1**). Survey effort ranged from one to two teams of either two or three field staff per team. This included one PENV field staff as a minimum, and either one or two LSMP staff. The total number of tagging nights in 2019 was six (**Table 2**).

2.2 Marine Turtle Nesting Activity

'Snapshot' survey days on each beach section were: Boyd-Pera: day one; Boyd Bay: day two; Pera – Thud: day four; Amban, Thud – Norman: day six; Northern: day seven. Generally, nesting activity recorded on 'snapshot' survey days showed potentially higher numbers of nests (**Table 3**) and false-crawls (**Table 4**) in previous weeks than overnight activity that was recorded during the remainder of the survey period. The exceptions were at those beach sections that had been monitored by the LSMP survey team prior to the commencement of this field survey, including Boyd Bay, Boyd-Pera, and Thud-Norman (**Tables 3** and **4**). There was little variation in the number of overnight nests laid on each beach section throughout the survey period.

The rate of overnight nesting success for all turtle species on the monitored beach sections (*n* = 6) was 38%. The rate of overnight nesting success on each beach ranged from 30% on Pera-Thud to 78% on Thud-Norman.

Table 2: Survey schedule for daytime track and night-time tagging surveys undertaken in September 2019. Notes: Trk: daytime beach survey; Tag: night-time tagging survey; Visits: total number of occasions on which the beach was visited; Days: Survey duration i.e. total number of days from the first to the last visit.

Survey Team	Survey Day	Northern	Boyd Bay	Boyd – Pera	Pera – Thud	Thud – Norm.	Amban	Southern
PENV + LSMP	1	-	-	Trk	-	-	-	Not accessible due to a cultural closure
	2	-	Trk	-	-	-	-	
	3	-	-	-	Trk	-	-	
	4	-	-	-	-	-	-	
	5	-	Trk	-	-	-	-	
	6	-	-	-	-	Trk	Trk	
	7	Trk	-	-	-	-	-	
	8	Trk	Trk	Tag	Trk	-	-	
	9	-	Trk	Tag	Trk	Trk	-	
	10	-	Trk	Tag/Trk	-	Trk	-	
	11	Trk	Trk	Tag	-	-	Trk	
	12	-	Trk	Tag/Trk	Trk	Trk	-	
	13	Trk	Trk	Tag/Trk	Trk	Trk	-	
LSMP	14	-	-	-	-	-	-	
	15	-	-	Trk	-	-	-	
	16	Trk	-	-	Trk	-	-	
	17	-	-	-	-	Trk	Trk	
	18	Trk	-	-	-	-	-	
Visits		6	8	8	6	6	3	0
Days		11	11	14	13	11	11	0

Table 3: Total nests (confirmed and potential) recorded on each beach section on each survey day in September 2019. Notes: 'Nests' includes nests and potential nests, combined; Total Activity o/n: Total overnight activity which therefore excludes data captured on the initial 'snapshot' survey day; Total Activity All: Total of all activity recorded on each surveyed section, including snapshot day. Grey cells indicate snapshot day.

Survey Team	Survey Day	Northern	Boyd Bay	Boyd – Pera	Pera – Thud	Thud – Norm.	Amban	Southern	Total
PENV + LSMP	1	-	-	1	-	-	-	Not accessible due to a cultural area closure	1
	2	-	1	-	-	-	-		1
	3	-	-	-	25	-	-		25
	4	-	-	-	-	-	-		0
	5	-	0	-	-	-	-		0
	6	-	-	-	-	2	6		8
	7	24	-	-	-	-	-		24
	8	1	0	2	1	-	-		4
	9	-	0	1	0	1	-		2
	10	-	0	1	-	1	-		2
	11	0	0	0	-	-	0		0
	12	-	0	0	1	0	-		1
	13	0	0	1	0	3	-		4
LSMP	14	-	-	-	-	-	-		0
	15	-	-	1	-	-	-		1
	16	1	-	-	1	-	-		2
	17	-	-	-	-	0	0		0
	18	0	-	-	-	-	-		0
Total Activity	o/n	2	0	6	3	5	0	NA	16
	All	26	1	7	28	7	6	NA	75

Table 4: Total nesting attempts (FCA and FCU) recorded on each beach section on each survey day in September 2019. Notes: 'Nesting Attempts' includes both FCU and FCA combined; Total Activity o/n: Total overnight activity which therefore excludes data captured on the initial 'snapshot' survey day; Total Activity All: Total of all activity recorded on each surveyed section, including snapshot day. Grey cells indicate snapshot day.

Survey Team	Survey Day	Northern	Boyd Bay	Boyd – Pera	Pera - Thud	Thud – Norm.	Amban	Southern	Total
PENV + LSMP	1	-	-	2	-	-	-	Not accessible due to a cultural area closure	2
	2	-	1	-	-	-	-		1
	3	-	-	-	47	-	-		47
	4	-	-	-	-	-	-		0
	5	-	0	-	-	-	-		0
	6	-	-	-	-	1	3		4
	7	7	-	-	-	-	-		7
	8	0	1	1	8	-	-		10
	9	-	0	1	3	0	-		4
	10	-	0	0	-	1	-		1
	11	1	0	0	-	-	0		1
	12	-	0	0	9	0	-		9
	13	0	0	1	0	0	-		1
LSMP	14	-	-	-	-	-	-		0
	15	-	-	0	-	-	-		0
	16	0	-	-	0	-	-		0
	17	-	-	-	-	0	0		0
	18	0	-	-	-	-	-		0
Total Activity	**o/n**	1	1	3	20	1	0	NA	26
	All	8	2	5	67	2	3	NA	87

2.3   Marine Turtle Nesting Density

Overnight nesting density (nests/km/night) in 2019 was highest at Boyd-Pera and lowest at Amban and Boyd Bay (**Table 5**).

Table 5: Total overnight nests and nesting density on each surveyed beach section in September 2019.

Beach Section	Overnight Nests	Survey Nights	Beach Length (km)	Nesting Density (nests/km)	Overnight Nesting Density (nests/km/night)
Northern	2	11	14.5	0.14	0.01
Boyd Bay	0	11	9.2	0.00	0.00
Boyd – Pera	6	14	6.5	0.92	0.07
Pera – Thud	3	13	6.0	0.50	0.04
Thud – Norm.	5	11	7.3	0.68	0.06
Amban	0	11	9.5	0.00	0.00
Southern	NA	NA	NA	NA	NA
(Total) Mean	(16)	11.5	(53.0)	0.37	0.03

Compared to the 2018 survey, overnight nesting density in 2019 was lower on all beach sections. Compared to baseline, overnight nesting density in 2019 was lower at all beach sections (**Table 6**).

On all monitored beach sections combined, overnight nesting density (nests/km/night) in 2019 was 0.03 ± 0.03 (range = 0.00 – 0.07, *n* = 6) which was lower than in all previous survey seasons (adjusted

for the same six beach sections monitored in 2019; 2018: 0.06 ± 0.05, 0.01 − 0.14; 2017: 0.08 ± 0.09, 0.00 − 0.20; 2016: 0.07 ± 0.04, 0.02 − 0.13; 2013 (baseline): 0.25 ± 0.16, 0.02 − 0.50, n = 6). The difference in mean overnight nesting density (nests/km/night) between 2019 and 2018 was not significant, however mean overnight nesting density (nests/km/night) in 2018 was significantly lower compared to 2013 ($p < 0.05$, U = 3) (**Table 6**).

Table 6: Variation in overnight nesting density in 2019 compared to 2018, 2017, 2016 and 2013 (baseline). Notes: Annual Mean: average nesting density; Annual Mean (v): numbers in brackets denote average variation between surveys.

Beach Section	Nests/km/night					Annual Variation	
	2019	**2018**	**2017**	**2016**	**2013**	**2019 v 2018**	**2019 v 2013**
Northern	0.01	0.03	0.01	0.05	0.23	-0.02	-0.22
Boyd Bay	0.00	0.01	0.00	0.10	0.02	-0.01	-0.02
Boyd – Pera	0.07	0.14	0.18	0.13	0.29	-0.07	-0.22
Pera – Thud	0.04	0.12	0.20	0.02	0.19	-0.08	-0.15
Thud – Norman	0.06	0.05	0.10	0.03	0.50	0.01	-0.44
Amban	0.00	0.02	0.00	0.07	0.26	-0.02	-0.26
Southern	NA	NA	NA	NA	NA	NA	NA
***Annual Mean (v)**	0.03	0.06	0.08	0.07	0.25	(-0.03)	(-0.22)

2.4 Species-specific Nesting Activity

In total, 162 events were recorded. Of these, 151 were assigned to one of four species of nesting marine turtles: flatback (*Natator depressus*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*), and green (*Chelonia mydas*). A further 11 events were not assigned to species (**Table 7**). Of nests that were identified to species, 63% were flatback, 24% were hawksbill, 10% were olive ridley, and 3% were green turtle nests.

Among species, the rate of nesting success was highest for green turtles (100%) (note that only two nests were identified for this species). The next highest nesting success was for flatback turtles (64%). Olive ridley turtle nesting success was the lowest (24%; **Table 7**).

Table 7: Number of nests and nesting attempts recorded by each species on each beach section in September 2019.

Beach Section	Flatback		Hawksbill		Olive ridley		Green		Unidentified		Total		
	Nests	FCA/A	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	All
Northern	20	7	5	1	0	0	1	0	0	0	26	8	34
Boyd Bay	1	1	0	0	0	1	0	0	0	0	1	2	3
Boyd – Pera	4	2	2	1	1	2	0	0	0	0	7	5	12
Pera – Thud	13	14	7	30	4	19	0	0	4	4	28	67	95
Thud – Norman	6	1	0	1	0	0	1	0	0	0	7	2	9
Amban	0	0	3	1	2	0	0	0	1	2	6	3	9
Southern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	44	25	17	34	7	22	2	0	5	6	75	87	162
	69		51		29		2		11				
% all activity	42.6		31.5		17.9		1.2		6.8				

2.4.1 Species-specific Morphological Measurements

Flatback track and plastron widths were 703 ± 66 mm (range = 546 – 846 mm, *n* = 66) and 231 ± 48 mm (range = 61 – 346 mm, *n* = 68), respectively. Olive ridley track and plastron widths were 555 ± 82 mm (range = 437 – 767 mm, *n* = 26) and 201 ± 43 mm (range = 150 – 280 mm, *n* = 26), respectively. Hawksbill track and plastron widths were 627 ± 94 mm (range = 425 – 790, *n* = 43) and 175 ± 42 mm (range = 57 – 233 mm, *n* = 43), respectively. The two green turtle tracks had widths of 773 mm and 953 mm, and plastron widths of 160 mm and 233 mm.

2.5 Tagged Turtles

Two nesting turtles (one flatback and one hawksbill) were observed on Boyd-Pera beach section on two of the six tagging nights in 2019. Both turtles were new and had not been sighted in previous seasons.

2.5.1 Turtle QA74227

At 22:00 on 21st September, tag numbers QA74227 (left) and QA74228 (right) were applied to the front flippers of a previously untagged adult flatback turtle measuring 838 mm (CCL) following successful nesting. Mean egg mass was 60.3 ± 2.0 g (range = 57.8 – 62.4 g, *n* = 4) and diameter was 46.1 ± 1.8 mm (range = 43.7 – 47.6 g, *n* = 4).

2.5.2 Turtle QA74229

At 02:32 on 25th September, tag numbers QA74229 (left) and QA74230 (right) were applied to the front flippers of a previously untagged adult hawksbill turtle. There was damage to the rear carapace of the turtle and therefore a CCL measurement was not recorded.

2.6 Hatchling Orientation

A total of 14 clutches were recorded as hatching during the field survey (see **Appendix A** for location). Hatchling sea finding orientation was recorded for ten of the hatched clutches (flatback, *n* = 3; olive ridley, *n* = 1; green , *n* = 1; unknown, *n* = 5) on Northern (*n* = 1), Boyd-Pera (*n* = 4), and Pera-Thud (*n* = 5) beach sections (**Table 8**). Unfortunately, the hatchling sea finding orientation was recorded incorrectly for the clutch on Northern beach section and was therefore excluded from the dataset. Four of the hatched clutches were recorded with <5 hatchling tracks from the point of emergence and therefore hatchling sea finding orientation could not be recorded. The location and orientation metrics (i.e. spread and offset) of all assessed nests (*n* = 9) is shown in **Figure 2**.

Mean hatchling fan spread and offset was 38 ± 17° (range = 25 – 70°, *n* = 9) and 9 ± 9° (range = 5 – 31°, *n* = 9), respectively. The spread and offset values at all beaches were small, indicating that offshore or land-based sources of artificial light were not likely to be influencing hatchling orientation (**Table 8**). Furthermore, all hatchling tracks demonstrated that they were able to successfully locate the ocean.

Legend

Hatchling Sea Finding Orientation:

Spread

Offset

Point of Emergence

Northern

Boyd-Pera

Boyd-Pera

Pera-Thud

Boyd-Pera

Pera-Thud

0   5   10   15 km

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Figure 2: Location and orientation metrics (i.e. spread and offset) of all assessed nests (*n* = 9).

N

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Coordinate System: GDA 1994 MGA Zone 50

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Table 8: Hatchling sea-finding orientation recorded in September 2019. Notes: Spread°: the angle of maximum dispersion of each group of hatchlings as they leave the nest in search of the ocean; Offset°: the degree of deflection from the most direct path toward the ocean; Tracks: the number of hatchlings tracks leaving the nest.

Survey Day	Species	Beach Section	Spread°	Offset°	Tracks	Evidence of Predation
3	FB	Pera-Thud	61	31	20	None
5	FB	Pera-Thud	40	5	11	None
8	FB	Boyd-Pera	27	15	30	None
8	Unk	Pera-Thud	25	2	19	None
8	Unk	Boyd-Pera	31	6	11	None
9	Unk	Pera-Thud	28	6	45	None
10	Unk	Boyd-Pera	30	5	30	None
11	OR	Northern	70	5	30	None
12	Unk	Pera-Thud	27	6	41	None

2.7   Hatched Nests – Incubation Success

A total of eight nests (flatback = 5; hawksbill = 3) were excavated and the contents examined to confirm species and determine incubation success (hatch and emergence). The excavated nests were situated on Boyd-Pera (*n* = 1) and Pera-Thud (*n* = 7). For the flatback turtle nests, mean clutch size was 59 eggs (*n* = 5) and mean hatch and emergence success were 93.4% and 85.0%, respectively. For the hawksbill turtle nests, mean clutch size was 97 eggs (*n* = 3) and mean hatch and emergence success were 97.1% and 91.9%, respectively (**Table 9**). Note that hatchling sea finding orientation was recorded for three of the excavated nests, with three other excavated clutches featuring <5 hatchling tracks (thus preventing the recording of hatchling sea finding orientation).

None of the nests showed evidence of predation at the time of excavation. One live hatchling was encountered during excavation and, after being allowed to crawl across the sand and/or intertidal platform, was released to the ocean. The location of all excavated hatched nests is shown in **Appendix A**.

Table 9: Incubation success of excavated clutches in September 2019. Notes: Species: FB flatback; HK hawksbill.

Species	Beach Section	Hatched Eggs			Unhatched Eggs	Overall		
		Empty Shells	Hatchlings			Total Clutch Size	Success (%)	
			Live	Dead			Hatch	Emergence
HK	Pera-Thud	102	0	0	0	102	100.0	100.0
HK	Pera-Thud	112	0	16	1	113	99.1	85.0
HK	Pera-Thud	70	0	1	6	76	92.1	90.8
FB	Pera-Thud	65	0	0	1	66	98.5	98.5
FB	Pera-Thud	46	0	24	11	57	80.7	38.6
FB	Pera-Thud	55	0	0	1	56	98.2	98.2
FB	Pera-Thud	55	0	0	2	57	96.5	96.5
FB	Boyd-Pera	55	1	0	4	59	93.2	93.2

2.8   Predation and Predator Activity

The overall rate of predation of marine turtle nests was 45%, equal to 34 nests that were predated out of the 75 nests recorded. The rate of predation varied among beach sections (**Table 10**) and turtle species (**Table 11**) and ranged from 0% - 69% and 0% - 52%, respectively.

The rate of predation of marine turtle nests varied between those sighted overnight (1 of 16 nests were predated; predation rate = 6 %) and those recorded during the snapshot (33 of 59 nests were predated; predation rate = 56 %) (**Table 10**). The one predated overnight nest was caused by feral pig (*Sus scrofa*) indicating a low predation rate of fresh nests during the field survey.

The overall feral pig nest predation rate was 29% (22 of 75 nests were predated by pig). This was a lower percentage when compared to each previous season (2016 = 58 of 110 nests (53%); 2017 = 65 of 124 nest (52%); 2018 = 51 of 98 nests (52%); **Table 12**).

Out of all nests that were predated (*n* = 34), the feral pig predation rate was 65% (*n* = 22), goanna (gen. Varanus) predation rate was 32 % (*n* = 11), and the rate of predation by unidentified predator species was 3% (*n* = 1).

Figure 3 shows the number and proportion of predated nests on each beach section. **Table 12** provides summary of nest predation on each section by each predator species. **Appendix A** shows the location of predation events on each beach section.

2.8.1   Predation

The rate of predation in 2019 (all predator species) was highest on Northern beach section (69%). Of the 24 nests found during the snapshot survey on Northern, 18 were predated. The next highest rate of nest predation was on Amban beach section (67%) where 4 of 6 nests found during the snapshot survey, were predated (**Figure 3**; **Table 10**).

Compared to 2018, the rate of predation in 2019 was lower on all beach sections except at the Northern and Amban beach sections. Overall, the annual rate of predation in 2019 was lower compared to all previous surveys (adjusted to exclude Southern beach section: 2016: 64%; 2017: 60%; 2018: 60%; **Table 10**).

Among nesting events that were assigned to species, the rate of predation in 2019 was highest in flatback turtle nests (52%). The rate of predation for each turtle species was lower when compared to all previous surveys (**Table 11**).

The predation rate was lower for fresh overnight nests (1 of 16 nests were predated; 6%) when compared to the predation rate of nests recorded at snapshot (33 of 59 nests were predated; 56%) (**Table 10**).

Figure 3: Number of nests and predated nests on each beach section in 2019.

Overview - Predation

Legend
Number of events (*n*)   **Number predated (*n*)**

Northern (69%)
18 of 26 nests

Boyd Bay (0%)
0 of 1 nests

Boyd-Pera (14%)
1 of 7 nests

Pera-Thud (32%)
9 of 28 nests

Thud-Norman (29%)
2 of 7 nests

Amban (67%)
4 of 6 nests

Southern
Not Monitored

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Figure 3: Number of nests and predated nests on each beach section in 2019.

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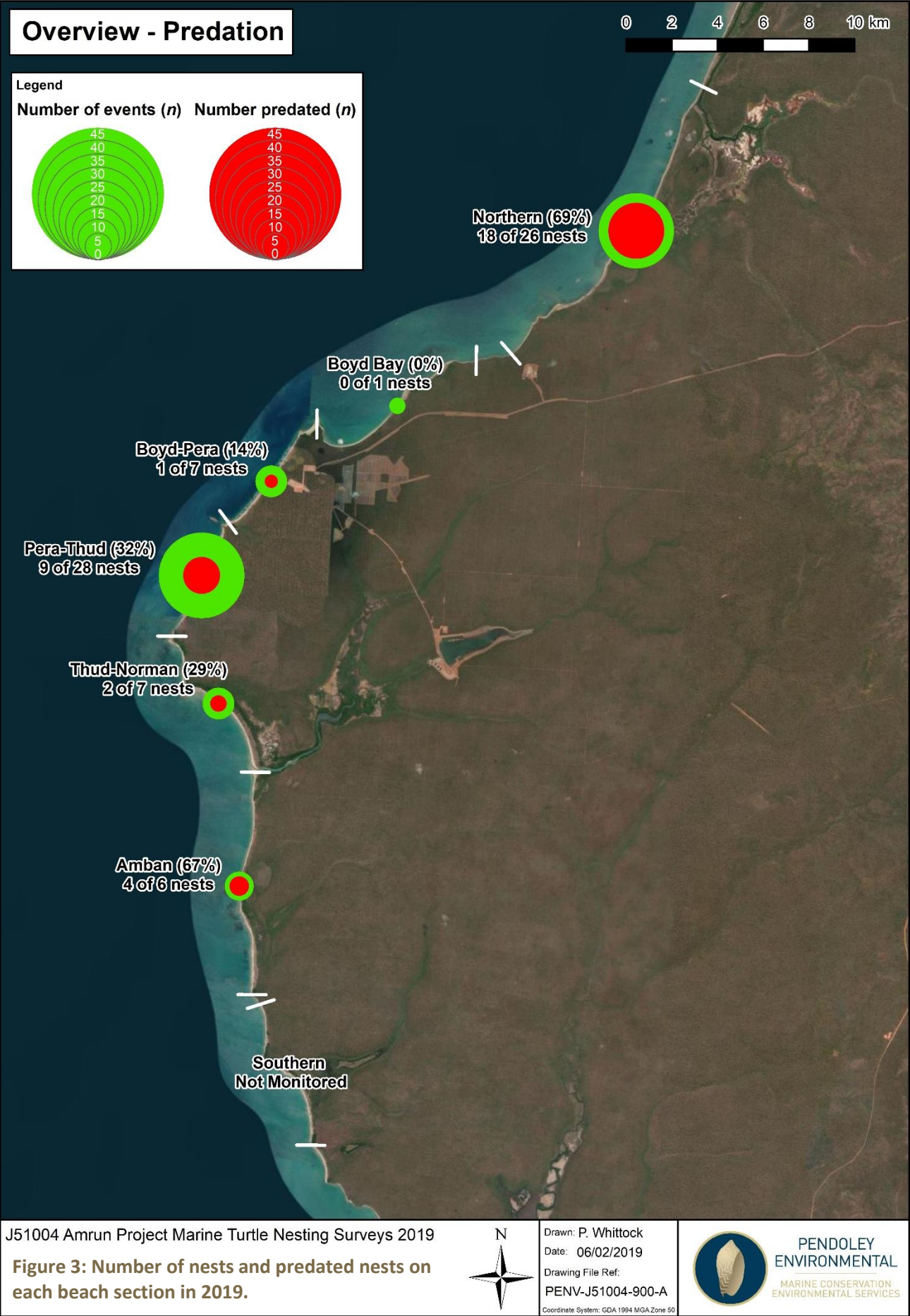MARINE CONSERVATION
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Table 10: Predated nests/potential nests for each beach section for all predator species during snapshot and overnight surveys in September 2019. *Adjusted to exclude nest and predation data from the Southern beach section to enable suitable comparison with 2019.

Beach Section	Overnight Nests			Snapshot Nests			All Nests		Overall Predation Rate (%)			
	Nests (*n*)	Pred. (*n*)	Pred. Rate (%)	Nests (*n*)	Pred. (*n*)	Pred. Rate (%)	Nests (*n*)	Pred. (*n*)	2019	2018	2017	2016
Northern	2	0	0	24	18	75	26	18	69	46	25	0
Boyd Bay	0	0	0	1	0	0	1	0	0	100	100	71
Boyd – Pera	6	1	20	1	0	0	7	1	14	76	36	88
Pera – Thud	3	0	0	25	9	36	28	9	32	36	79	96
Thud – Norm.	5	0	0	2	2	100	7	2	29	71	84	100
Amban	0	0	0	6	4	67	6	4	67	56	67	21
Southern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	16	1	6	59	33	56	75	34	45	60*	60*	64*

Table 11: Predated nests/potential nests for each turtle species in September 2019.

Species	Nests (*n*)	Predated Nests (*n*)	Overall Predation Rate (%)			
			2019	2018	2017	2016
Flatback	44	23	52	72	69	67
Hawksbill	17	7	41	50	-	52
Olive ridley	7	3	43	68	71	72
Green	2	0	0	0	100	-
Unidentified	5	1	20	75	92	86
Total	75	34	45	70	76	69

2.8.2   Predator Species

Two predator species were observed: feral pigs and goannas. Feral pigs were the predominant predator of marine turtle nests during the survey (see **Figure 4**). Feral pigs were recorded as the sole predator at 15 predation events and one of two predators at seven predation events (where there was also evidence of goanna activity; **Table 12**). Goannas were recorded as the sole predator at 11 predation events. Predator species could not be identified at one confirmed predation events (see **Sections 1.4.3** and **Section 1.7**). This observation, listed separately in **Table 12**, was included in the predation rate estimate.

2.8.3   Predator Activity

During daytime surveys, predator species were identified from tracks and evidence of digging for eggs, at and around each nesting event. Feral pig activity was identified by rooting holes and tracks, and goannas by tracks/tail drags in the sand. No feral pigs or goannas were detected in field camera footage from predation events that occurred during the field survey (**Section 2.8.4**).

Each observed indicator of either predation or predator activity was assigned to a category, as defined in **Section 1.4.3**. The frequency of each indicator and its location relative to the turtle nest (and eggs) is given in **Table 13**. The location of all predation events is shown in **Appendix A**.
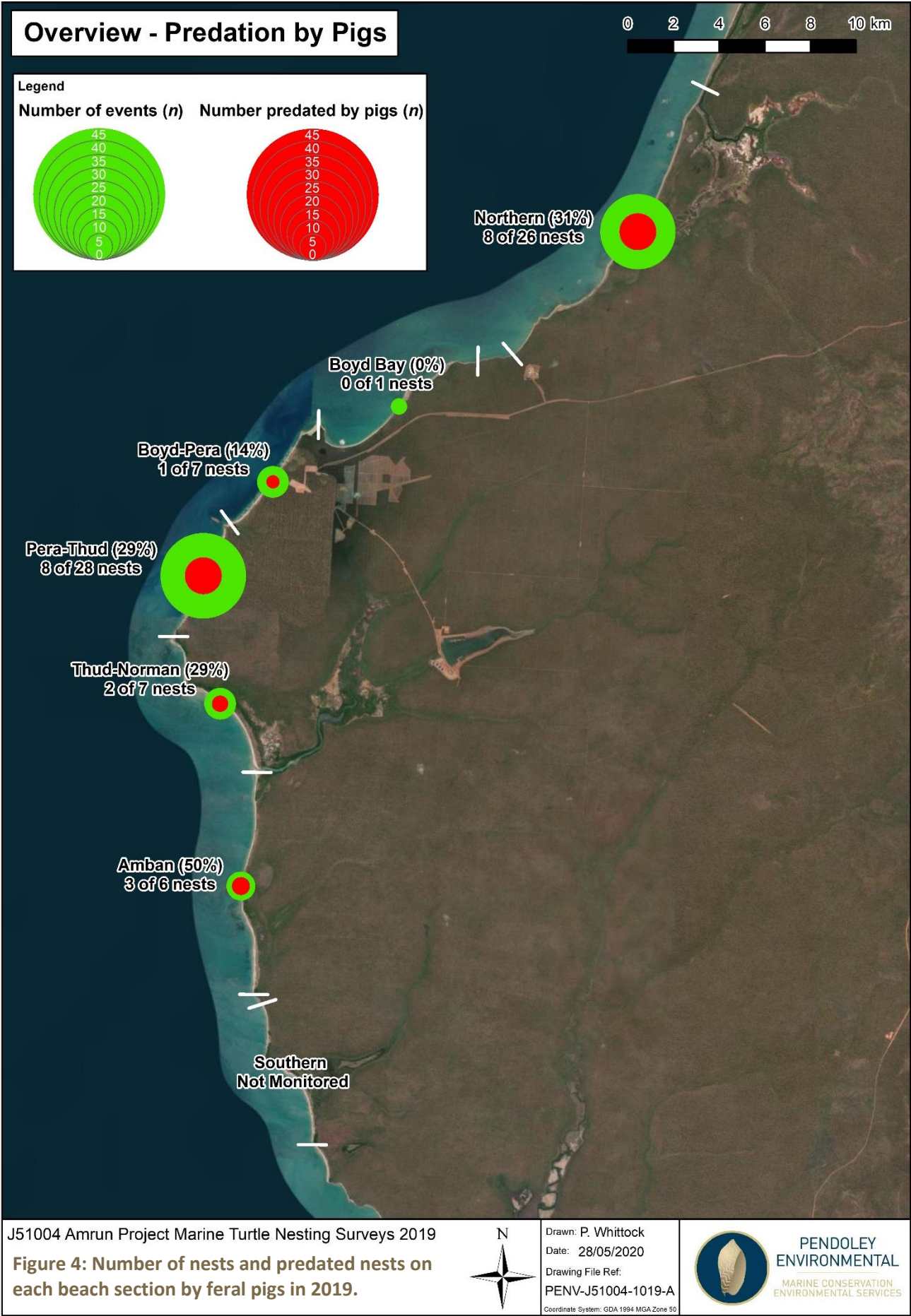
Figure 4: Number of nests and predated nests on each beach section by feral pigs in 2019.

Table 12: Predator species and predation rate of marine turtle nests recorded on each beach section in September 2019. Notes: *Nests includes 'potential nests'. Unid = Unidentified. #Adjusted to exclude nest and predation data from the Southern beach section to enable suitable comparison with 2019.

Beach Section	Nests		Predator Species (n)						Feral Pig Predation Rate (%)			
	Nests*	Pred. Nests	Feral Pig (beach survey)	Feral Pig (field cam)	Feral Pig & Goanna	Goanna	Unid	Total Feral Pig	2019	2018	2017	2016
Northern	26	18	1	0	7	10	0	8	31	31	17	0
Boyd Bay	1	0	0	0	0	0	0	0	0	100	100	29
Boyd - Pera	7	1	1	0	0	0	0	1	14	61	31	80
Pera - Thud	28	9	8	0	0	1	0	8	29	36	68	91
Thud - Norman	7	2	2	0	0	0	0	2	29	71	79	100
Amban	6	4	3	0	0	0	1	3	50	44	60	14
Southern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	75	34	15	0	7	11	1	22	29	#52	#52	#53

Table 13: Location and frequency of all predator activity and predation on each beach section, relative to the position of the turtle nest in September 2019. Notes: Due to the categorisation method used in these observations, the total number of nests where either predator activity or predation given in this table does not equal that given in **Table 12**.

Beach Section	Predator Observations (n)							
	Predator Activity			Predation/Attempted Predation				
	Nest	Tracks	Nearby	Nest	Tracks	Nearby	Shells	Remains
Northern	18	3	15	18	0	0	18	0
Boyd Bay	0	0	0	0	0	0	0	0
Boyd – Pera	1	0	0	1	0	0	1	0
Pera – Thud	9	0	1	9	0	0	3	0
Thud – Norman	2	1	1	2	0	0	1	0
Amban	4	1	3	3	0	0	4	0
Southern	NA	NA	NA	NA	NA	NA	NA	NA
Total	34	5	20	33	0	0	27	0

2.8.4   Field Camera Observations

Four field cameras were deployed at four 'potential' nests on Northern (*n* = 3) and Thud – Norman (*n* = 1) beach sections (**Table 14**). None of the cameras captured predation events during the field survey. Note that additional field cameras had been deployed at 'potential' nests by the LSMP survey team prior to the commencement of this field survey, however there were no field cameras at any of the 34 predated nests recorded during this field survey.

Table 14: Field camera deployment schedule. Notes: °: Field camera deployed; Shaded cells: deployment period; Camera retrieval: E: End of survey (not predated).

Beach Section	Survey Day													Duration (o/n)
	1 - 6	7	8	9	10	11	12	13	14	15	16	17	18	
Northern		°											E	11
Northern		°											E	11
Northern		°											E	11
Thud - Norman				°									E	9

2.9   Traditional Owner Engagement

Traditional owners were engaged for the duration of the surveys in 2019, with several of the same team members as in the previous survey in 2018. One LSMP Advisor has now participated in all four surveys, since 2016.

In total, nine LSMP Advisors participated in training delivered by PENV in the form of individual modules, including:

- PEN001: Tagging Assessment;

- PEN002: Track Census Assessment;

- PEN003: Camera Deployment/Retrieval;

- PEN004: Hatchling Orientation; and

- PEN005: Nest Excavation.

Each module included the delivery of a standalone presentation prior to departure to the field, training when in the field throughout the duration of the survey, and a competency assessment where verification of an individual's knowledge and skills occurred. In-field training was delivered at every opportunity: when an event was observed, LSMP Advisors were shown the approach used by PENV staff with regards to all field survey tasks and given the direction and support required for them to complete each task. Certificates were presented to each individual LSMP team member where verification of competency was possible.
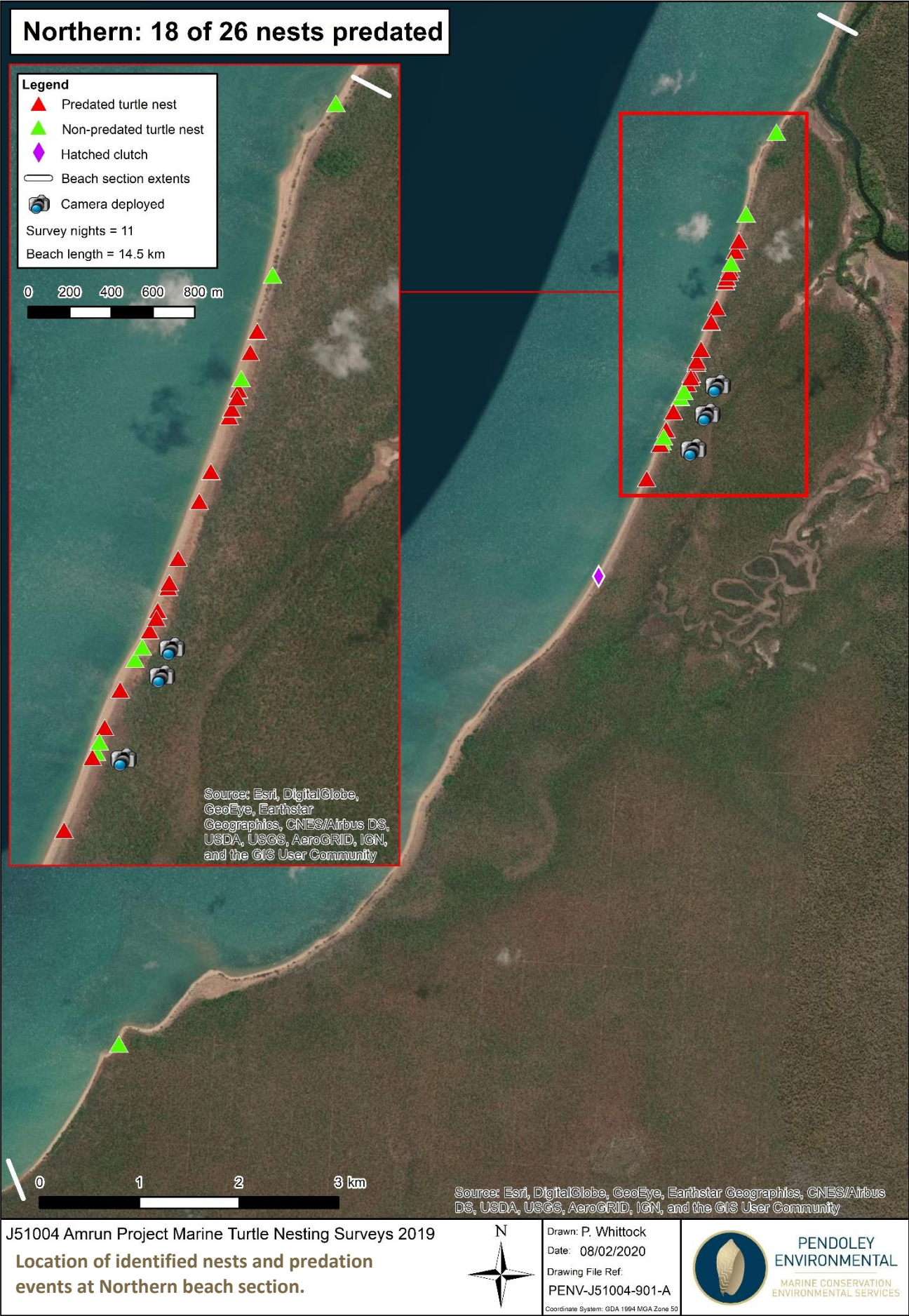
There were insufficient nesting turtles (*n* = 2) encountered to provide adequate training to LSMP Advisors in marine turtle tagging. Both encountered turtles were tagged by LSMP Advisors, however a larger sample is required to verify competency.

In the field, the PENV survey team took every opportunity to train LSMP crew members and give them the skills and experience to successfully manage and execute these field surveys. This was demonstrated by the undertaking of additional survey days (26th – 30th September 2019; see **Table 2**) exclusively by the LSMP survey team following demobilisation of the PENV survey team on 26th September 2019.

3   REFERENCES

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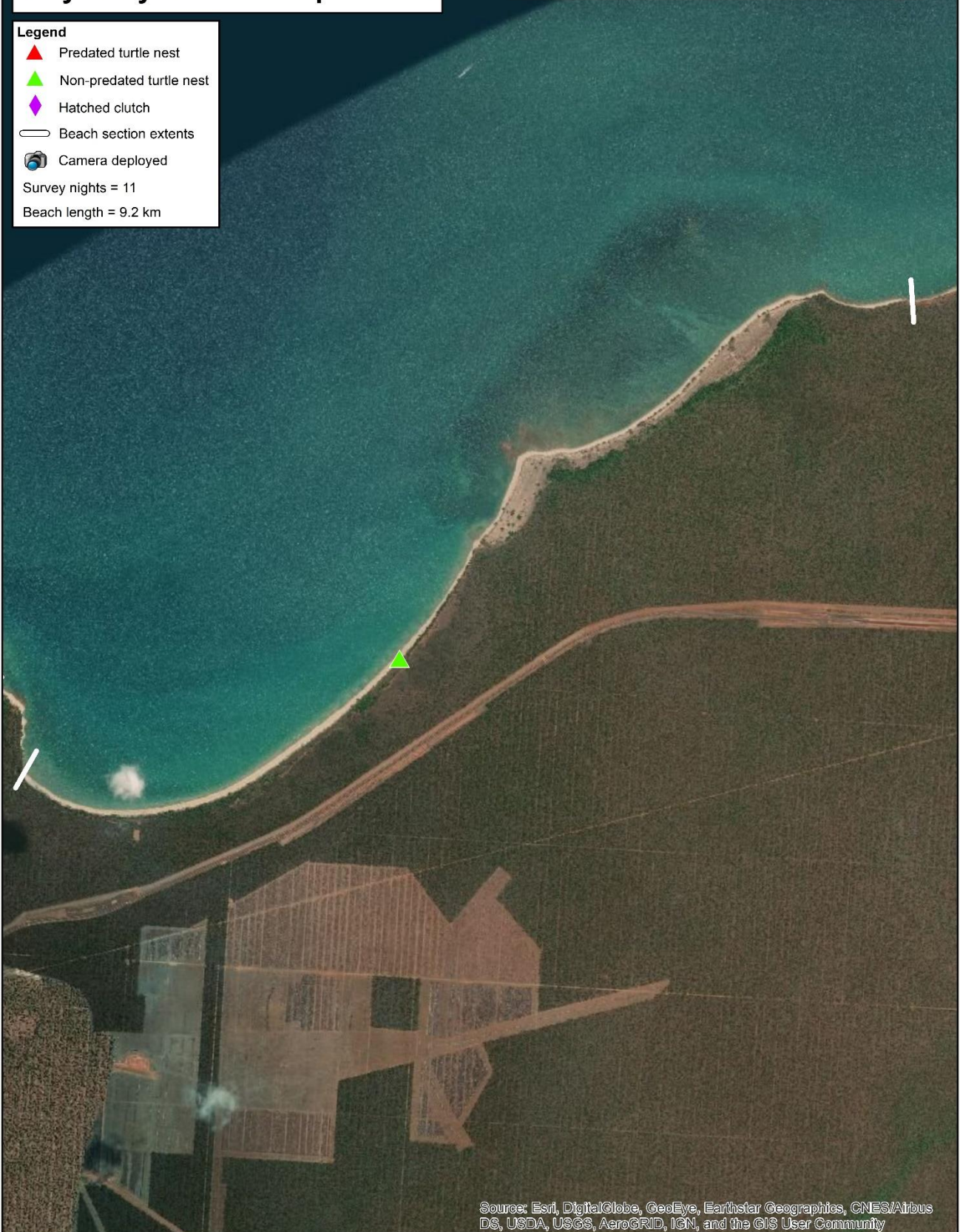**Appendix A: Location of Predated Nests at each Beach Section in 2019**

Northern: 18 of 26 nests predated

Legend

▲ Predated turtle nest

▲ Non-predated turtle nest

◆ Hatched clutch

▭ Beach section extents

📷 Camera deployed

Survey nights = 11

Beach length = 14.5 km

0 200 400 600 800 m

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 1 2 3 km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Location of identified nests and predation events at Northern beach section.

N

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Date: 08/02/2020

Drawing File Ref:

PENV-J51004-901-A

Coordinate System: GDA 1994 MGA Zone 50

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Boyd Bay: 0 of 1 nest predated

Legend

▲ Predated turtle nest

▲ Non-predated turtle nest

◆ Hatched clutch

▭ Beach section extents

📷 Camera deployed

Survey nights = 11

Beach length = 9.2 km

0   1   2   3 km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus
DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

J51004 Amrun Project Marine Turtle Nesting Surveys 2019

Location of identified nests and predation events at Boyd Bay beach section.

N

Drawn: P. Whittock

Date: 08/02/2020

Drawing File Ref:

PENV-J51004-905-A

Coordinate System: GDA 1994 MGA Zone 50

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Boyd - Pera: 1 of 7 nests predated

Legend

▲ Predated turtle nest

▲ Non-predated turtle nest

◆ Hatched clutch

⬭ Beach section extents

📷 Camera deployed

Survey nights = 14

Beach length = 6.5 km

Turtle tagged

0   500   1,000   1,500 m

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

J51004 Amrun Project Marine Turtle Nesting Surveys 2019

Location of identified nests and predation events at Boyd – Pera beach section.

N

Drawn: P. Whittock

Date: 08/02/2020

Drawing File Ref:

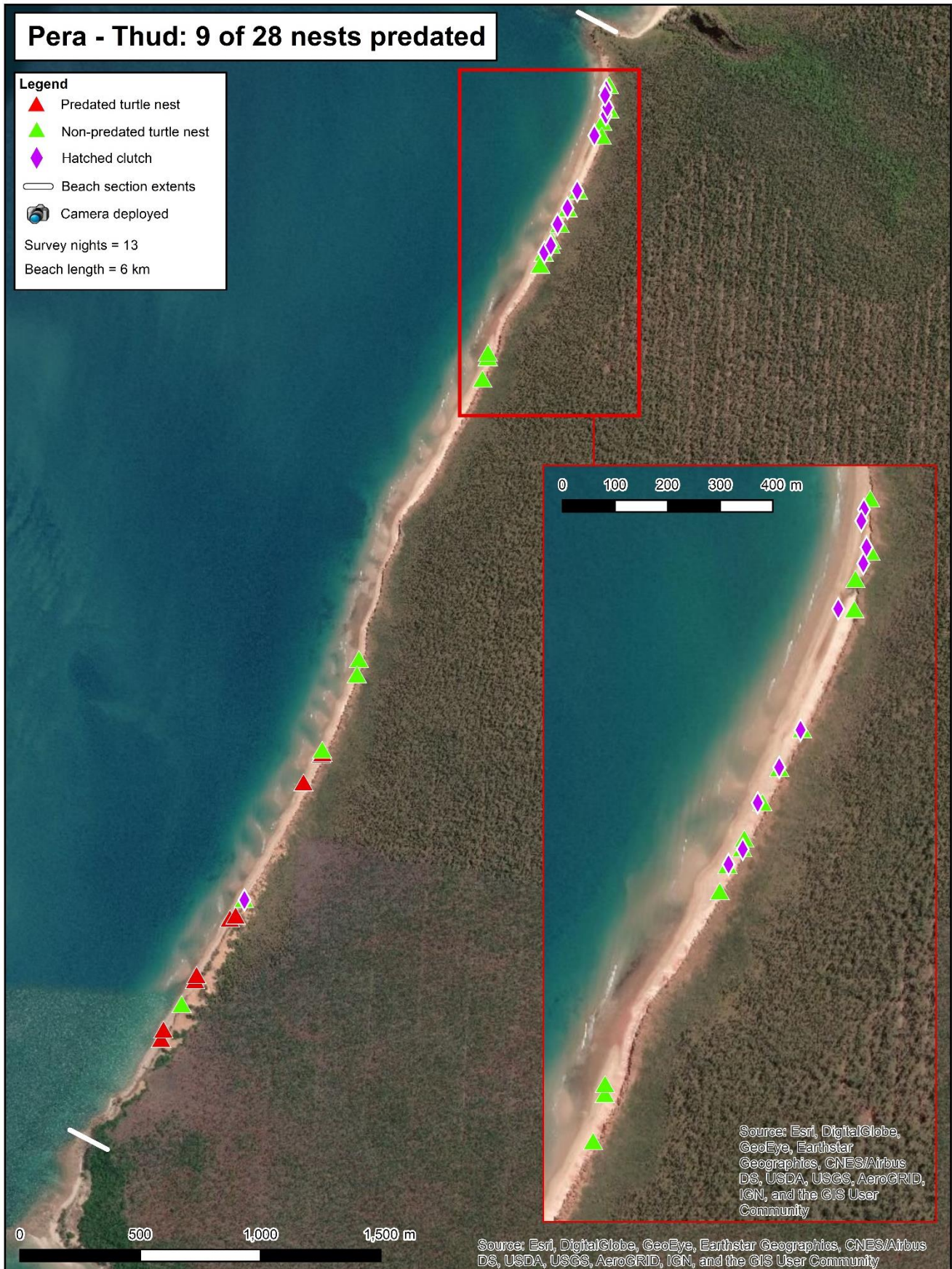PENV-J51004-903-A

Coordinate System: GDA 1994 MGA Zone 50

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Pera - Thud: 9 of 28 nests predated

Legend
▲ Predated turtle nest
▲ Non-predated turtle nest
◆ Hatched clutch
▭ Beach section extents
📷 Camera deployed

Survey nights = 13
Beach length = 6 km

0 100 200 300 400 m

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 500 1,000 1,500 m

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

J51004 Amrun Project Marine Turtle Nesting Surveys 2019

Location of identified nests and predation events at Pera-Thud beach section.

N

Drawn: P. Whittock
Date: 08/02/2020
Drawing File Ref:
PENV-J51004-902-A
Coordinate System: GDA 1994 MGA Zone 50

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Thud - Norman: 2 of 7 nests predated

Legend
- ▲ Predated turtle nest
- ▲ Non-predated turtle nest
- ◆ Hatched clutch
- ▭ Beach section extents
- 📷 Camera deployed
- Survey nights = 11
- Beach length = 7.3 km

0   1   2 km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

J51004 Amrun Project Marine Turtle Nesting Surveys 2019

Location of identified nests and predation events at Thud – Norman beach section.

N

Drawn: P. Whittock
Date: 08/02/2020
Drawing File Ref:
PENV-J51004-904-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY
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Amban: 4 of 6 nests predated

Legend

▲ Predated turtle nest

▲ Non-predated turtle nest

♦ Hatched clutch

⬭ Beach section extents

📷 Camera deployed

Survey nights = 11

Beach length = 9.5 km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

| 0 | 1 | 2 | 3 km |

J51004 Amrun Project Marine Turtle Nesting Surveys 2019

Location of identified nests and predation events at Amban beach section.

N

Drawn: P. Whittock

Date: 08/02/2020

Drawing File Ref:

PENV-J51004-906-A

Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL

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