RTA WEIPA PTY LTD

AMRUN PROJECT MARINE TURTLE NESTING SURVEYS

SEPTEMBER 2017

Prepared by Pendoley Environmental Pty Ltd

For

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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
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

To ensure the objective was met and for consistency with baseline surveys, 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. 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).

1.2.1 Survey Area

Surveys assessed activity at all known marine turtle nesting habitat in proximity to the Amrun project (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).

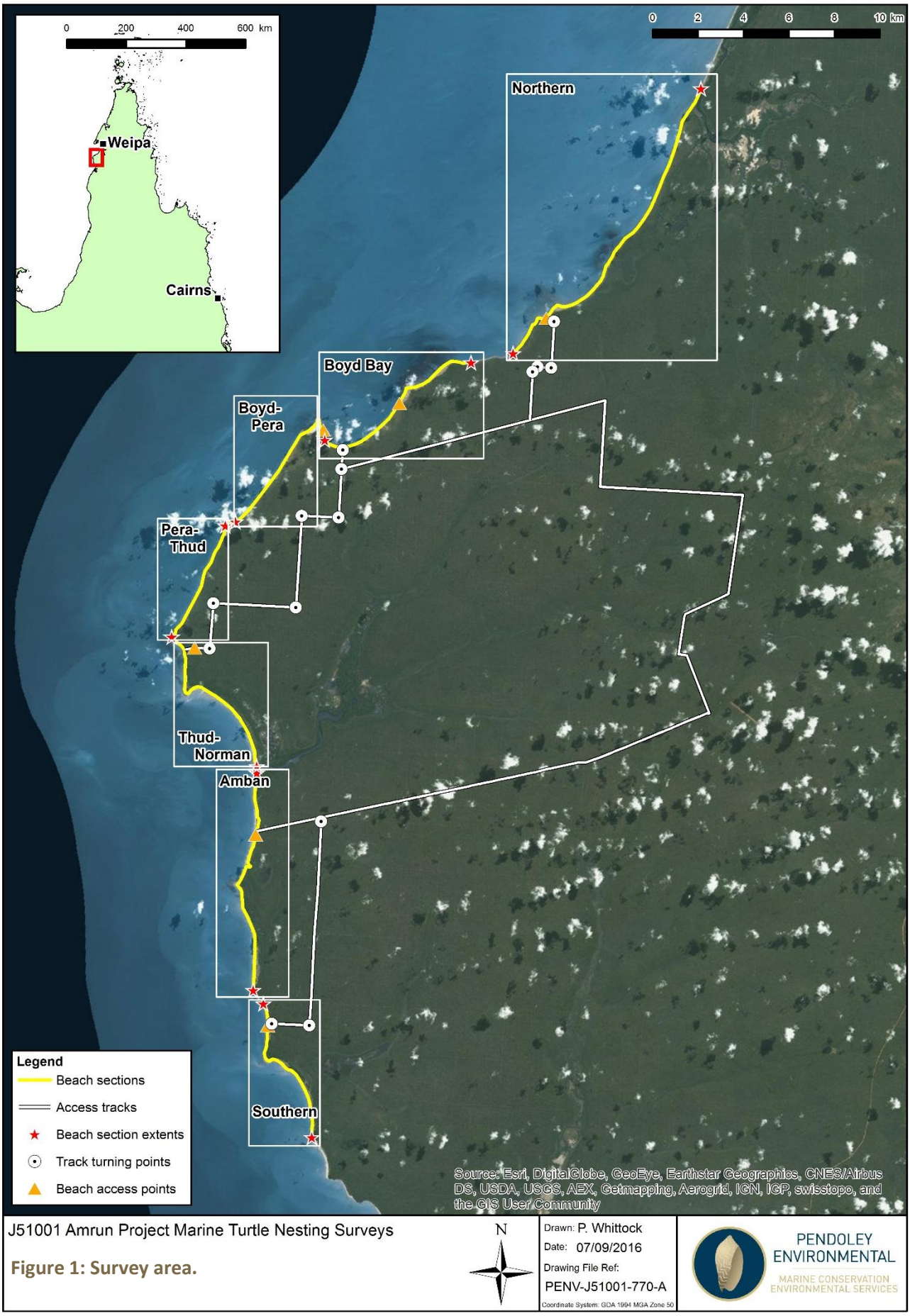

Figure 1: Survey area.

Table 1: Surveyed beach sections, September 2017.

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

Table 1 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.

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 experience 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), 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.

1.2.3 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 activity could not be assigned to species, the event was assigned to the category 'unidentified'.

1.2.3.1 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 of predator behaviour categories:

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

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.

1.2.3.2 Night-time beach survey

To monitor for predation and predator activity, motion sensitive field cameras (Reconyx) were deployed at 16 freshly laid 'potential' nests where no previous predation or predator activity was observed.

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. 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 Field Team recorded the date, time, beach, GPS position (of the field camera and the clutch), beach position, distance of camera from clutch, positon 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).

1.2.4 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.

1.2.4.1 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).

1.2.4.1 Hatchling Orientation

Where hatchling tracks were visible, hatchling orientation was recorded to measure hatchling dispersal patterns 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 almost entirely to hatching events occurring during the night preceding the survey.

1.2.5 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) and curved carapace width (CCW) 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). A sample of 10 eggs from each clutch were weighed (mass: +/- 0.1 g) and measured (diameter: +/- 0.1 mm).

1.2.6 Traditional Owner Engagement

Traditional Owners (TOs) from the Land and Sea Management Program (LSMP) accompanied the Field Team, fulfilling support roles and receiving training and on-the-job training from PENV field staff.

1.3 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 (SD), (range, *n*).

1.3.1 Nesting Activity and Density

Total nesting activity included both categories i.e. ‘nests’ and ‘attempts’ (**Section 1.2.3**).

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 baseline surveys, 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 baseline surveys, 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) and current (2017) surveys.

1.3.2 Species-specific Morphological Measurements

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

1.3.3 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 (listed separately in **Table 10**) were included in estimates of predation rates.

1.4 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.

1.5 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:

- 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.

1.6 Limitations

Estimates of abundance and assigning of both nesting and predator activity to species was in some cases constrained by either high winds and/or rain erasing tracks or by predator activity or predation, which obliterated track detail.

2 RESULTS

2.1 Survey Timing, Schedule and Effort

Survey timing (6th – 17th September 2017) fell within the peak nesting period for this region (August/September; Guinea 2014).

2.1.1 Daytime Beach Surveys

Daytime survey effort ranged from one to three teams of either two or three field staff, depending on available resources and survey requirements. The full length of the survey was 12 days comprising one snapshot survey day and a maximum of 11 census survey days on which overnight nesting was assessed. Total survey duration was 12 days. It was not possible to survey all beach sections on each survey day (see **Section 1.5**) and therefore survey duration ranged among beach sections from 10 to 11 days. Average survey duration was 10.4 days (**Table 2**).

2.1.2 Night-time Tagging Surveys

The night-time tagging survey focused on nesting habitat from Boyd Point to Pera Head (Boyd – Pera) for consistency with baseline and 2016 surveys (**Figure 1**). Survey effort ranged from one to two teams of two to three field staff. The total number of tagging nights on Boyd – Pera was seven (**Table 2**).

Table 2: Survey schedule for daytime track (track) and night-time tagging (tag) surveys.

Survey Day	Northern	Boyd – Bay	Boyd – Pera	Pera – Thud	Thud – Norm.	Amban	Southern
1			Track		Track		Track
2	Track	Track		Track		Track	
3		Track	Tag	Track			
4			Tag			Track	Track
5	Track		Tag	Track	Track		
6		Track	Tag	Track			
7		Track	Tag	Track	Track		
8		Track	Tag	Track	Track		
9		Track	Tag	Track	Track		
10		Track	Track	Track	Track	Track	Track
11	Track		Track	Track	Track	Track	Track
12	Track	Track	Track	Track	Track	Track	
Visits	**4**	**8**	**11**	**10**	**8**	**5**	**4**
Survey Days	**3**	**7**	**10**	**9**	**7**	**4**	**3**
Duration	**10**	**10**	**11**	**10**	**11**	**10**	**10**

Table 2 Notes: track: daytime track survey; tag: night-time tagging survey; Visits: total number of occasions on which the beach was visited; Survey days: the total number of days on which each section was assessed for overnight nesting activity; Duration: total number of days from the first, to the last visit inclusive, on each beach section.

2.2 Marine Turtle Nesting Activity

Initial activity recorded on the 'snapshot' days (survey days one and two) indicated higher numbers of nests (**Table 3**) and false-crawls (**Table 4**) in previous weeks than was recorded throughout the

remainder of the survey period. There was little variation in the number of overnight nests laid on each beach section throughout the survey period. On each survey night, the number of successful nesting attempts i.e. nests (**Table 3**) was greater than the number of unsuccessful nesting attempts (**Table 4**) on all beach sections. The rate of nesting success ranged from 71% on Boyd-Pera to 100% on Northern and Thud - Norman beach sections. Average nesting success on all beaches where nesting was recorded (*n* = 5) was 91%.

Table 3: Total nests (confirmed and potential) recorded on each beach section on each survey day September 2017.

Beach Section	Survey Day												Total Activity	
	1	2	3	4	5	6	7	8	9	10	11	12	o/n	All
Northern	-	10	-	-	1	-	-	-	-	-	1	0	2	12
Boyd Bay	-	1	0	-	-	0	0	0	0	0	-	0	0	1
Boyd – Pera	26	-	5	0	0	1	2	1	3	0	1	0	13	39
Pera – Thud	-	26	0	-	0	6	3	0	0	0	3	0	12	38
Thud – Norman	11	-	-	-	3	-	2	0	2	1	0	0	8	19
Amban	-	15	-	0	-	-	-	-	-	0	0	0	0	15
Southern	78	-	-	5	-	-	-	-	-	7	0	0	12	90
Total	115	52	5	5	4	7	7	1	5	8	5	0	47	214

Table 3 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.

Table 4: Total nesting attempts (FCA and FCU) recorded on each beach section on each survey day, September 2017.

Beach Section	Survey Day												Total Activity	
	1	2	3	4	5	6	7	8	9	10	11	12	o/n	All
Northern	-	20	-	-	0	-	-	-	-	-	0	0	0	20
Boyd Bay	-	0	0	-	-	0	0	0	0	0	-	0	0	0
Boyd – Pera	11	-	1	0	0	0	0	0	0	0	0	0	1	12
Pera – Thud	-	34	1	-	0	0	1	0	0	0	1	2	5	39
Thud – Norman	0	-	-	-	0	-	0	0	0	0	0	0	0	0
Amban	-	12	-	0	-	-	-	-	-	0	0	0	0	12
Southern	12	-	-	1	-	-	-	-	-	0	0	-	1	13
Total	23	66	2	1	0	0	1	0	0	0	1	2	7	96

Table 4 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.

2.3 Marine Turtle Nesting Density

Overnight nesting density (nests/km/night) in 2017 was highest on Southern and lowest on Boyd Bay and Amban beach sections where no nests were recorded after the initial 'snapshot' days. (**Table 5**).

Table 5: Total overnight nests and nesting density on each surveyed beach section in September 2017.

Beach Section	Overnight Nests	Survey Nights	Beach Length (km)	Nesting Density (Nests/km)	Overnight Nesting Density (Nests/km/night)
Northern	2	10	14.5	0.14	0.01
Boyd Bay	0	10	9.2	0.00	0.00
Boyd – Pera	13	11	6.5	2.00	0.18
Pera – Thud	12	10	6.0	2.00	0.20
Thud – Norman	8	11	7.3	1.10	0.10
Amban	0	10	9.5	0.00	0.00
Southern	12	10	5.1	2.35	0.24
Total	47	10.3	58.1	0.81	0.08

Compared to the previous 2016 survey, overnight nesting density in 2017 was lower on Northern, Boyd Bay and Amban beach sections. Compared to the 2013 (baseline) survey, overnight nesting density in 2017 was lower on all beach sections except Pera – Thud. On all beaches combined, mean ± SD (range, *n*) overnight nesting density (nests/km/night) in 2017 (0.10 ± 0.10, 0.00 – 0.21, *n* = 7) was higher than in 2016 (0.09 ± 0.07, 0.02 – 0.22) but the difference was not significant. Mean overnight nesting density (nests/km/night) in 2017 was significantly lower compared to 2013 (0.38 ± 0.38, 0.02 – 1.17, *n* = 7) ($p < 0.05$, U = 6) (**Table 6**).

Table 6: Variation in overnight nesting density in 2017 compared to 2016 and 2013 (baseline).

Beach Section	Nests/km/night			Annual variation	
	2013	2016	2017	2017 v 2016	2017 v 2013
Northern	0.23	0.05	0.01	- 0.04	- 0.22
Boyd Bay	0.02	0.10	0.00	- 0.10	- 0.02
Boyd – Pera	0.29	0.13	0.18	+ 0.05	- 0.11
Pera – Thud	0.19	0.02	0.20	+ 0.18	+ 0.01
Thud – Norman	0.50	0.03	0.10	+ 0.07	- 0.40
Amban	0.26	0.07	0.00	- 0.07	- 0.26
Southern	1.17	0.22	0.24	- 0.02	- 0.93
Annual Mean	0.38	0.09	0.10	(+ 0.02)	(- 0.28)

2.4 Species-Specific Nesting Activity

In total, 247 events were recorded by four species of nesting marine turtles; flatback (*Natator depressus*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*). An additional 63 events were not assigned to species (**Table 7**). Of nests that were identified to species, 70.3% were flatback, 29.0% were olive ridley and 0.7% were green turtle nests.

Nesting activity (flatback, olive ridley and green) was highest on Southern and lowest on Boyd Bay (**Table 7**). Among species, the rate of nesting success was greatest in flatback turtles (82.6%). Olive ridley turtle nesting success was 42.5% (**Table 7**).

Table 7: Number of overnight nests and nesting attempts recorded by each species on each beach section, September 2017.

Beach Section	Flatback		Hawksbill		Olive ridley		Green		Unidentified		Total	
	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U	Nests	FCA/U
Northern	6	1	0	0	4	19	0	0	2	0	12	20
Boyd Bay	0	0	0	0	1	0	0	0	0	0	1	0
Boyd – Pera	27	6	0	1	6	4	0	0	6	1	39	12
Pera – Thud	26	10	0	7	6	20	0	0	6	2	38	39
Thud – Norman	10	0	0	0	7	0	0	0	2	0	19	0
Amban	5	2	0	0	9	9	0	0	1	1	15	12
Southern	35	4	0	0	12	9	1	0	42	0	90	13
Total	109	23	0	8	45	61	1	0	59	4	214	96
	132		8		106		1		63		310	
% all activity	53.4		3.2		43.0		0.4		-		100	

2.4.1 Species-specific Morphological Measurements

Mean ± Standard deviation (range, *n*) flatback track and plastron widths were 735 ± 69 mm (587 – 930, *n* = 94) and 193 ± 47 mm (103 – 390, *n* = 94), respectively. Mean olive ridley track and plastron widths were 579 ± 87 mm (413 – 870, *n* = 48) and 168 ± 48 mm (97 – 382, *n* = 48), respectively. Mean hawksbill track and plastron widths were 623 ± 52 mm (587 – 737, *n* = 8) and 140 ± 11 mm (123 – 160, *n* = 7) respectively. Track width of the single green turtle activity recorded was 760 mm and plastron width was 263 mm.

2.5 Tagged Turtles

Four adult female flatback turtles were tagged following completion of nesting on Boyd – Pera beach section.

2.5.1 Turtle QA74204

At 22:55 on 12th September, tag numbers QA74205 (left) and QA74204 (right) were applied to the front flippers of a previously untagged adult flatback turtle measuring 889 mm (CCL). Total clutch size was 60 eggs. Mean egg mass was 68.8 ± 3.4 g (range = 60.1 – 72.5, *n* = 10) and diameter was 49.1 ± 105 mm (range = 45.1 – 50.3, *n* = 10).

2.5.2 Turtle QA74221

At 21:25 on 13th September, tag numbers QA74222 (left) and QA74221 (right) were applied to the front flippers of a previously untagged adult flatback turtle measuring 870 mm (CCL). Total clutch size was 53 eggs. Mean egg mass was 71.1 ± 1.8 g (range = 69.6 – 74.8, *n* = 10) and diameter was 50.1 ± 0.8 mm (range = 48.6 – 51.2, *n* = 10).

2.5.3 Turtle QA74208

At 18:55 on 14th September, tag numbers QA74207 (left) and QA74208 (right) were applied to the front flippers of a previously untagged adult flatback turtle measuring 887 mm (CCL). The turtle was discovered after egg laying had commenced (during oviposition) and therefore no clutch or egg morphometric data were collected.

2.5.4 Turtle QA74211

At 22:00 on 14th September, tag numbers QA74209 (left) and QA74211 (right) were applied to the front flippers of a previously untagged adult flatback turtle measuring 875 mm (CCL). Total clutch size was 42 eggs. Mean egg mass was 62.6 ± 6.4 g (range = 47.0 – 68.3, *n* = 10) and diameter was 46.7 ± 1.9 mm (range = 44.0 – 49.0, *n* = 9).

2.6 Hatched Nests

Three hatched clutches were recorded during the survey period (**Table 8**).

1. Boyd – Pera: Initially observed on 6th September, one hatched flatback clutch was excavated for incubation success data on 9th September. Total clutch size was 72 eggs of which 68 eggs hatched successfully and four eggs did not contain an embryo.
2. Pera – Thud: On 14th September one hatched flatback clutch was observed and assessed for orientation indices. On 16th September the clutch was excavated for incubation success data. This clutch had been predated and only 12 eggs remained, 10 of which hatched successfully.
3. Northern: On 7th September, 55 dead hawksbill hatchlings were found on the sand approximately 5 m from the high tide line. The likely cause of death was dehydration due to warm temperatures and exposure to direct sunlight i.e. there was no evidence of predation. The exact clutch location was not determined and no further data were gathered (**Figure 2**).

The two flatback turtle clutches located for excavation had a mean hatch success of 88.9 % and mean emergence success of 86.8 %.

Figure 2: Deceased hawksbill hatchlings found on Northern beach section on 7th September 2017.

Table 8: Incubation success of excavated clutches found in 2017.

Beach Section	Species	Date	Predation	Hatched Eggs					Unhatched Eggs			Overall		
				Empty Eggshells	Hatchlings		Pipped Eggs		Development			Total Clutch Size	Success (%)	
					Live	Dead	Live	Dead	0	Part.	100%		Hatch	Emerge.
Northern	Hawksbill	07/09/17	No	NA	NA	55+	NA	NA	NA	NA	NA	NA	NA	NA
Boyd – Pera	Flatback	09/09/17	No	68	3	0	0	0	4	0	0	72	94.4	90.3
Pera – Thud	Flatback	16/09/17	Pig	10	0	0	0	0	0	1	1	12	83.3	83.3

2.7 Predation and Predator Activity

The overall rate of predation of marine turtle nests was 76%, equal to 162 nests that were predated of the total of 214 nests. The rate of predation varied among beach sections (**Table 9**) and turtle species (**Table 10**) and ranged from 0% - 100% and 69% - 100%, respectively.

The overall feral pig (*Sus scrofa*) nest predation rate was 66% (*n* = 142).

Of nests that were predated, the feral pig predation rate was 88% (*n* = 142), goanna (gen. *Varanus*) predation rate was 1% (*n* = 2) and the rate of predation by unidentified predator species was 11% (*n* = 18).

Evidence of feral pig activity was documented at every recorded event where predation and predator activity could be assigned to species with the exception of two nests that were predated by goannas.

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 nests and predation events on each beach section.

2.7.1 Predation

Predation in 2017 was highest on Boyd Bay (100%). This represents the single nest found on this beach section which had been predated. If Boyd Bay is excluded, predation was highest on Southern beach section (98%) where there was evidence of predation at all but two nesting events observed during the initial snapshot day survey and all overnight nesting events (total: 88 of 90) (**Figure 3**; **Table 9**).

The rate of predation in the 2017 survey increased in comparison to the previous (2016) season, on Northern, Boyd-Bay and Amban beach sections. On all other beach sections, the rate of predation in 2017 was lower than during the previous (2016) survey.

Table 9: Nests/potential nests, predated nests/potential nests by beach section in snapshot and overnight surveys, September 2017.

Beach Section	Snapshot Nests			Overnight Nests			All Nests		
	Nests (*n*)	Predated (*n*)	Predation Rate (%)	Nests (*n*)	Predated (*n*)	Predation Rate (%)	Nests (*n*)	Predated (*n*)	Predation Rate (%)
Northern	10	3	30	2	0	0	12	3	25
Boyd Bay	1	1	100	0	0	0	1	1	100
Boyd – Pera	26	14	54	13	0	0	39	14	36
Pera – Thud	26	21	81	12	9	75	38	30	79
Thud – Norm.	11	9	82	8	7	88	19	16	84
Amban	15	10	67	0	0	0	15	10	67
Southern	78	76	97	12	12	100	90	88	98
Total	167	134	80	47	28	60	214	162	76

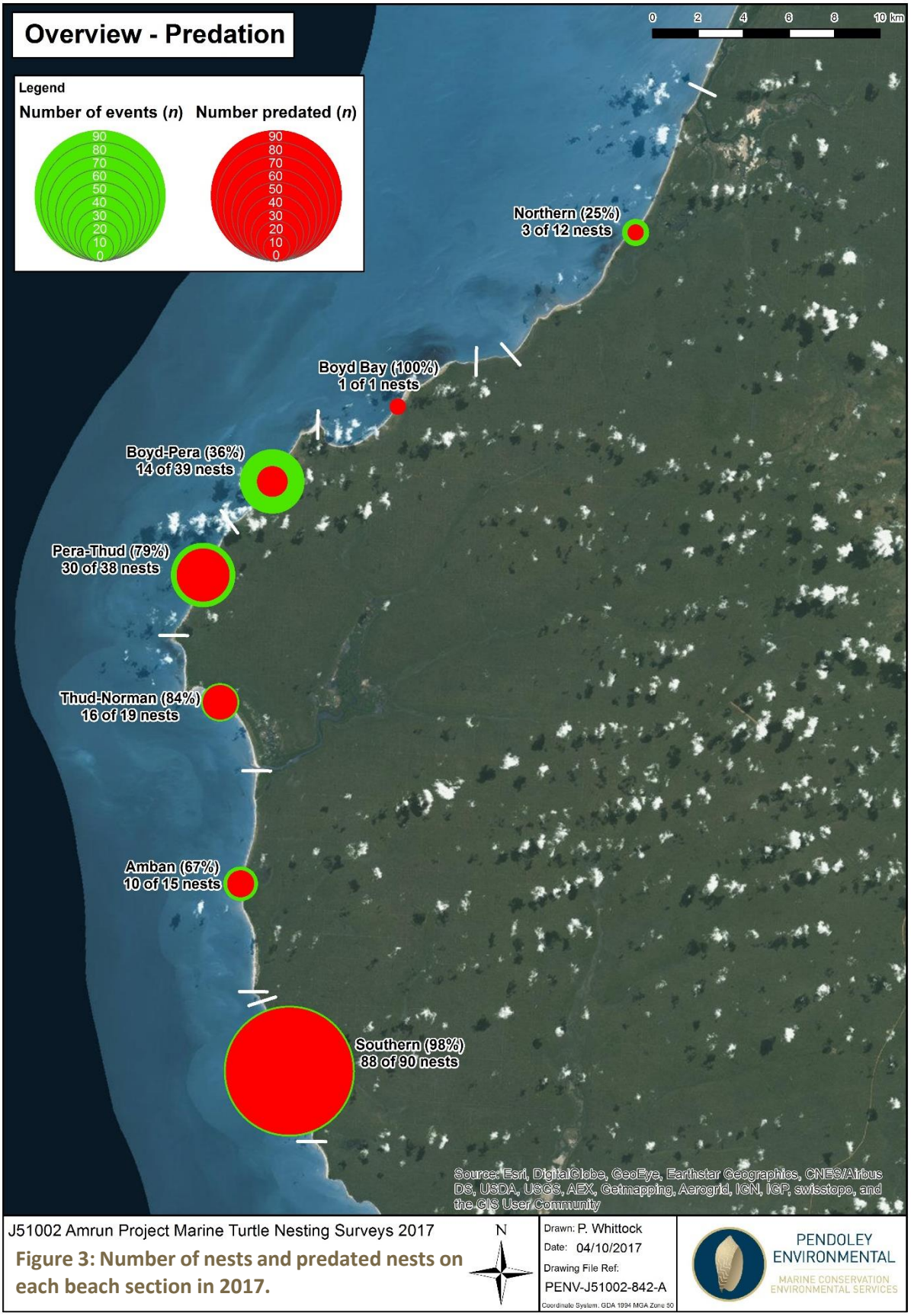

Figure 3: Number of nests and predated nests on each beach section in 2017.

Among nesting events that were assigned to species and excluding the single green turtle nest which was predated, the rate of predation in 2017 was highest in olive ridley nests (**Table 10**).

Table 10: Nests/potential nests, predated nests/potential nests by nesting turtle species, September 2017.

Species	Nests (*n*)	Predated Nests (*n*)	Predation Rate (%)
Flatback	109	75	69
Hawksbill	0	0	-
Olive ridley	45	32	71
Green	1	1	100
Unidentified	59	54	92
Total	214	162	76

2.7.1 Predator Species

In total, in 2017, four predator species were observed: feral pigs, wild dogs or dingos (*Canis lupus dingos)*, goannas, and crocodiles (*Crocodylus porosus*). Feral pigs were the predominant predator of marine turtle nests along this coastline. Evidence of feral pig activity was documented at every predation event where the predator could confidently be assigned to species (*n* = 160) with two exceptions: Amban (*n* = 1) and Northern (*n* = 1) beach sections where only goanna tracks and digging were observed.

Feral pigs were recorded as the sole predator at 119 predation events and one of two predators at 23 predation events (goanna: *n* = 18; dingo = 5) (**Table 11**).

Predator species could not be identified at all events (see **Sections 1.2.4** and **Section 1.6**). These observations, listed separately in **Table 11**, were included in the predation rate estimate.

Table 11: Predator species and predation rate of marine turtle nests recorded on each beach section, September 2017.

Beach Section	Nests		Predator Species						Predation Rate (%)	
	Nests*	Predated Nests	Feral Pig	Feral Pig & Goanna	Feral Pig & Dingo	Goanna	Unid. Predator Species	Total Feral Pig	Total Feral Pig (%)	Total (%)
Northern	12	3	2	0	0	1	0	2	67	25
Boyd Bay	1	1	1	0	0	0	0	1	100	100
Boyd - Pera	39	14	12	0	0	0	2	12	86	36
Pera - Thud	38	30	16	7	3	0	4	26	87	79
Thud - Norman	19	16	14	1	0	0	1	15	94	84
Amban	15	10	8	0	1	1	0	9	90	67
Southern	90	88	66	10	1	0	11	77	88	98
Total	214	162	119	18	5	2	18	142	88	76

Table 11 Notes: Nests* includes 'potential nests' Unid: Unidentified

2.7.2 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, wild dogs by tracks and goannas and crocodiles by tracks/tail drags in the sand. Feral pig and wild dog activity was also identified from review of field camera footage (**Section 2.7.4**). All documented indicators were assigned to categories, defined in **Section 1.3.3.**

The frequency of each documented indicator of predation and predator activity and the location of each relative to the turtle nest is given in **Table 12.**

The location of all predation events is shown in **Appendix A** and a detailed breakdown of predation and predator activity observation indicators recorded on each beach section is shown in **Appendix B**.

Table 12: Location and frequency of all predator activity and predation on each beach section, relative to the position of the turtle nest, September 2017.

Beach Section	Predator Observations						
	Predator Activity			Predation/Attempted Predation			
	Nest	Tracks	Nearby	Nest	Tracks	Nearby	Shells
Northern	7	14	18	7	1	0	3
Boyd Bay	0	0	1	1	0	0	1
Boyd – Pera	8	4	21	17	0	1	14
Pera – Thud	19	34	44	24	1	1	26
Thud – Norman	14	9	10	14	0	0	16
Amban	8	8	13	10	0	0	10
Southern	81	45	42	88	3	8	88
Total	137	114	149	161	5	10	158

2.7.3 Field Camera Observations

Thirteen field cameras were deployed at 16 potential nests on Northern (*n* = 2), Boyd – Pera (*n* = 6), Pera – Thud (*n* = 5), Amban (*n* = 1) and Southern (*n* = 2) beach sections for a maximum duration of nine days (**Table 13**). A total of 4003 images were gathered from 405 camera trigger events. None of the nesting events where field cameras were deployed were confirmed prior to deployment via observation of nesting or sighting of the eggs and all events were therefore considered 'potential nests'.

Cameras deployed at seven of the 16 potential nests captured predation events on Boyd – Pera (*n* = 1), Pera – Thud (*n* = 4) and Southern (*n* = 2) beach sections (**Figures 3** to **9**; **Section 2.7.4.1** to **2.7.4.3**). Feral pigs were the only species recorded by field cameras actively digging to search for and consume eggs. One camera on Southern recorded dingoes passing by the nest on two separate occasions but there was no evidence that they were either looking for, or were interested in, the nest. The remaining nine cameras did not capture any predator activity.

Total active pig predation time captured on all cameras combined was 227 minutes. The average time pigs spent digging for and/or consuming eggs was 38 ± 17 mins (19 – 64, *n* = 6). At each event, only one pig was active at the nest area at a time. Boyd – Pera was the only exception where two pigs were recorded investigating the same area but digging/predation was not recorded at that time (**Figure 4**).

Table 13: Field camera deployment schedule.

Beach Section	Species	Survey Day												Duration (days)
		1	2	3	4	5	6	7	8	9	10	11	12	
Southern	Flatback				P (6)									3
Amban	Olive ridley													8
Pera –Thud	Flatback													7
Northern	Flatback													9
Pera –Thud	Flatback				P (2)									3
Boyd – Pera	Flatback													8
Boyd – Pera	Olive ridley													8
Boyd – Pera	Flatback													8
Boyd – Pera	Flatback													8
Southern	Flatback										P (7)			6
Northern	Olive ridley													6
Pera –Thud	Flatback							P (3)						1
Pera –Thud	Flatback									P (4)				6
Boyd – Pera	Flatback										P (1)			5
Pera –Thud	Olive ridley										P (5)			5
Boyd – Pera	Flatback													4

Table 13 Notes: Shaded cells: deployment period; Camera retrieval: P: predation event; Species: all nesting species unconfirmed; Duration: number of nights the camera was deployed at each location; superscript (1): Event reference number as per **Sections 2.7.4.1** to **2.7.4.3**

2.7.3.1 Boyd – Pera

Event 1: On 13th September at 02:08, 161 images of two feral pigs were captured. The pigs searched for the clutch (sniffing) for three minutes and were not successful. On 15th September at 20:06, 10 images show one pig searching for the clutch (**Figure 4**). The predation event was not captured on camera but was observed on retrieval of the camera on 16th September.

Figure 4: Feral pigs at Boyd – Pera beach section on 13th September 2017.

2.7.3.2 Pera – Thud

Event 2: On 9th September at 22:44, 178 images show one pig digging and consuming multiple eggs over a duration of 19 minutes. At 23:26, a pig is captured climbing out of the predated nest area in a single trigger of ten images and it is not known if it is the same pig or if more eggs were consumed (**Figure 5**).

Figure 5: Feral pig at Pera – Thud beach section on 9th September 2017. Left: image captured at 22:44 prior to location of the eggs; right: image captured at 23:27, showing a pig exiting the nest area.

Event 3: On 12th September at 00:09, 680 images were captured of one pig digging and consuming multiple eggs over 51 minutes (**Figure 6**).

Figure 6: Feral pig at Pera – Thud beach section on 12th September 2017. Top left: image captured at 00:11 shows the pig searching for the eggs; top right: image captured at 00:15 during the digging/consuming period; bottom left: image captured at 00:28 show the pig continuing to dig and consume eggs; bottom right: image captured at 00:59, showing the pig exiting the nest area.

Event 4: On 14th September at 23:57, 408 images were captured of one pig digging and consuming multiple eggs over 64 minutes (**Figure 7**).

Figure 7: Feral pig at Pera – Thud beach section on 14th September 2017.

Event 5: On 15th September at 04:30, 810 images were captured of one pig digging and consuming multiple eggs over 38 minutes. On 16th September at 00:41, 552 images were captured of one pig digging and consuming multiple eggs over 22 minutes (**Figure 8**).

Figure 8: Feral pig at Pera – Thud beach section on 15th September 2017. Left: image captured at 04:45 on 15th September, shows a pig consuming eggs; right: image captured at 01:01 on 16th September shows a pig digging for and consuming eggs.

2.7.3.3 Southern

Event 6: On 6th September at 22:06, 35 images were captured of one pig exiting the nest area which had been predated. The pig then dug in another area before leaving the camera's field of view after three minutes (**Figure 9**).

Figure 9: Feral pig at Southern beach section on 6th September 2017. Left: image captured at 22:06 on 6th September, shows a pig exiting the nest area which had previously already been predated; right: image captured at 22:07 shows the pig digging in a second area adjacent to the previous, predated nest area.

Event 7: On 9th September at 19:20, 11 images were captured as a dingo passed through the area. Later that night at 23:51, the camera captured 1,069 images of one pig digging for and consuming eggs over 33 minutes. The camera was triggered again at 00:22 on 11th September by a pig that passed by but did not dig or find eggs and one more time at 08:00 on 14th September as a dingo passed by the area. The dingo did not appear to be aware of, or interested in, the previously predated nest site (**Figure 10**).

Figure 10: Feral pig and dingo activity at Southern beach section between 9th – 14th September, 2017. Top left: 19:20 on 9th September, a dingo passes by the nest area; top right, middle left and middle right: 23:51 on 9th September, one pig consumes eggs; bottom left: 00:22 on 11th September, a pig investigates the site and moves on; bottom right: 08:00 on 14th September, a dingo passes by, unaware of the predated nest area.

2.8 Traditional Owner Engagement

Traditional owners were engaged for the duration of the surveys in 2017. A total of eight LSMP Advisors and two crew leaders participated in training delivered by PENV in the form of a formal presentation prior to conducting fieldwork and ongoing training in the field on survey each day throughout the survey duration.

Initial training was given in a presentation prior to departure to the field and consisted of:

i. Relevant aspects of Pendoley Environmental's HSEQ policies and procedures, review of the field survey JSA and evaluation of identified risks potentially associated with carrying out the field survey component of the surveys; and

ii. Data collection techniques and protocols including review of datasheets and PENV data handling and management protocols.

In the field, the PENV Field Team took every opportunity to train LSMP crew members and give them the skills and experience to successfully manage an execute these field surveys as follows:

i. 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.

ii. Skills obtained included e.g. data collection, understanding observation made in the field, data recording, and animal handling and management, turtle and track morphological measurements, egg handling and management, turtle tagging, nest excavation and hatchling orientation.

Following training, on the final survey day in 2017 the LSMP crew successfully surveyed Amban and Southern beach sections without the PENV Field Team and these data are included in this report.

3 REFERENCES

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LIMPUS, C J, PARMENTER, J. B. AND FLEAY, A (1983) The flatback turtle, *Chelonia depressa*, in Queensland: Post-nesting migration and feeding ground distribution. *Aust. Wildl. Res*. 10, 557 - 561.

LIMPUS, C. J. (1971) The flatback turtle, *Chelona depressa*, Garman in Southeast Qld Australia, *Herpetologica* 27(4): 431-446.

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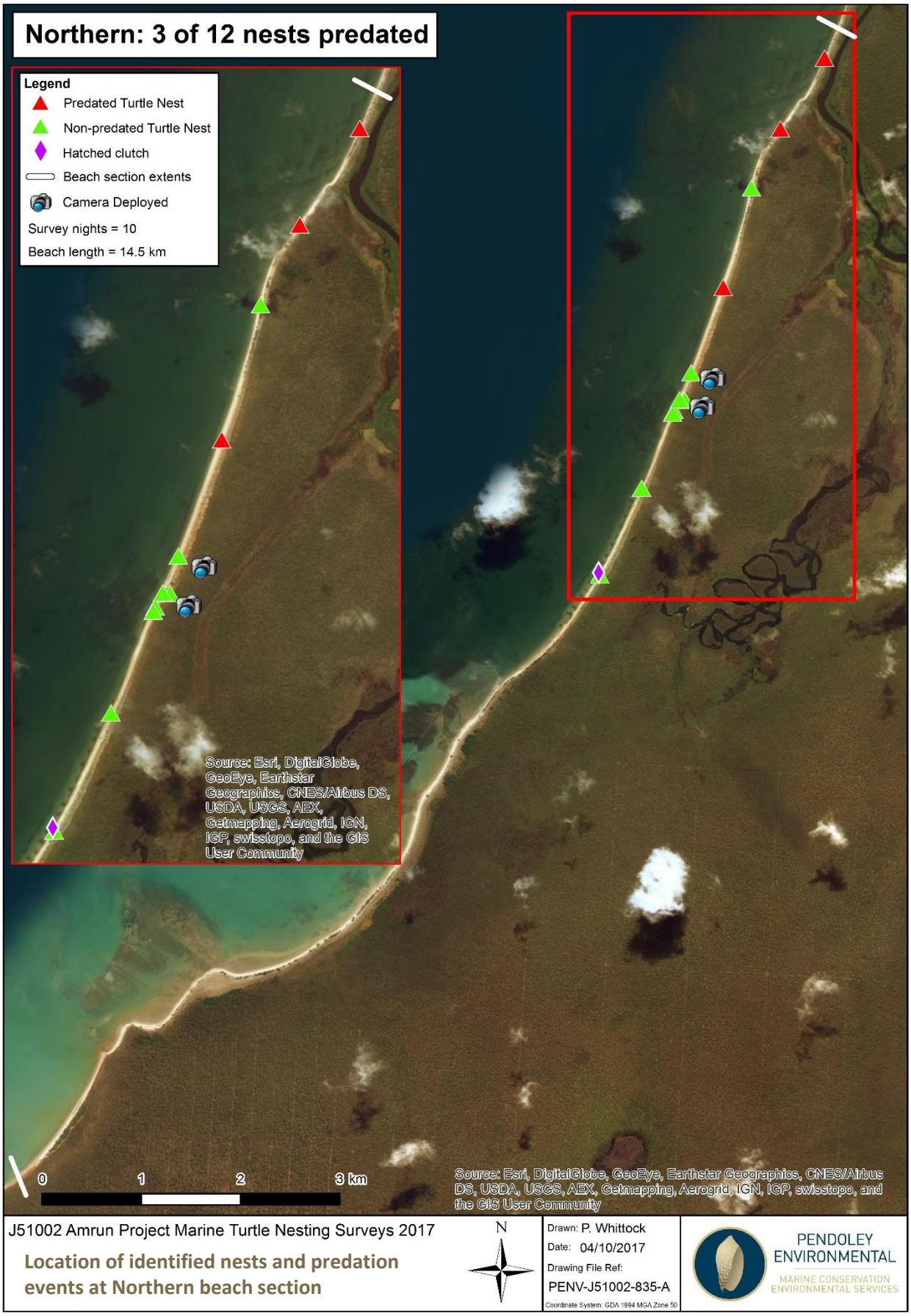
PENDOLEY ENVIRONMENTAL (2017) Pendoley Environmental Predation and Predator Activity Monitoring Standard Operating Procedure PIMS-SOP21.

APPENDIX A: LOCATION OF PREDATED NESTS



J51002 Amrun Project Marine Turtle Nesting Surveys 2017

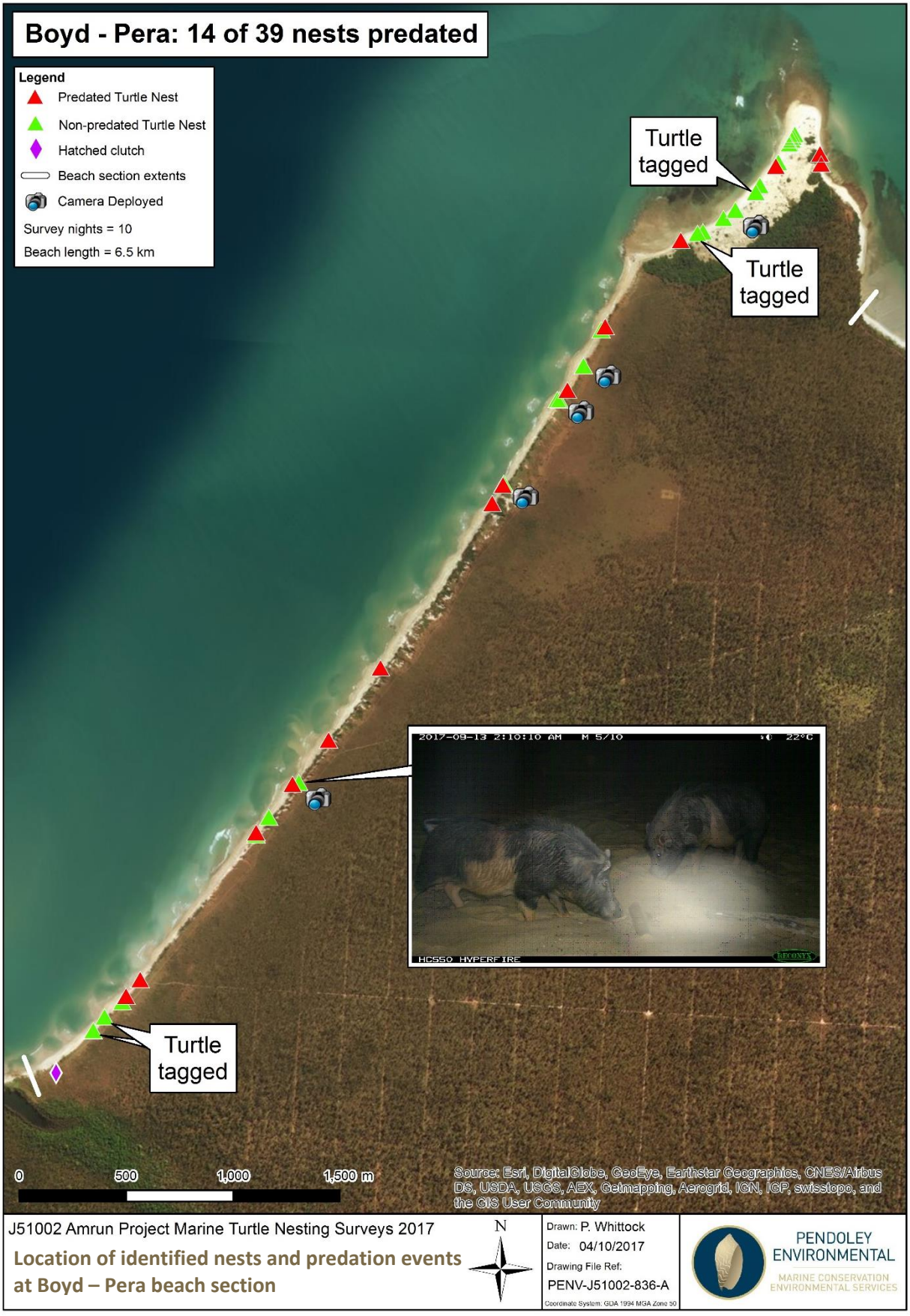
Location of identified nests and predation events at Northern beach section

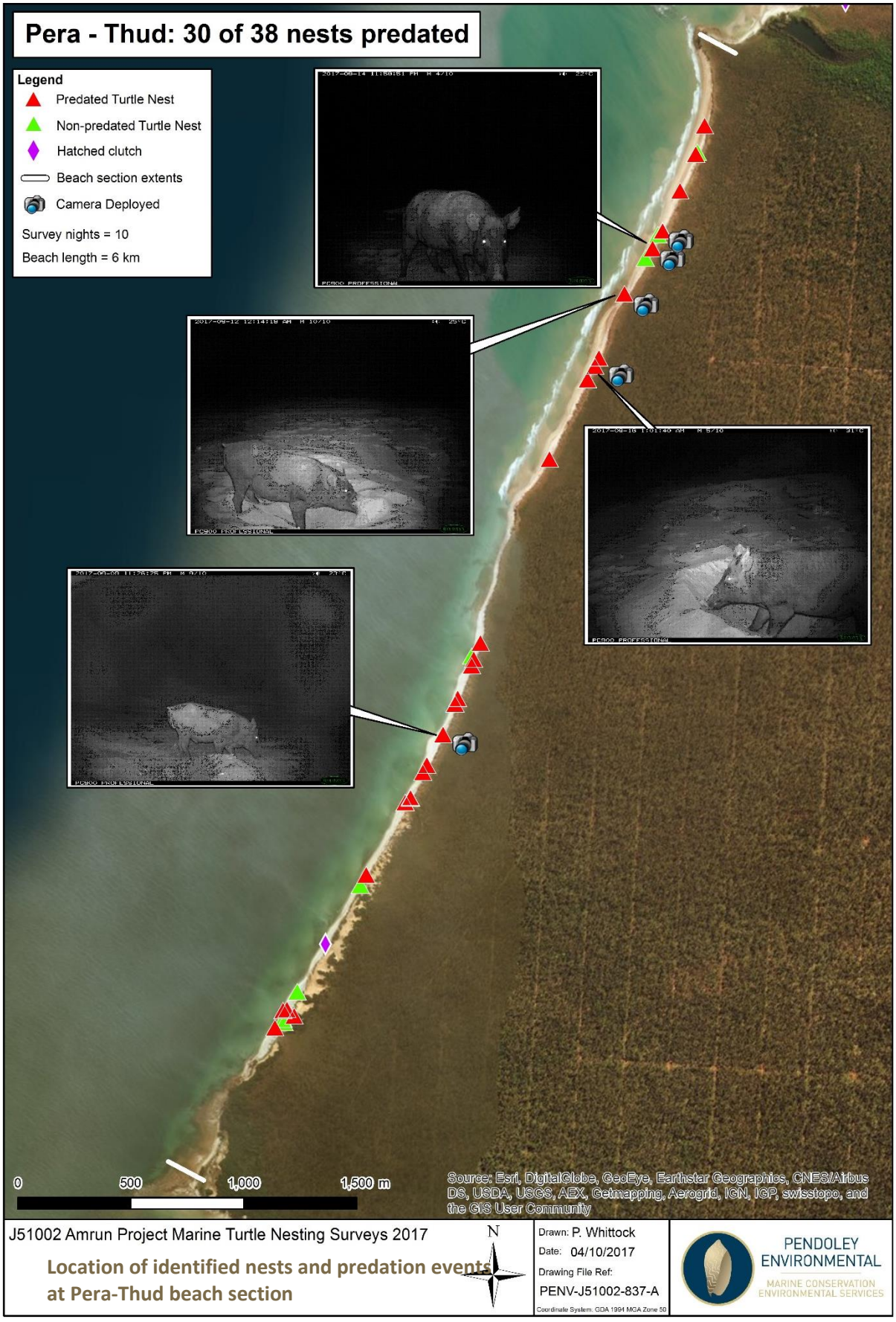
N

Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-835-A
Coordinate System: GDA 1994 MGA Zone 50

PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Boyd Bay: 1 of 1 nests predated
0
1
2
3 km
Legend
Predated Turtle Nest
Non-predated Turtle Nest
Beach section extents
Camera Deployed
Survey nights = 10
Beach length = 9.2 km
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Boyd Bay beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-839-A
Coordinate System: GDA 1994 MGA Zone 55
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Boyd - Pera: 14 of 39 nests predated
Legend
Predated Turtle Nest
Non-predated Turtle Nest
Hatched clutch
Beach section extents
Camera Deployed
Survey nights = 10
Beach length = 6.5 km
Turtle tagged
Turtle tagged
Turtle tagged
2017-09-13 2:10:10 AM M 5/10 22°C
HC550 HYPERFIRE
0
500
1,000
1,500 m
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Boyd – Pera beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-836-A
Coordinate System: GDA 1994 MGA Zone 55
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Pera - Thud: 30 of 38 nests predated
Legend
Predated Turtle Nest
Non-predated Turtle Nest
Hatched clutch
Beach section extents
Camera Deployed
Survey nights = 10
Beach length = 6 km
0
500
1,000
1,500 m
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Pera-Thud beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-837-A
Coordinate System: GDA 1994 MGA Zone 55
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Thud - Norman: 16 of 19 nests predated
Legend
Predated Turtle Nest
Non-predated Turtle Nest
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, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Thud – Norman beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-838-A
Coordinate System: GDA 1994 MGA Zone 50
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Amban: 10 of 15 nests predated
Legend
Predated Turtle Nest
Non-predated Turtle Nest
Beach section extents
Camera Deployed
Survey nights = 10
Beach length = 9.5 km
0
1
2
3 km
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Amban beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
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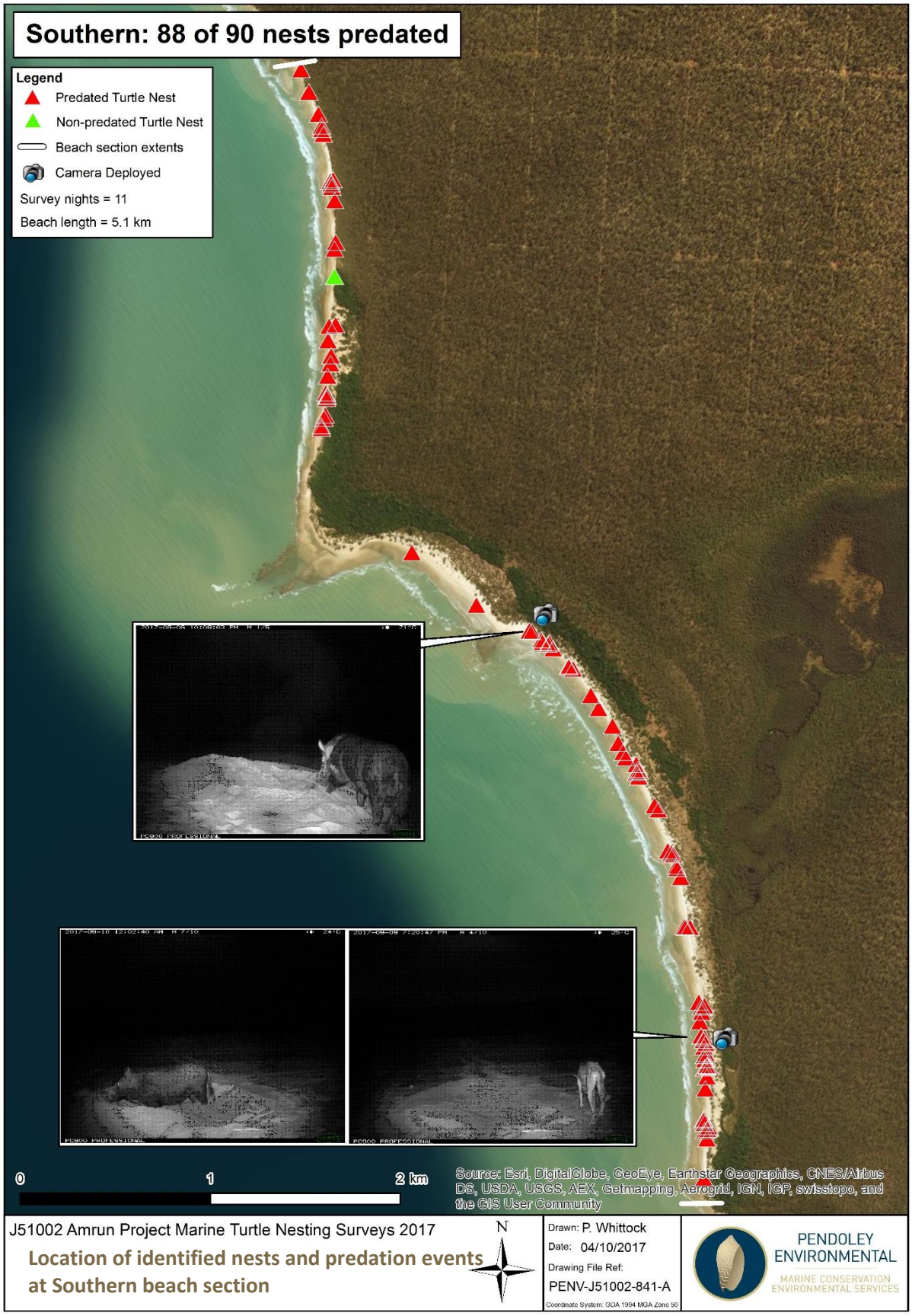
Coordinate System: GDA 1994 MGA Zone 50
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES


Southern: 88 of 90 nests predated
Legend
Predated Turtle Nest
Non-predated Turtle Nest
Beach section extents
Camera Deployed
Survey nights = 11
Beach length = 5.1 km
0
1
2 km
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
J51002 Amrun Project Marine Turtle Nesting Surveys 2017
Location of identified nests and predation events at Southern beach section
N
Drawn: P. Whittock
Date: 04/10/2017
Drawing File Ref:
PENV-J51002-841-A
Coordinate System: GDA 1994 MGA Zone 55
PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES