Western Range:

Pilbara Leaf-nosed Bat VHF Study

Biologic Environmental Survey

Report to Rio Tinto Iron Ore

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EXECUTIVE SUMMARY

Biologic Environmental Survey (Biologic) was commissioned by Rio Tinto Iron Ore Pty Ltd (Rio Tinto) to undertake a second VHF tracking study on the Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) at their Greater Paraburdoo mining operations, located approximately 6 kilometres (km) south of the town of Paraburdoo. The overarching objective of the study was to gain a better understanding of the movements of the conservation significant bat species occurring within the Project Area and to determine significant habitats, particularly with regards to foraging grounds. The survey built on a VHF tracking study on Pilbara Leaf-nosed Bat foraging habitats conducted by Biologic in the dry season of 2018. By increasing sample size and expanding the VHF tower array considerably compared to the original study, knowledge on foraging habitats and movement patterns within the Project Area were able to be further refined.

The field survey comprised two phases. Phase 1 was conducted between the 19th and 30th September 2019 to construct fixed-location VHF towers and to attach the digitally encoded transmitters to the Pilbara Leaf-nosed Bats. Phase 2 was conducted between the 20th and 24th November 2019 to retrieve data from the VHF towers. A total of 35 towers were established at Greater Paraburdoo, comprising 27 omni-directional towers and eight directional towers.

During Phase 1 survey, 20 Pilbara Leaf-nosed Bats (comprising 9 males and 11 females) were captured and tagged from the Permanent Diurnal Roost at Ratty Springs (Ratty Springs Roost). A total of 88,382 raw detections were recorded from all 20 tagged bats between the 24th of September (night of tagging) and the 14th of October 2019 (the sampling period). The 88,382 detections were aggregated into 2,574 unique detection events. Each individual was recorded by an average of 128.7 detection events over the sampling period, with a minimum of 32 detections and a maximum of 248.

Thirty-one of the 35 towers recorded detections. The three towers installed in the immediate vicinity of the Ratty Springs Roost (4135, 5BE8 and AC48) and near a permanent water pool recorded the highest number of detection events (*n* = 1414) and a significant portion of the time spent in the detection area (~112.5 hours). This suggests that Pilbara Leaf-nosed Bats utilised the pool as a water source on a regular basis throughout the sampling period. Furthermore, the data suggests that the roost does not only provide a diurnal roosting site for the species, but is also used throughout the night as a nocturnal refuge for night resting, feeding and/or social interactions. Bats roosted at the Ratty Springs Roost most (74.5%) nights. One individual also roosted 40 km to the north of the Ratty Springs Roost at Mt Truchanas on one night, suggesting limited regional movement between roost sites in the wider area. One individual also roosted to the north-east of the Ratty Springs Roost (near tower 052F A2 and A3), adding further evidence that a second diurnal roosting site (Paraburdoo East Roost) is located nearby. Four bats likely also roosted in the western section of the Project Area near towers B549 A1 and 9E15 A2.

Pilbara Leaf-nosed Bats moved from the Ratty Springs Roost to the north, east and to the south, but very rarely headed west into Western Range. The 13 omni-directional towers located within Western Range generally received low numbers of detection events throughout the sampling period. Most detections within Western Range were made at the very eastern section of Western Range which is attributable to their close location to the Ratty Springs Roost. Only seven of the twenty bats flew further west to visit the

central section of Western Range, and only four bats visited towers in the western section of Western Range. Visits at the central and western sections of Western Range were short and represented bats simply flying by the towers without spending much time in their vicinity. As the detection coverage within the Western Range Development Envelope was very high (>90%), these results indicate that this area did not represent an important foraging ground for the Pilbara Leaf-nosed Bats during the sampling period.

Bats spent approximately 70% or their nightly activity periods outside of the detection range of all towers, suggesting that the main foraging grounds of the 20 tagged Pilbara Leaf-nosed Bats were located outside of the detection range of the towers during the sampling period. Repeated detections by towers in the plains to the north, south and north-east of the Ratty Springs Roost indicate that bats foraged extensively in those areas. Thus, the tracking data suggests that the preferred foraging habitats of the 20 Pilbara Leaf-nosed Bats were located near drainage lines and ephemeral watercourses next to the Ratty Springs Roost and in the plains to its north, north-east and south.

The results of the current survey were highly comparable to those recorded from the dry season study in 2018, and thus demonstrate that VHF tracking can be a highly effective and consistent method for determining habitat use and identifying likely foraging grounds of Pilbara Leaf-nosed Bats. Whilst a current limitation of VHF tracking studies is that only an overview of bat activity within a short period of time can be gained, the current survey provides both a second season of data, a larger sample size of the local Pilbara Leaf-nosed Bat colony as well as greater detection range through a considerably expanded tower array, providing further credence to the results obtained here and the previous study.

1 INTRODUCTION

1.1 Background

Rio Tinto Iron Ore Pty Ltd (Rio Tinto) owns and operates the Greater Paraburdoo mining operations in the Pilbara bioregion of Western Australia, approximately 6 kilometres (km) south of Paraburdoo (Figure 1.1). Rio Tinto, on behalf of the joint venture participants, is evaluating the potential development of a new iron ore mine at Western Range (deposits 36 West to 66 West) and the extension of existing operations at Paraburdoo (deposits 4EE, 14W-16W, 20W & 27W) and Eastern Range (deposits 42EE & 47E) within the Greater Paraburdoo locality (the Project Area).

As part of collating baseline information to support future environmental approvals of the Project, Rio Tinto commissioned Biologic Environmental Survey Pty Ltd (Biologic) to undertake the second round of a Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia* [Pilbara form]) foraging study over the Project Area using automated VHF tracking array. This species has historically been recorded roosting within the Project Area (Astron, 2014, 2018a, 2018b; Bat Call, 2014, 2015, 2018; Biota, 2010, 2011, 2014), and Biologic have already completed one round of VHF tracking (Biologic, 2019). This previous study, which tracked 14 Pilbara Leaf-nosed Bats in September 2018, found that the individuals very rarely utilised Western Range as a flight path or foraging ground. Instead, the bats spent the majority of time within Pirraburdu Creek where it passes through Western Ranges (where the bats were originally tagged) and in the plains to the north and south of the ranges (Biologic, 2019). The present survey was undertaken to confirm and refine the results from the original study, tag additional Pilbara Leaf-nosed bats to increase sample size and to capture potential differences in habitat use across years. The VHF tower array was considerably expanded, allowing the tracking of bats on a more continuous basis and closing any gaps in detection range at Western Range identified from the previous study.

1.2 Objectives

The key objectives of this second study were to better understand Pilbara Leaf-nosed Bat movements across the Project Area and to further confirm the use of significant habitat areas identified in the 2018 study, particularly with regards to foraging grounds and flight paths. Biologic attached (digitally encoded) VHF transmitters to individuals and used a fixed location automated VHF tracking system to satisfy the following specific objectives:

- Further characterise broad flight paths utilised by Pilbara Leaf-nosed Bats at Western Range and beyond; and
- Further determine significant habitat areas, in particular the preferred foraging areas, utilised by the local colony of Pilbara Leaf-nosed Bats.

1.3 Species Background Information

The Pilbara Leaf-nosed Bat is recognised as a geographically isolated population of the Orange Leaf-nosed Bat, distributed across northern Australia and separated from the Pilbara populations by approximately 400 km of the Great Sandy Desert (Armstrong, 2001). The Pilbara population is regarded as representing a single interbreeding population comprising multiple colonies (TSSC, 2016). Recently

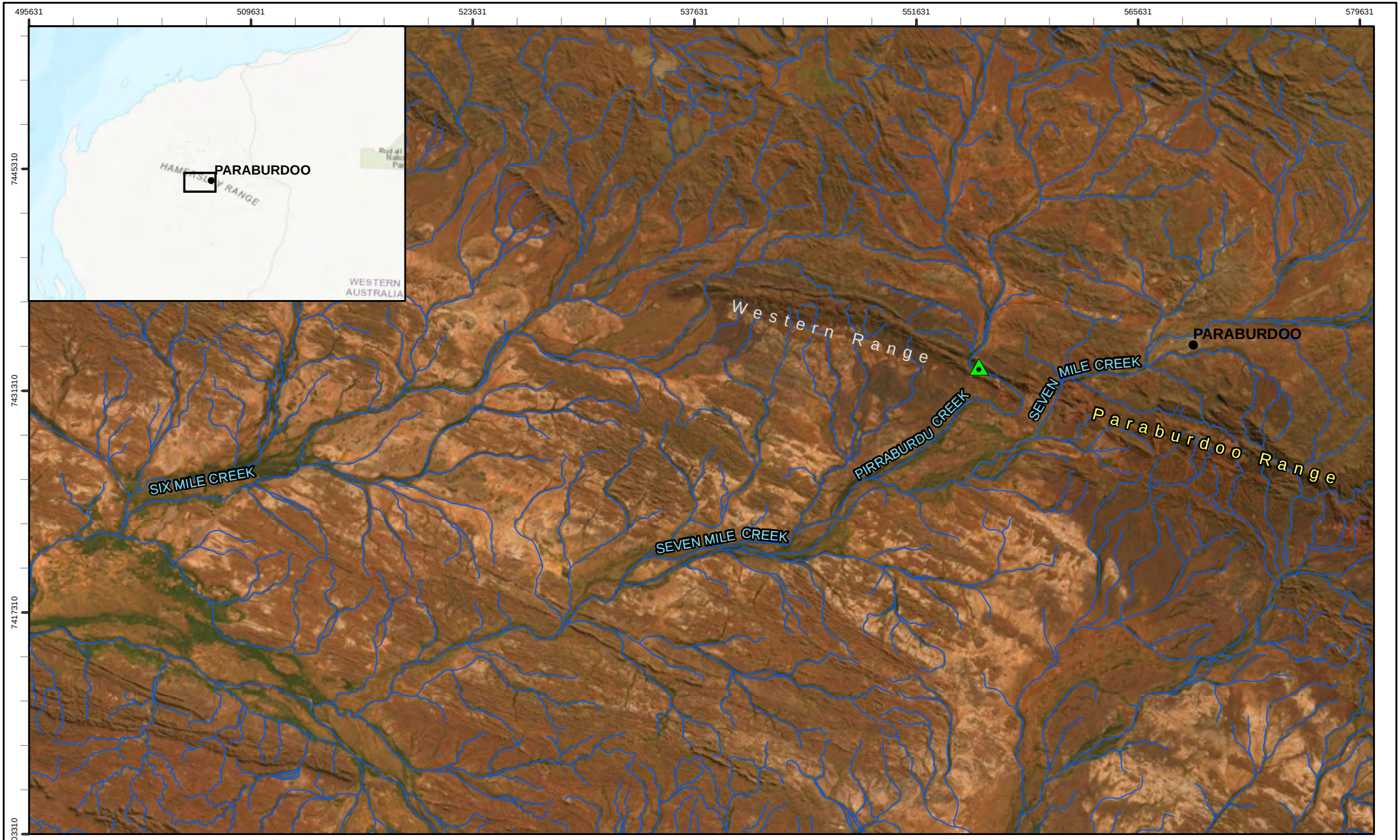
updated conservation advice stated that there were at least 10 confirmed day roosts (including maternity roosts), and a further 23 unconfirmed roosts throughout the Pilbara region (TSSC, 2016), although this is likely to be an underestimate based on unpublished data.

Pilbara Leaf-nosed Bats typically roost in undisturbed caves, deep fissures or abandoned mine shafts (Armstrong, 2000; Armstrong, 2001). The species' limited ability to conserve heat and water (Baudinette *et al.*, 2000) means they require warm (28-32ºC) and very humid (85-100%) roost sites to persist in arid and semi-arid climates (Armstrong, 2001; Churchill, 1991). Caves with such attributes are relatively uncommon in the Pilbara, and the limiting factor of the species distribution (Armstrong, 2001). During the dry season, (June to November), individuals are believed to aggregate in caves that provide a suitably warm, humid microclimate (Armstrong, 2000; Armstrong, 2001; Bullen & McKenzie, 2011). While in the wet season (December to May), when conditions are generally wetter and more humid, individuals typically disperse, roosting in seasonally suitable caves (Armstrong, 2000; Armstrong, 2001; Bullen & McKenzie, 2011). TSSC (2016) categorised underground refuges used by the species into four categories:

- **Permanent Diurnal Roosts** (Priority 1 – critical habitat for daily survival): are occupied year-round and are likely to be the focus for some part of the 9-month breeding cycle,
- **Non-Permanent Breeding Roosts** (Priority 2 – critical habitat for daily and long-term survival): are used during some part of the 9-month breeding cycle but not year-round,
- **Transitory Diurnal Roosts** (Priority 3 – critical habitat for daily and long-term survival): are occupied outside the breeding season and could facilitate long distance dispersal.
- **Nocturnal Refuge** (Priority 4 – not considered critical but important for persistence in a local area): are occupied or entered at night for resting, feeding or other purposes (excluding overhangs).

Additionally, foraging sites surrounding known or suspected roosts can be critical to the survival of the species. TSSC (2016) categorised foraging habitat for the species into five categories:

- **Gorges with pools** (Priority 1 – sites of relatively large biomass production, sometimes containing caves): watercourses through upland areas bounded by sheer rock walls for parts of their length, often containing pools that remain for weeks or months;
- **Gullies** (Priority 2 – less biomass production than Priority 1 gorge habitat): primary drainage with limited riparian development in upland rocky habitats, sometimes containing small pools that may last for weeks;
- **Rocky outcrop** (Priority 3): areas of exposed rock at the top of rocky outcrop and mesa hills that contain caves and overhangs, and boulder piles in the granite terrains;
- **Major watercourses** (Priority 4 – generally supports higher productivity of biomass than the surrounding habitats): riparian vegetation on flat land plus the main gravelly or sandy channel of the river bed, sometimes containing pools that persist for weeks or months; and
- **Open grassland and woodland** (Priority 5): dominated by Triodia, on lowland plains, colluvial slopes and hilltops.



Legend

- Ratty Springs Roost
- Watercourse

biologic Environmental Survey

N

1:300,000

0 3.5 7 14 km

Rio Tinto Iron Ore

Western Range PLNB VHF Study

Figure 1.1: The Project Area

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 13/01/2020

2 METHODS

2.1 Timing and Survey Team

The field study comprised two phases. Phase 1 was conducted between the 19th and 30th September 2019 to construct additional fixed-location VHF towers and to attach the digitally encoded transmitters to the Pilbara Leaf-nosed Bats. Phase 2 was conducted between the 20th and 24th November 2019 to retrieve data from the VHF towers.

The study was undertaken late in the Pilbara dry season for several reasons. Firstly, the timing corresponds with a period when individuals are believed to congregate back to their most important roosts known as 'Permanent Diurnal Roosts' (Bullen & McKenzie, 2011), thus increasing the possible sampling size of the study. Secondly, food abundance and available drinking resources are reduced during the dry season, and thus the most critically important habitats for the species are more readily identified.

Phase 1 was conducted by Thomas Rasmussen, Aidan Williams and Syngeon Rodman of Biologic, and Robert Bullen of Bat Call WA, all of whom have extensive experience surveying bats of conservation significance within the Pilbara region. Phase 2 was undertaken by Thomas Rasmussen and Aidan Williams. The study was conducted under the Department of Biodiversity, Conservation and Attractions (DBCA) Regulation 17 license 08-001704-6, issued to Chris Knuckey.

2.2 Climate and Weather

In the six months prior to Phase 1 (March to August 2019), Paraburdoo Aero Station (weather station 7185, ~10 km north of the Project Area) recorded 43 millimetres (mm) of rainfall; which is substantially lower than the long-term annual average for the same time period (138.9 mm; BoM, 2019) (Figure 2.1). Of the rainfall observed during this period, nearly all (82.3 %) of the rainfall was received in March 2019 (24.4 mm) and April 2019 (11 mm). No rainfall was observed in the month preceding the study, nor was any rainfall recorded during the sampling period (Table 2.1, Figure 2.1).

Minimum temperatures immediately prior and during the survey ranged from 10.5°C to 27.5°C, with an average of 16.4°C (Table 2.1). Maximum temperatures ranged from 25.9°C to 42.4°C, with an average of 35.4°C (Table 2.1). Observed maximum monthly temperatures were slightly higher compared with the long-term annual average temperatures for the same period. Relative humidity during (and immediately prior to) the survey (recorded at 0900 and 1500) ranged between 2-55% and was relatively low, although typical for the time of year (Table 2.1).

The below average rainfall experienced prior to and during the sampling period may have influenced Pilbara Leaf-nosed Bat activity and movement. Specifically, the lack of water in the landscape is most likely to have increased the requirement for bats to visit semi-permanent and permanent water sources due to lack of alternative options. Open water sources are critically important for Pilbara Leaf-nosed Bats, particularly during the dry season.

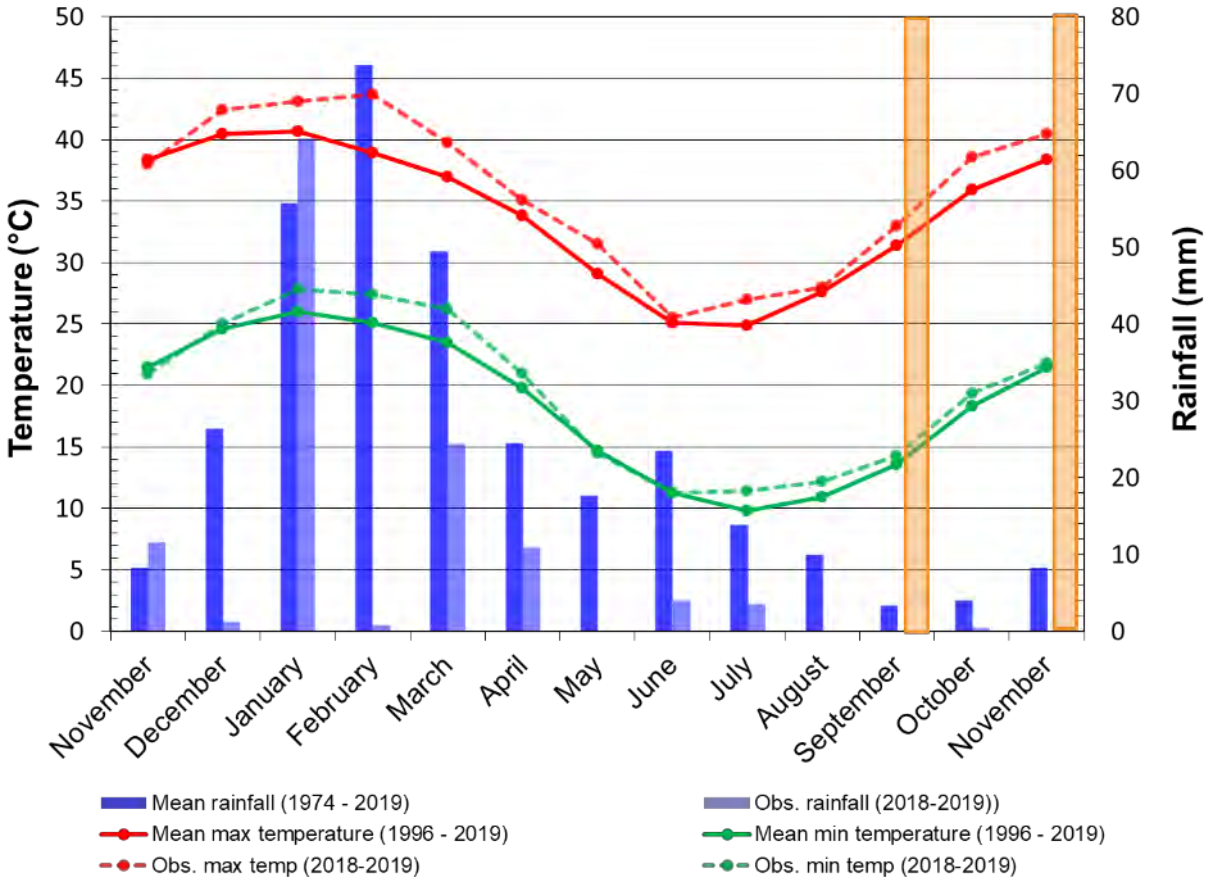


Figure 2.1: Long term average and current (2018-2019) climatic data at Paraburdoo Aero Station (data from BoM 2019*)

*Note: Approximate survey timing is indicated by orange boxes.

Table 2.1: Daily climate data recorded at Paraburdoo (Station 001785) prior and during the survey period

Date	Survey timing	Temperature (°C)		Rainfall (mm)	Humidity (%)	
		Min	Max		900	1500
10/09/2019	Prior survey	16.3	37.1	0	25	12
11/09/2019	Prior survey	18	36.4	0	25	9
12/09/2019	Prior survey	14.6	35.9	0	12	6
13/09/2019	Prior survey	13.2	35.6	0	7	2
14/09/2019	Prior survey	10.5	35.3	0	6	3
15/09/2019	Prior survey	12.6	35.7	0	10	4
16/09/2019	Prior survey	13	36.5	0	10	5
17/09/2019	Prior survey	13.9	35.9	0	23	9
18/09/2019	Prior survey	14.2	36.4	0	11	8
19/09/2019	Prior survey	17.2	28.3	0	55	20
20/09/2019	Prior survey	13.9	25.9	0	25	9
21/09/2019	Prior survey	14.7	27.6	0	12	6
22/09/2019	Prior survey	15	26.6	0	13	9
23/09/2019	Prior survey	15.7	30.6	0	12	9
24/09/2019	During survey	17.2	30.8	0	31	13
25/09/2019	During survey	14	32.9	0	23	13
26/09/2019	During survey	14.3	35.4	0	16	10
27/09/2019	During survey	13.1	33.8	0	16	12
28/09/2019	During survey	12.4	28.7	0	32	18
29/09/2019	During survey	11	35.7	0	19	8
30/09/2019	During survey	13.8	36.8	0	27	9
1/10/2019	During survey	14.5	37.5	0	14	12
2/10/2019	During survey	17.3	39	0	12	11
3/10/2019	During survey	17.1	39.7	0	15	10
4/10/2019	During survey	20	34.3	0	20	21
5/10/2019	During survey	17.2	34.4	0	22	9
6/10/2019	During survey	16.6	39.2	0	13	7
7/10/2019	During survey	19.6	39.9	0	13	8
8/10/2019	During survey	27.5	41.3	0	13	9
9/10/2019	During survey	20.7	42.4	0	13	6
10/10/2019	During survey	21.9	40.3	0	13	8
11/10/2019	During survey	24.5	40.4	0	12	8
12/10/2019	During survey	21.5	37.1	0	17	11
13/10/2019	During survey	18.5	37.1	0	20	11
14/10/2019	During survey	17.8	37	0	16	10

2.3 VHF Tracking System

VHF tracking typically comprises two components, a transmitter and a receiver (in this case a receiver tower). The transmitter is programmed to regularly emit a high frequency sound that can be detected by a specially tuned receiver when within an appropriate distance.

The automated VHF tracking system used in this study was developed and implemented using two types of fixed-location VHF tracking towers, omni-directional and directional. The key to the system was the use of digitally coded transmitters which all operate off the same frequency, thus allowing the towers to

continuously receive VHF transmissions from all the tags when in range. Unlike traditional VHF transmitters, which are differentiated by the frequency they operate on, the digitally encoded transmitters are differentiated by a digital code, which can only be read by a specifically programmed computer and identified within a digital sound transmitter database. Each tower comprised an onboard SensorGnome computer powered by a 12-volt solar-charged battery.

The system for which the SensorGnome operated, and the transmitters were identified, was the Motus Wildlife Tracking System. Motus is an international collaborative research network, primarily based in North America, that uses an automated radio telemetry array to track the movement and behaviour of small flying organisms (Taylor *et al.*, 2017). The purpose of Motus is to facilitate landscape-scale research and education on the ecology and conservation of migrating animals (Taylor *et al.*, 2017).

2.3.1 VHF Transmitters

Lotek digitally encoded VHF radio-transmitters (model NTQB2-2) were used for the system. Transmitters were set to operate on a frequency of 151.500 MHz, as is the official Motus operating frequency along the East Asian Flyway (Bird Studies Canada, 2019). Each transmitter was programmed to emit a transmission every 4.7 seconds, over a 24-hour period, and therefore had an expected battery life of 30 days. Prior to deployment, digital codes of each transmitter were recorded and submitted to Motus for transmitter registration. Each transmitter weighed approximately 0.35 g (grams), well below 5% of the average weight of a Pilbara Leaf-nosed Bat (Churchill, 2008), which is generally accepted as the international ethical limit for tracking of wildlife (O'Mara *et al.*, 2014). It should be noted that the detectability of any given transmitter is influenced by a number of factors including, but not limited to, temperature, background noise, obstructions between the transmitter and the antenna (including orientation of the bat) and orientation of the transmitter's antenna. Long periods of inactivity (i.e. no detections for several hours) are considered to likely represent times when the individual temporarily moved outside of the detection area and/or was obstructed from detection due to the surrounding terrain (i.e. caves).

2.3.2 Omni-directional Towers

A total of 27 (24 full-size and three mini) omni-directional towers were constructed throughout the Project Area (Table 2.2, Figure 2.5, Appendix A). Each full-size tower consisted of a single mast, measuring 3 to 6 meters (m) in height, and was fitted with a 3 m high collinear omni-directional antenna (Figure 2.2). The mini omni-directional towers were fitted with shorter masts, measuring approximately 1 m (Figure 2.3). The mast of each antenna was secured to the ground using a pegged baseplate and support struts and was weighed down with heavy material.

The sensitivity of each full-size omni-directional tower was adjusted to record transmissions within a distance of approximately 1-2 km (Figure 2.5), giving an approximate minimum detection area of 314 hectares (ha) for each tower. It should be noted that this is an indicative distance only as the detection area for each tower varies depending on surrounding terrain. Three of the 27 towers were mini omni-directional towers with shorter antennas and a much smaller detection range, detecting transmissions within a distance of approximately 250 m (Figure 2.5, Table 2.2). This equates to a minimum detection area of approximately 20 ha.

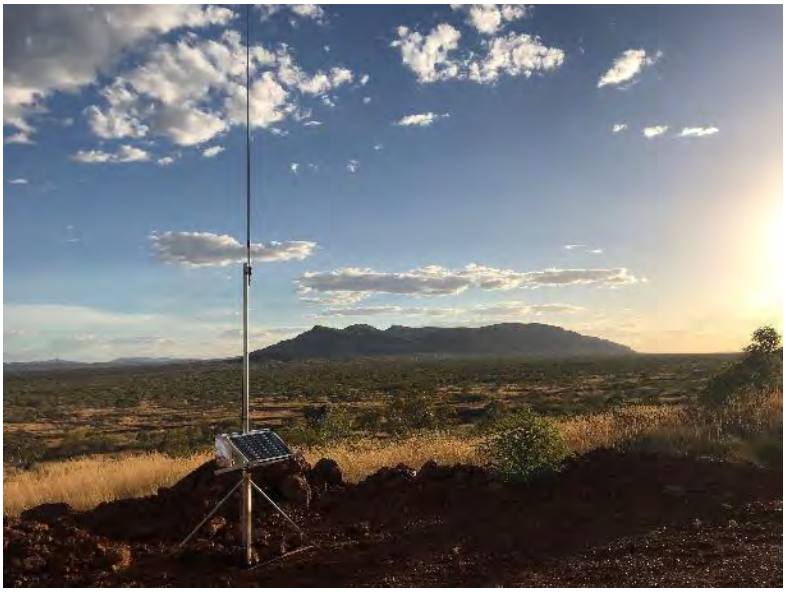


Figure 2.2: Example of a full-sized omni-directional tower

Figure 2.3: Example of a mini omni-directional tower

2.3.3 Directional Towers

A total of eight directional towers were established (Table 2.2, Figure 2.4, Appendix A). Each directional tower consisted of a single mast, measuring 3 to 6 meters in height, and fitted with 2-4 custom tuned 8-element directional Yagi antennas. The mast of each tower was secured to the ground using a pegged baseplate and support struts and was weighed down with heavy material. Additional guy-wires were fixed to the main mast from the Yagi antennas. Where multiple antennas were mounted to a single mast, antennas were directed with consideration to the study objectives and surrounding terrain.

The accuracy and maximum detection distance of each antenna was dependent on the surrounding terrain, although it was expected that the detection area for most directional tower antennas was approximately 5 km (Figure 2.5). It should be noted that this is an indicative distance only, and the detection area for each tower varied depending on a number of factors. Environmental variables which

can affect the potential detection range of each omni-directional and directional antennas include dust, humidity, air temperature, air pressure, air stability and moon position. Other variables include the elevation of a tower in relation to the surrounding landscape and the proximity of the tower and the direction of its antennas in relation to geographic barriers such as hills, which can block signals. The indicative detection area displayed in Figure 2.5 was developed using a 10° buffer on the known bearing of each antenna over a distance of 5 km.

Figure 2.4: Example of a directional tower with four antennas

2.3.4 Tower Configuration

Each of the 35 towers established within the Project Area (27 omni-directional towers and eight directional towers) was named using the last four digits of their corresponding onboard computer (Table 2.2, Figure 2.5, Appendix A). Omni-directional towers were used as the primary tool in the array, enabling an almost-conclusive confirmation of an individual being within a minimum 314 ha area around the tower at a given time.

The configuration of the towers was optimised to identify significant Pilbara Leaf-nosed Bat habitats within the Project Area, particularly with regards to foraging habitats:

- 13 omni-directional towers were set-up at Western Range to determine the relative importance of this area as a roosting and foraging habitat for Pilbara Leaf-nosed Bats. One tower (53E7) was located in front of Cave 14, a diurnal roost for Pilbara Leaf-nosed Bats.
- Three omni-directional towers (4135, AC48 and 5BE8) were placed near the Ratty Springs Roost, a permanent diurnal roost for Pilbara Leaf-nosed Bats. The roost is located where Pirraburdu Creek cuts through Western Range, an area which likely represents suitable foraging grounds for the bats. A permanent freshwater pool is also located in the nearby vicinity of the tower, potentially providing drinking opportunities for the target bat species.

- Three omni-directional towers (CDAD, B893 and 522B) were placed in the flats just north/ north-east of Western Range to assess whether Pilbara Leaf-nosed Bats leave the upper ranges to forage in the plains to the north.
- One tower (CCD3) was positioned at Kelly's Pool, an open water body that potentially provides drinking and foraging opportunities for the Pilbara Leaf-nosed Bats. A further omni-directional tower was placed at the Paraburdoo Waste Water Plant (8AC3), as the plant might also represent a water resource to the bats.
- One omni-directional tower (9E54) was set-up at the Paraburdoo Gas Pipeline Lease in the flats to the south-east of the Paraburdoo Ranges to assess whether Pilbara Leaf-nosed Bats frequent this area.
- One omni-directional tower (9869) was located within Seven Mile Creek just outside of Paraburdoo township to monitor Pilbara Leaf-nosed Bat movements along the creekline.
- Two towers (7295, F06C) were positioned at the base of Mount Truchanas, located 35 km north of the Project Area. Several caves available to the Pilbara Leaf-nosed Bat are located in the immediate vicinity of the two towers (Biologic, 2018). The two towers aimed to identify any regional movements of Pilbara Leaf-nosed Bats between the roost sites at Western Range and Mt Truchanas.
- One tower (E510) was placed in upper ranges at Turee. Several Pilbara Leaf-nosed Bat day and night roosts are located in the immediate vicinity of the tower. The tower aimed to identify any regional movements of Pilbara Leaf-nosed Bats between the roost sites at Western Range and Turee.
- The remaining omni-directional tower (B939) was positioned at Eastern Range to assess whether Pilbara Leaf-nosed Bats are utilising the upper ranges in the eastern section of the Project Area.

Directional towers enable the approximate direction of an individual to be determined and have a larger range than omni-directional towers. However, they provide less accuracy with regard to distance, and thus location. Therefore, the directional towers were used to indicate broad movements of bats outside the detection areas of omni-directional towers. In some instances, the detection areas of these directional towers overlap with the detection areas of the omni-directional towers (Figure 2.5).

- One directional tower (9E15) was placed in upper ranges at the western section of Western Range. Both antennas faced towards the south to monitor Pilbara Leaf-nosed Bat movements in the plains in the south of Western Range.
- One directional tower (B549) was placed in upper ranges in the western section of Western Range. All three antennas faced towards the north to monitor Pilbara Leaf-nosed Bat movements from the ranges towards the plains in the north.
- One directional tower (2EA7) was established south of the Western Ranges to identify potential foraging grounds in the southern plains. The three antennas of the tower faced Six Mile Creek

and several other drainage/creek lines and pools which may represent suitable Pilbara Leaf-nosed Bat foraging habitats.

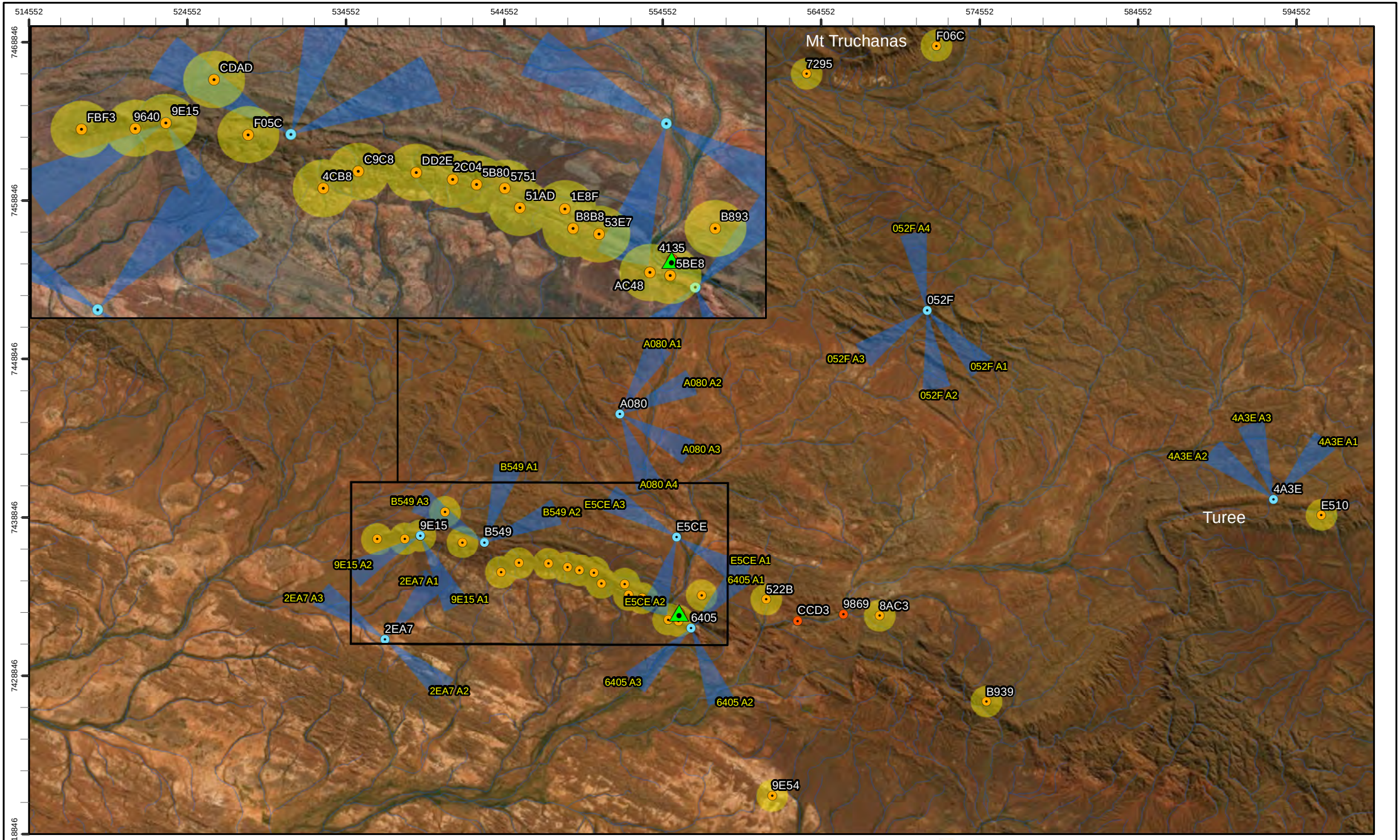
- One directional tower (6405) was placed where Pirraburdu Creek cuts through the Western Ranges to identify potential flight paths from the Western Ranges to the plains in the south (along Pirraburdu Creek). One 6405 antenna also pointed towards a small drainage line north-east of Western Range which may represent suitable foraging grounds for the Pilbara Leaf-nosed Bats.
- One tower (4A3E) was positioned in the upper Turee ranges at the very eastern section of the Project Area. Several Pilbara Leaf-nosed Bat day and night roosts are located in the immediate vicinity of the tower. The tower aimed to identify any regional movements of Pilbara Leaf-nosed Bats between the roost sites at Western Range and Turee, and identify potential foraging grounds along Bellary Creek.
- Two directional towers (E5CE and A080) were placed in the plains to the north of the Paraburdoo Ranges to identify flight paths and potential foraging grounds along Pirraburdu Creek.
- The remaining directional tower (052F) was placed in a mountainous area 18 km north-east of Paraburdoo township to identify potential habitat use in the upper ranges.

Table 2.2: VHF tower locations and details

Area	Area description	Tower ID	Antenna Direction	Date Installed	Date Deactivated	Location	
						Latitude	Longitude
Omni-directional towers							
Western Range	Located in upper ranges at the most western section of Western Range.	FBF3	-	02/09/19	-	-23.171	117.357
Western Range	Located within Six Mile Creek where it cuts through the western section of Western Range. Near Caves 7-10.	9640	-	02/09/19	-	-23.171	117.374
Western Range	Located in upper ranges at the western section of Western Range.	F05C	-	22/02/19	-	-23.173	117.410
Western Range	Located at southern, lower lying area of Western Range.	4CB8	-	25/02/19	-	-23.190	117.433
Western Range	Located in upper ranges in central area of Western Range. Near Caves 12 and 15.	C9C8	-	04/09/18	-	-23.185	117.444
Western Range	Located in upper ranges in central area of Western Range. Near Cave 13.	DD2E	-	04/09/18	-	-23.185	117.463
Western Range	Located in upper ranges in central area of Western Range.	2C04	-	04/09/18	-	-23.187	117.474
Western Range	Located in upper ranges in eastern section of Western Range.	5B80	-	24/02/19	-	-23.189	117.482
Western Range	Located in upper ranges in eastern section of Western Range. Near Caves 6, 16 and 17.	5751	-	22/02/19	-	-23.190	117.491
Western Range	Located in upper ranges in eastern section of Western Range. Near Caves 4 and 5.	51AD	-	21/02/19	-	-23.196	117.495
Western Range	Located in upper ranges in eastern section of Western Range.	1E8F	-	02/09/19	-	-23.197	117.510
Western Range	Located in upper ranges in eastern section of Western Range.	B8B8	-	23/02/19	-	-23.203	117.512
Western Range	Located within valley at eastern section of Western Range. Near Cave 14.	53E7	-	21/02/19	-	-23.205	117.520
Ratty Springs/ Pirraburdu Creek	A Permanent Diurnal Roost for Pilbara Leaf-nosed Bats, located where Pirraburdu Creek cuts through the Paraburdoo Ranges. A permanent water pool (Ratty Springs) is also located in the area.	4135 (mini)	-	02/09/19	-	-23.213	117.544
Ratty Springs/ Pirraburdu Creek	Upper ranges at the eastern section of Western Range, overlooking Pirraburdu Creek and the Ratty Springs Roost.	AC48	-	25/02/19	-	-23.217	117.537
Ratty Springs/ Pirraburdu Creek	Upper ranges at the most eastern section of Western Range, overlooking Pirraburdu Creek and the Ratty Springs Roost.	5BE8	-	21/02/19	-	-23.218	117.543
Flats north of Western Range	Overlooking Pirraburdu Creek north of the Western Ranges.	B893	-	02/09/19	-	-23.203	117.557
Flats north of Western Range	Overlooking Six Mile Creek north of the western section of Western Ranges.	CDAD	-	02/09/19	-	-23.156	117.399
Flats north-east of Western Range	Located in tributary to Bellary Creek, 6 km east of the Ratty Springs Roost.	522B	-	30/09/19	-	-23.205	117.597
Kelly's Pool	150 m long waterbody. Potential foraging/ drinking site.	CCD3 (mini)	-	02/09/19	-	-23.217	117.616

Area	Area description	Tower ID	Antenna Direction	Date Installed	Date Deactivated	Location	
						Latitude	Longitude
Seven Mile Creek	Within Seven Mile Creek near Paraburdoo township.	9869 (mini)	-	02/09/19	-	-23.213	117.645
Paraburdoo Waste Water Plant	Open wastewater plant. Potential foraging/ drinking site.	8AC3	-	02/09/19	-	-23.214	117.667
Flats south-east of Western Range	Located in plains to the south-east of Western Range.	9E54	-	02/09/19	-	-23.317	117.601
Eastern Range	Located in upper ranges.	B939	-	02/09/19	-	-23.263	117.733
Turee Roosts	Located in the upper Turee ranges near Bellary Creek. Several Pilbara Leaf-nosed Bat day and night roosts are located in the immediate vicinity of the tower.	E510	-	02/09/19	-	-23.155	117.939
Mt Truchanas Roosts	Located at the south-western base of Mt Truchanas. Several Pilbara Leaf-nosed Bat day and night roosts are located in the nearby vicinity.	7295	-	02/09/19	-	-22.905	117.621
Mt Truchanas Roosts	Located at the south-eastern base of Mt Truchanas. Several Pilbara Leaf-nosed Bat day and night roosts are located in the nearby vicinity.	F06C	-	02/09/19	-	-22.889	117.700
Directional towers							
Western Range	Located in upper ranges at the western section of Western Range. Both antennas are facing towards the flats in the south.	9E15	SE - 153º SW - 240º	04/09/18	-	-23.169	117.384
Western Range	Located in upper ranges at the western section of Western Range. All three antennas are facing towards the flats in the north.	B549	N - 17º NE - 67º NW - 303º	23/02/19	-	-23.173	117.423
Flats to south of Western Range	Located in the flats to the south of Western Range, antennas are facing towards several drainage lines.	2EA7	NE - 40º SE - 130º NW - 305º	04/09/18	-	-23.228	117.362
Western Range	Located in upper ranges in eastern section of Western Range. Antennas are facing towards a minor drainage line (NE) and the flats associated with Pirraburdu Creek (S, NW).	6405	NE - 43º S - 158º NW - 226º	04/09/18	-	-23.222	117.551
Flats north of Western Range	Overlooking Pirraburdu Creek north of the Ranges.	E5CE	SE - 120º S - 197º NW - 300º	04/09/18	-	-23.170	117.542
Flats north of Western Range	Overlooking Pirraburdu Creek north of the Ranges.	A080	NE - 30º E - 66º SE - 119º S - 158º	24/02/19	-	-23.100	117.506

Area	Area description	Tower ID	Antenna Direction	Date Installed	Date Deactivated	Location	
						Latitude	Longitude
Ranges north-east of Paraburdoo township	Located in upper Ranges 18 km north-east of Paraburdoo.	052F	SE - 136º S - 173º SW - 235º N - 350º	25/02/19	-	-23.040	117.695
Turee Roosts	Located in the upper Turee ranges near Bellary Creek. All antennas are facing north towards Bellary Creek.	4A3E	NE - 41º NW - 308º N - 343 º	02/09/19	-	-23.146	117.910



Legend

- Roost
- Watercourse

VHF Towers

- Directional
- Omni-directional
- Mini Omni-Towers

Indicative Detection Area

- Directional
- Omni-directional
- Mini Omni-directional

biologic Environmental Survey

N

1:300,000

0 3.5 7 14 km

Rio Tinto Iron Ore

Western Range PLNB VHF Study

Figure 2.5: Tower Configuration

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 13/01/2020

2.4 Bat Capture and Processing

2.4.1 Capturing

Once the VHF tower array was established, twenty bats were trapped at the Ratty Springs Roost for the attachment of transmitters. Trapping was completed during Phase 1 on the 24th of September 2019, between 1800 and 2200.

Individual Pilbara Leaf-nosed Bats were captured by placing a mist net across the entrance of the Ratty Spring Roost just prior to civil twilight (typical emergence time for the species; Bullen, 2013). The net was only placed across the entrance once Pilbara Leaf-nosed Bats had been confirmed leaving the roost, to avoid significant bi-catch of non-target species. Captured bats were immediately removed from the net and stored in calico capture bags for processing. The mist net was removed periodically from the cave entrance while bats were being captured to ensure other bats could exit freely and reduce overall disturbance to the colony.

2.4.2 Processing

Prior to attachment of transmitters, individuals were sexed, had a DNA sample taken (left wing clip) and their forearm lengths were measured. Transmitters were glued to the backs of each bat, between the shoulder blades, as recommended and reported by Mackenzie *et al.* (2015); O'Mara *et al.* (2014). Each transmitter weighed approximately 0.35 g (grams), well below 5% of the average weight of a Pilbara Leaf-nosed Bat (Churchill, 2008) which is generally accepted as the international ethical limit for tracking of wildlife (O'Mara *et al.*, 2014). Prior to attachment, the fur of the bat was trimmed and cleaned using an alcohol-based cleanser. Transmitters were attached using a latex-based skin adhesive, Permatype, which was applied following the manufacturer's recommendations. Based on previous studies summarised by O'Mara *et al.* (2014), transmitters attached using this method were predicted to last for an average of 8-9 days.

All bats were released at the site of capture immediately after being processed and no bats were held for longer than 30 minutes prior to release.

2.5 Data Analysis

Data was directly downloaded from each tower in November 2019. Once downloaded, the recording files were submitted and processed by Motus to produce a complete database of unique detections for each tower. Tower performance such as on/off cycles of receivers, GPS, or antenna were also compiled and summarised. Once processed, raw detection data was analysed in R, a language for statistical computing (R Core Team, 2018), following methods and scripts developed and recommended by Crewe *et al.* (2018). Additional packages (libraries of source code) that were used within the R environment included: Brzustowski and Lepage (2018) for Motus data access and some manipulation; (Wickham H. *et al.*, 2018) for most data manipulation (including summaries); and Kahle and Wickham (2013) and Wickham (2017) for plots.

For each detection of a single transmitter by a single antenna, the number of uninterrupted, consecutive transmissions was recorded, referred to as the 'run-length' (*rl*). According to Crewe *et al.* (2018) detections with very low run lengths may actually be random radio noise (static) and falsely interpreted

as the transmission of a tag. Crewe *et al.* (2018) suggests filtering out detections with a run length of 2, although acknowledges that in this process a number of true detections will be lost. More recently, Motus advises to filter out any detections with a run length of less than 3 (Berrigan, 2019). To avoid the loss of potentially meaningful data and interpretation of meaningless data, the following precautions were undertaken. For the most part flight movements are discussed without *rl*'s of less than 3. However, where they are likely to have substantially altered the flight path, we have included them in text but stated the *rl.* Where they do not alter the flight path, they are not discussed. Where such detections appear out of context (indicated by prior and following detections) such detections have been ignored.

Due to the high number of raw detections recorded, all uninterrupted (>60 seconds) and consecutive transmissions (*rl*'s*)* at the same receiver/antenna were aggregated, for each bat and for each night, to single detection events. All results presentation and interpretation hereafter refer to the detection event, unless otherwise stated.

The detection period was calculated for each bat as the time between its first and last detection on any of the towers during the sampling period. The sampling period describes the maximum detection period of all the bats combined, and thus represents the longest time a tag was knowingly attached on a bat during the study. Indicative roosting locations of the bat species during the sampling period were obtained as follows. A bat was considered roosting near a tower if its first detection of the night and its last detection in the previous night were recorded at the same tower. Tagged bats that did not record any detections during the survey period were excluded from analysis.

3 RESULTS AND DISCUSSION

3.1 Bat Capturing and Processing

Twenty Pilbara Leaf-nosed Bats (comprising 9 males and 11 females) were captured and tagged at the Ratty Springs Roost during Phase 1 (Table 3.1). As 14 Pilbara Leaf-nosed Bats were tagged in the 2018 study, this increased the total number of tagged bats within the Project Area to 34 individuals. The average forearm length of captured individuals was 47.6 mm, whereby the average forearm length of females was 47.8 mm and the average forearm length of males was 47.2 mm (Table 3.1). None of the males exhibited signs of sexual activity (i.e. swollen testes) and none of the females exhibited signs of pregnancy.

Table 3.1: Pilbara Leaf-nosed Bats tagged during the study

Individual ID	Tag ID	Tagging date	Sex	Wing clip (Y/N)	Forearm length (mm)
37987	221	24/09/19	M	Y	46
37988	222	24/09/19	F	Y	46
37989	223	24/09/19	F	Y	49
38451	226	24/09/19	F	Y	48
37991	228	24/09/19	F	Y	46
37992	231	24/09/19	M	Y	48
37993	232	24/09/19	M	Y	46
37994	233	24/09/19	F	Y	49
37995	234	24/09/19	M	Y	47
37996	235	24/09/19	F	Y	47
37997	236	24/09/19	F	Y	49
37998	237	24/09/19	F	Y	47
37999	238	24/09/19	M	Y	48
38001	240	24/09/19	M	Y	47
38455	249	24/09/19	F	Y	49
38459	256	24/09/19	F	Y	49
38014	260	24/09/19	M	Y	49
38015	261	24/09/19	F	Y	47
38016	262	24/09/19	M	Y	47
38018	264	24/09/19	M	Y	47
Average					**47.6**

3.2 Bat Activity

3.2.1 General

A total of 88,382 raw detections were recorded from all 20 tagged bats between the 24th of September (night of tagging) and the 14th of October 2019. The 88,382 detections were aggregated into 2,574 unique detection events – the results of which are reported on hereafter. Each Pilbara Leaf-nosed Bat individual was recorded by an average of 128.7 detection events over the sampling period, with a minimum of 32

detections (individual 37987, male) and a maximum of 248 detections (individual 37988, female) (Table 3.2).

Table 3.2: Overview of Pilbara Leaf-nosed Bat detections

Bat ID	Detection events (aggregated)			Sampling Length (nights)
	First	Last	Total	
37987	24/09/2019 (pm)	29/09/2019 (am)	32	5
37988	24/09/2019 (pm)	06/10/2019 (am)	248	12
37989	24/09/2019 (pm)	02/10/2019 (am)	123	8
38451	24/09/2019 (pm)	04/10/2019 (am)	45	10
37991	24/09/2019 (pm)	29/09/2019 (pm)	107	6
37992	24/09/2019 (pm)	01/10/2019 (am)	195	7
37993	24/09/2019 (pm)	28/09/2019 (pm)	123	5
37994	24/09/2019 (pm)	14/10/2019 (pm)	171	21
37995	24/09/2019 (pm)	26/09/2019 (pm)	39	3
37996	24/09/2019 (pm)	05/10/2019 (am)	246	11
37997	24/09/2019 (pm)	30/09/2019 (am)	75	6
37998	24/09/2019 (pm)	04/10/2019 (am)	86	10
37999	24/09/2019 (pm)	04/10/2019 (pm)	188	11
38001	24/09/2019 (pm)	03/10/2019 (am)	179	9
38455	24/09/2019 (pm)	03/10/2019 (am)	180	9
38459	24/09/2019 (pm)	30/09/2019 (pm)	155	7
38014	24/09/2019 (pm)	01/10/2019 (pm)	80	8
38015	24/09/2019 (pm)	01/10/2019 (pm)	181	8
38016	24/09/2019 (pm)	29/09/2019 (pm)	39	6
38018	24/09/2019 (pm)	28/09/2019 (pm)	82	5
Average			**128.7**	**8.4**
Total			**2,574**	**167**

On average, individuals were detected for 8.4 nights, with a minimum detection period of three nights (individual 37995, male) and a maximum detection period of 21 nights (individual 37994, female) (Table 3.2). The sampling duration is in line with previous studies (summarised by O'Mara *et al.* (2014)) that estimated that transmitters remain attached to bats for an average of 8-9 days, and is also similar to the sampling length obtained in the 2018 study at Western Range (10.6 days, Biologic 2019).

The activity for each Pilbara Leaf-nosed Bat individual over the course of the sampling period is shown in Figure 3.1. Most of the individuals were detected regularly until the end of their respective detection periods, with short periods of inactivity most likely representing times when individuals were outside the detection area, either in microhabitats that restrict transmitter signal (i.e. caves) or outside of the detection area completely. Three Pilbara Leaf-nosed Bats (individual 37988, 37989 and 37998) were not detected on one night, and one bat (individual 38451) was not detected on six of the nights, suggesting that these individuals either did not leave their roost during this time or that they temporarily vacated the Project Area and foraged and roosted elsewhere (Figure 3.1).

The detection period of most Pilbara Leaf-nosed Bats was substantially lower than the anticipated battery life of a single tag (~30 days). Thus, it can be confidently assumed that the transmitters either became dislodged or that individuals migrated out of the detection areas. For this reason, the average possible detection period is likely to be less than the actual average, as an unknown number of individuals are likely to have vacated the area and not returned prior to the tag detaching.

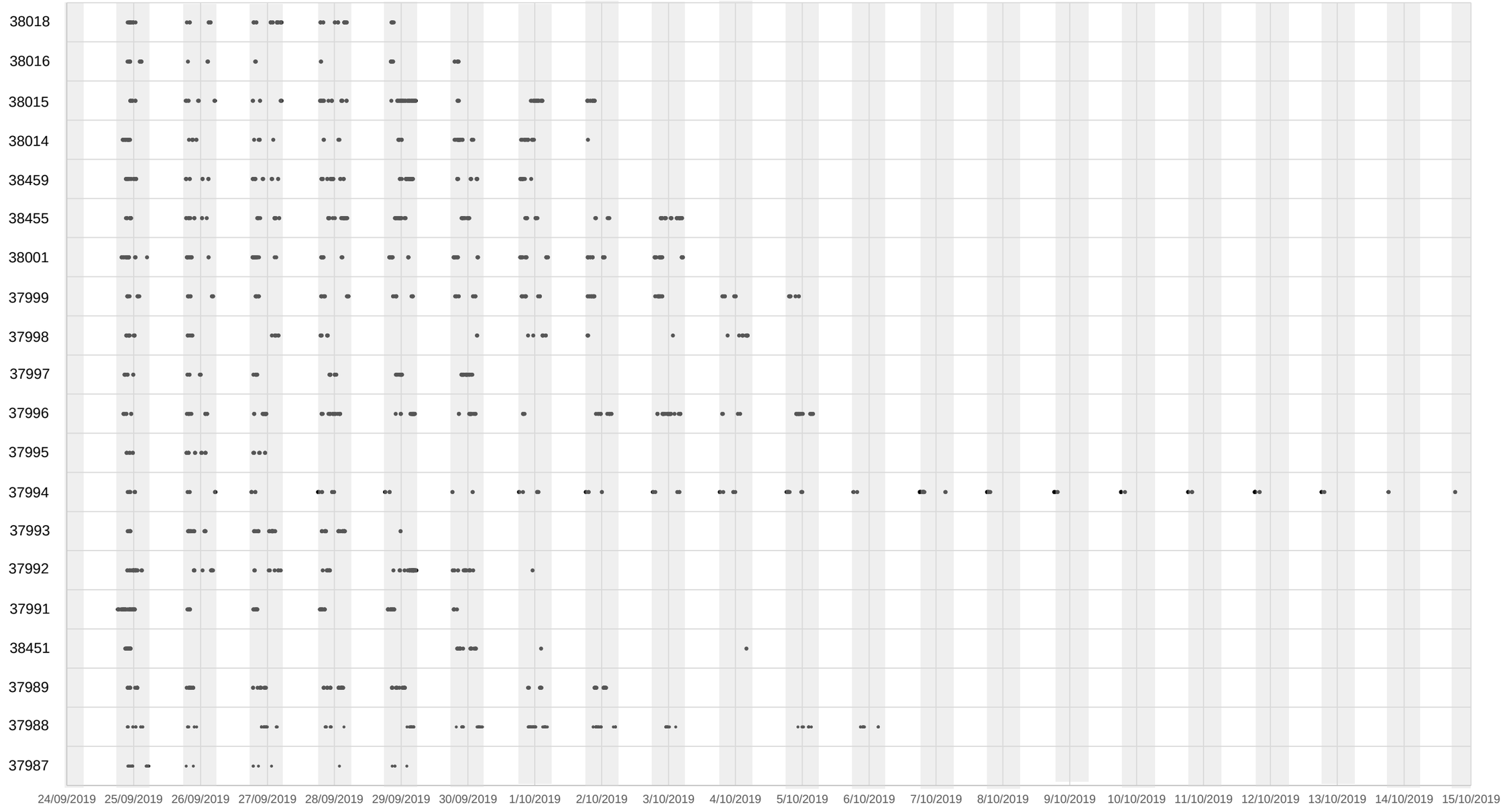


Figure 3.1: Bat activity, per individual, over the course of the sampling period

Note: Each black dot represents a unique detection event for that individual. Nights are shaded in grey.

3.2.2 Activity per Tower

Tower functionality

Tower activity was inferred based not only on the presence of detection events with a run length >3, but also through the presence of "noise" via pulse count plots, which infers that the tower was receiving signals. All towers were fully operational during their respective deployment periods (see Table 2.2), and therefore had the capacity to receive tag detections. Pulse counts for four towers within the Project Area are shown below in Figure 3.2 as examples of activity levels of operational towers during the survey.

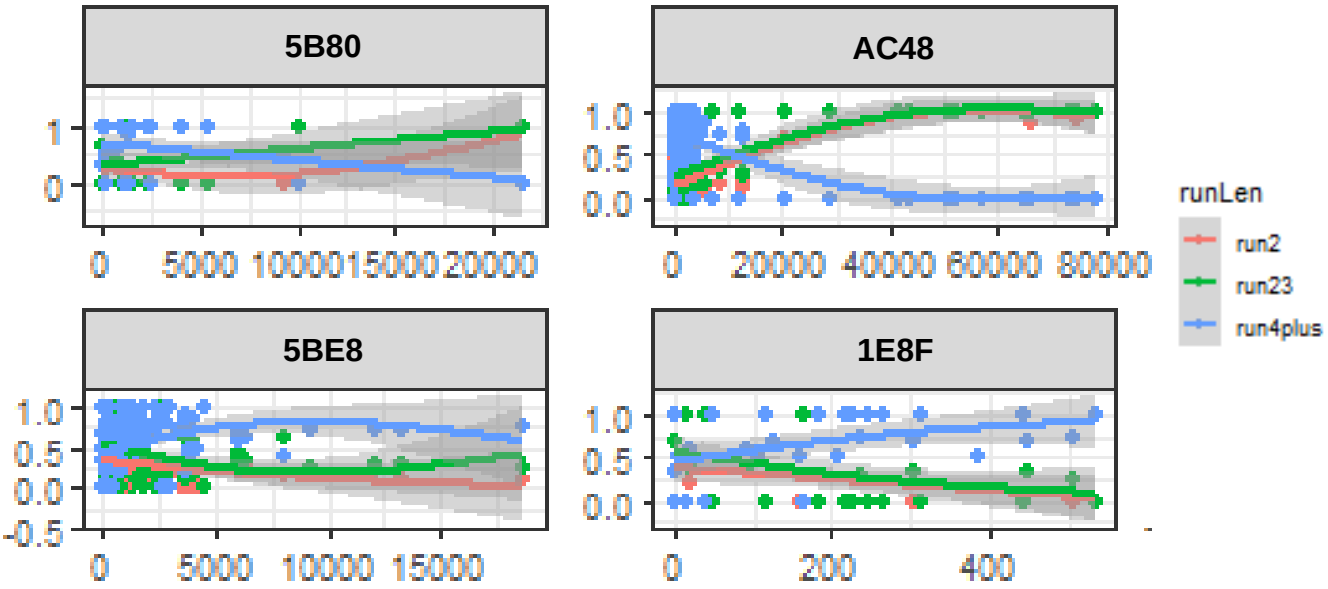


Figure 3.2: Examples of pulse counts, representative of tower functionality

Note: The lines represent "true detections", and the points are "noise" detected by the tower indicating functionality

Pilbara Leaf-nosed Bat tower activity

Of the 35 towers installed throughout the Project Area, 31 towers received Pilbara Leaf-nosed Bat detections. The number of detections for each tower and bat is shown in Table 3.3, and the total duration of all detection events for each tower and bat is shown in Table 3.4. Due to the large number of towers installed throughout the Project Area, only towers that received detections are displayed in the tables. Table 3.5 and Table 3.6 represent heat maps of the number and duration of all detection events for each significant area and for each bat.

Table 3.7 shows the time bats were detected by the tower array relative to their nightly activity periods, and the estimated percentage of time they spent outside of detection range of all towers installed throughout the Project Area. On average, bats were only detected for approximately 30.5% of their nightly activity period, with approximately 70% or their time spent outside of the detection range of all towers (Table 3.7).

Table 3.3: Total number of detection events at each tower and for each bat

Bat ID	2EA7	FB F3	96 40	9E 15	9E15		CD AD	F0 5C	B549			4C B8	5B 80	57 51	51 AD	1E 8F	B8 B8	53 E7	AC 48	41 35	5B E8	6405			B8 93	E5CE			A080				052F			52 2B	CC D3	98 69	8A C3	B9 39	9E 54	72 95	F0 6C	Total
	A2				A1	A2			A1	A2	A3											A1	A2	A3		A1	A2	A3	A1	A2	A3	A4	A2	A3	A4								
37987																			10	8	14																						32
37988					1	2						1	1			1		2	56	24	44	14	16	21	10	10	4	2				2	14	10		3	2		5	2	1			248
37989	3	1			3	3	3	3	5	9	10	2	5	2	3	7	5	5	15	9	20	1					6						3									123
38451	1	1			2	1	1	1	1	2	2		1			1			2	5	5	1	5	4	2		3					1	2					1				45
37991										1						4		1	22	17	20				20		20						2									107
37992																1	1	7	47	23	41	15	2	7	11	9	7	1				3	7	6		1	2	1	2	1			195
37993										2						7	1	6	21	10	21				20	2	24	2						7									123
37994																		16	45	34	49				3	7	9					7		1								171
37995																		1	11	8	11	2			1	1	2					2										39
37996	2				2	3	1		2	2	3	1			1	4	2	4	51	38	58	29	6	7	3	4	10	3					8		2							246
37997									5	6	4					5		2	11	8	14	5				2	5	2					6									75
37998	1		1	1	1	4			2	2	4		1					1	22	14	21	4		6			1															86
37999																			31	27	36				46		48															188
38001																		46	28	24	31				3	2	45															179
38455									3	7	1					2		2	16	18	20	1			10	15	17	11	2	13	16	15		8	1					1	1	180
38459						1							1		1	2	1	7	42	37	41	1	2	3	1	2	9	1				2		1								155
38014																2		14	27	8	27						2															80
38015	3			1	2	2	1	1	1	1	2	2	2	1	3	6	2	9	32	34	39	1	5	8		5	11	2				1		4								181
38016																1		1	8	3	9				10		7															39
38018																1			19	8	20	4	2	2	2	2	13	1				4	1	1		2						82
Total	**10**	**2**	**1**	**2**	**11**	**16**	**6**	**5**	**19**	**32**	**26**	**6**	**11**	**3**	**8**	**44**	**12**	**124**	**516**	**357**	**541**	**78**	**38**	**58**	**142**	**61**	**243**	**25**	**2**	**13**	**16**	**37**	**22**	**59**	**1**	**6**	**6**	**1**	**7**	**4**	**1**	**1**	**1**	**2574**

Note: Only towers with detections are listed. Towers are listed from west to east.

Table 3.4: Total detection event duration (in minutes) at each tower and for each bat

Bat ID	2EA7	FB F3	96 40	9E 15	9E15		CD AD	F0 5C	B549			4C B8	5B 80	57 51	51 AD	1E 8F	B8 B8	53 E7	AC 48	41 35	5B E8	6405			B8 93	E5CE			A080				052F			52 2B	CC D3	98 69	8A C3	B9 39	9E 54	72 95	F0 6C	Total
	A2				A1	A2			A1	A2	A3											A1	A2	A3		A1	A2	A3	A1	A2	A3	A4	A2	A3	A4								
37987																			49	37	83																						169
37988					2	5						2	1			5		6	220	128	449	55	64	377	14	22	8	7				1	30	22		4	1		13	8	3			1449
37989	10	7			24	20	15	6	17	25	46	9	17	6	3	19	13	22	55	35	163	6					7						7									531
38451	1	7			8	13	5	3	1	9	13		2			16			40	11	46	6	20	43	13		13					1	5					3				278
37991										1						16		12	88	61	160				100		82						2									523
37992																5	11	23	232	182	264	95	2	11	23	33	10	2				1	23	15		8	2	>1	7	2			952
37993										13						18	1	10	89	64	95				83	12	275	13						19									692
37994																		89	91	82	268				3	50	106					40		2									732
37995																		14	38	21	38	6			2	13	15					3										151
37996	6				4	3	2		5	6	6	3			1	13	5	7	217	132	382	394	169	44	7	16	43	15						26		2							1510
37997									23	41	8					18		9	19	13	148	28				7	15	7						13									349
37998	4		2	6	4	13			8	14	20		4					2	71	62	105	13		191			1															521
37999																			73	50	119				321		256															820
38001																		250	117	42	126				5	5	639															1183
38455									6	22	1					7		7	46	39	69	7			26	100	57	33	2	54	35	35		11	3					5	3	568
38459						1							1		4	7	3	19	216	156	306	1	10	24	4	5	11	2				4		6								781
38014																6		55	180	14	293						9															557
38015	6			3	7	18	4	2	3	8	8	4	8	3	3	13	4	64	151	93	253	6	34	100		12	29	12				1		15								865
38016																7		1	10	4	37				94		18															171
38018																1			55	15	41	9	2	2	3	8	205	4				4	3	2			2						356
Total	**28**	**14**	**2**	**9**	**49**	**73**	**25**	**10**	**64**	**140**	**103**	**19**	**32**	**9**	**11**	**151**	**37**	**589**	**2059**	**1243**	**3446**	**627**	**301**	**792**	**701**	**283**	**1799**	**95**	**2**	**54**	**35**	**90**	**55**	**145**	**3**	**14**	**5**	**0**	**20**	**13**	**3**	**5**	**3**	**13158**

Note: Only towers with detections are listed. Towers are listed from west to east.

Ratty Springs Roost & immediate surroundings

Towers 5BE8, AC48 and 4135 recorded the highest number of detection events (*n* = 541, 516 and 357 respectively) over the sampling period (Table 3.3, Table 3.5) and were visited by all 20 bats on a regular basis. All three towers were located in the immediate vicinity of the Ratty Springs Roost and were also the towers that recorded the highest total duration of detection events, with bats spending approximately 112.5 hours (~51% of total recorded time) at this location throughout the sampling period (Figure 3.4). This suggests that the Ratty Springs Roost is the most significant feature sampled during the study. The consistency of the data received at this tower indicates that the roost does not only provide a diurnal roosting site for bats, but that it is also used throughout the night. Therefore, next to providing a daytime refuge, the Ratty Springs Roost and the area in the immediate vicinity of the roost is potentially also used as a nocturnal refuge for night resting, feeding and/or social interactions.

Next to frequent detections at 5BE8, AC48 and 4135, the Pilbara Leaf-nosed Bats were frequently detected by towers E5CE A2 (*n* = 243), B893 (*n* = 142), and 53E7 (*n* = 124) (Table 3.3). This suggests that bats frequently circled between towers located in the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges (in the immediate vicinity of the roost) and towers to the immediate north of the Paraburdoo Ranges (also along Pirraburdu Creek), spending a combined total of 154 hours in that area. Bats also occasionally flew into the minor drainage line located 1.3 km south of the Ratty Springs Roost (*n* = 78, Table 3.5), where they spent approximately 10.5 hours (Table 3.6).

Western Range

The 13 omni-directional towers located within Western Range, to the west of the Ratty Springs Roost, received relatively low numbers of detection events throughout the sampling period (Figure 3.3). Of these, towers at the very eastern section of Western Range (between towers 1E8F and 53E7) were visited most frequently (*n* = 180, Table 3.5) which is attributable to their close location to the Ratty Springs Roost. As such, detections at 53E7 (*n* = 124) made up the majority of the 180 detection events recorded at Western Range – east, and this tower is located just 2.5 km west of the Ratty Springs Roost.

Only seven of the 20 bats flew further west to visit the central section of Western Range (area between towers 4CB8 and 51AD, Table 3.5). Towers in the central section of Western Range only recorded a total of 28 detection events. Most detection events represented flybys, as Pilbara Leaf-nosed bats only spent a total of 70 min within that area (Table 3.6).

Towers at the very western section of Western Range (area between towers FBF3 and F05C) were only visited by four of the 20 bats. A combined total of 10 detection events were recorded in that area and represented bats simply flying by the towers without spending time in their vicinity (Table 3.6).

Mt Truchanas and Turee

The detection data suggests that there were limited regional movements of Pilbara Leaf-nosed Bats between the roost sites at Western Range and Mt Truchanas/ Turee during the sampling period. None of the twenty bats visited the towers at Turee (4A3E and E510), and only one bat (individual 38455) visited towers installed at Mt Truchanas (F06C, 7295). This individual flew approximately 40 km north to Mount Truchanas in one of the nights (1 detection at both F06C and 7295), roosted in the vicinity of tower F06C before returning to the Ratty Springs area the following evening. The typical nightly foraging range of

Pilbara Leaf-nosed Bats is thought to be up to 20 km in the dry season, and up to 50 km in the wet season (Bullen, 2013). However, the detection data obtained in this study indicates that Pilbara Leaf-nosed Bats can move much larger distances in one night than previously estimated, also considering that this study was undertaken in a particularly dry year.

Table 3.5: Heat map showing the number of detection events for each Pilbara Leaf-nosed Bat and area

Bat ID	Flats south of Western Range - west	Flats south of Western Range - east	Western Range - west	Western Range - central	Western Range - east	Flats north of Western Range - west	Flats north of Western Range - east	Ratty Springs roost	Drainage line north-east of Ratty Springs Roost	Kelly's Pool, Seven Mile Creek, Wastewater plant	Eastern Range	Turee roosts	Mt Truchanas roosts
37987	0	0	0	0	0	0	0	32	0	0	0	0	0
37988	3	38	0	2	3	0	55	124	14	7	2	0	0
37989	9	0	4	12	17	27	9	44	1	0	0	0	0
38451	4	9	2	1	1	6	8	12	1	0	1	0	0
37991	0	0	0	0	5	1	42	59	0	0	0	0	0
37992	0	9	0	0	9	0	45	111	15	5	1	0	0
37993	0	0	0	0	14	2	55	52	0	0	0	0	0
37994	0	0	0	0	16	0	27	128	0	0	0	0	0
37995	0	0	0	0	1	0	6	30	2	0	0	0	0
37996	7	13	0	2	10	8	30	147	29	0	0	0	0
37997	0	0	0	0	7	15	15	33	5	0	0	0	0
37998	6	6	2	1	1	8	1	57	4	0	0	0	0
37999	0	0	0	0	0	0	94	94	0	0	0	0	0
38001	0	0	0	0	46	0	50	83	0	0	0	0	0
38455	0	0	0	0	4	11	108	54	1	0	0	0	2
38459	1	5	0	2	10	0	16	120	1	0	0	0	0
38014	0	0	0	0	16	0	2	62	0	0	0	0	0
38015	7	13	2	8	17	5	23	105	1	0	0	0	0
38016	0	0	0	0	2	0	17	20	0	0	0	0	0
38018	0	4	0	0	1	0	24	47	4	2	0	0	0
Total	**37**	**97**	**10**	**28**	**180**	**83**	**627**	**1414**	**78**	**14**	**4**	**0**	**2**

Table 3.6: Heat map showing the duration of detection events for each Pilbara Leaf-nosed Bat and area

Bat ID	Flats south of Western Range - west	Flats south of Western Range - east	Western Range - west	Western Range - central	Western Range - east	Flats north of Western Range - west	Flats north of Western Range - east	Ratty Springs roost	Drainage line north-east of Ratty Springs Roost	Kelly's Pool, Seven Mile Creek, Wastewater plant	Eastern Range	Turee roosts	Mt Truchanas roosts
37987	0	0	0	0	0	0	0	169.25	0	0	0	0	0
37988	7.75	444.3	0	3.04	11.42	0	107.38	797.51	55.17	14.31	8.23	0	0
37989	53.33	0	12.69	35	54.2	103.6	13.2	253.11	6.1	0	0	0	0
38451	21.76	63.17	10.41	2.12	15.52	27.35	31.72	97.52	5.88	0	2.5	0	0
37991	0	0	0	0	27.8	1.4	184.5	309.21	0	0	0	0	0
37992	0	12.88	0	0	38.9	0	114.5	678.63	95.49	9.69	2.03	0	0
37993	0	0	0	0	29.23	12.95	402.28	247.62	0	0	0	0	0
37994	0	0	0	0	89.19	0	201.71	441.01	0	0	0	0	0
37995	0	0	0	0	13.7	0	34.38	97.07	6.27	0	0	0	0
37996	13.29	212.79	0	3.83	25.48	19.45	109.51	731.54	393.72	0	0	0	0
37997	0	0	0	0	26.84	71.92	41.67	180.7	28.09	0	0	0	0
37998	21.45	190.56	7.84	3.83	1.72	42.75	1.1	238.62	12.9	0	0	0	0
37999	0	0	0	0	0	0	577.12	242.5	0	0	0	0	0
38001	0	0	0	0	250.03	0	648.36	284.38	0	0	0	0	0
38455	0	0	0	0	13.32	29.47	356.87	153.73	6.58	0	0	0	8.15
38459	1.25	34.17	0	4.53	28.91	0	31.88	678.67	1.48	0	0	0	0
38014	0	0	0	0	61.8	0	8.55	486.63	0	0	0	0	0
38015	31.22	134	4.79	18.35	80.81	23.04	70.01	497.06	6.03	0	0	0	0
38016	0	0	0	0	7.45	0	111.95	51.33	0	0	0	0	0
38018	0	4.02	0	0	1.02	0	229.28	111.16	9.31	1.56	0	0	0
Total	**150.05**	**1095.89**	**35.73**	**70.7**	**777.34**	**331.93**	**3275.97**	**6747.25**	**627.02**	**25.56**	**12.76**	**0**	**8.15**

3.2.3 Kelly's Pool, Paraburdoo Waste Water Plant

Two towers were placed near open water bodies that potentially provide drinking and foraging opportunities for the Pilbara Leaf-nosed Bats; one at Kelly's Pool (CCD3) and one at the Paraburdoo Waste Water Plant (8AC3). Both towers were only visited by two of the 20 bats (13 detection events in total, Table 3.3), and the time the two bats spent near the towers was short (25 min in total, Table 3.4). This indicates that the two areas did not represent an important foraging ground or water source for the majority of Pilbara Leaf-nosed Bats during the sampling period, and that bats must have utilised other water sources during this time (*i.e.* the permanent freshwater pool in the vicinity of the Ratty Springs Roost).

3.2.4 Foraging grounds

On average, bats were only detected for approximately 30.5% of their nightly activity period, with approximately 70% or their time spent outside of the detection range of all towers (Table 3.7). This suggests that the main foraging grounds of the 20 tagged Pilbara Leaf-nosed Bats were located outside of the detection range of the towers. However, it is important to note that an unknown portion of the undetected time may have been spent within the detection area but was not detected by nearby towers (i.e. due to bats being in caves, behind outcrops etc.).

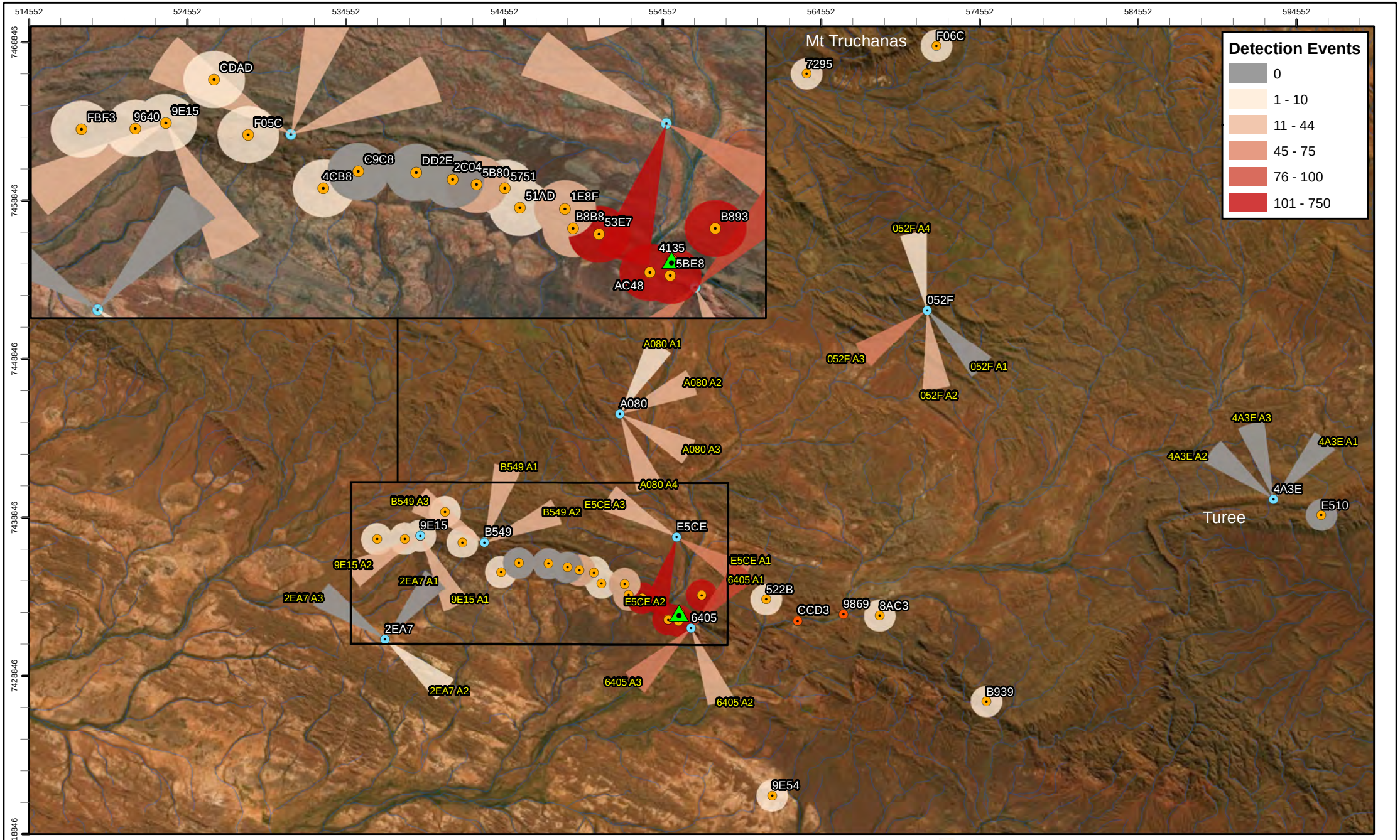
Nineteen of the twenty bats were regularly detected by towers in the plains to the north of the Paraburdoo Ranges (Table 3.5). Pilbara Leaf-nosed Bats repeatedly circled between E5CE (all antennas), B893, A080 (all antennas), 052F (all antennas) and B549 (all antennas) throughout the night. Whilst the number and duration of all detection events in these areas is much lower compared to detections close to the Ratty Springs Roost, analysis of detection data indicates that this is mainly attributable to the towers being farther apart from each other. The time periods between consecutive detections at different towers in the northern plains were relatively long, suggesting that bats slowly moved between towers and foraged extensively in the area in-between.

Eight of the Pilbara Leaf-nosed Bats were also regularly detected by towers in the flats to the south of the Paraburdoo Ranges (Table 3.5). These bats frequently headed south following emergence from the Ratty Springs Roost, flew by 6405 (A2 and A3) and disappeared for extended periods of time, indicating that they were foraging extensively in the plains to the south of the roost. Bats were also occasionally detected by 2EA7 and 9E15 throughout the night, indicating that foraging also occurred along the plains to the south of Western Range.

In summary, the detection data indicates that a large and significant Pilbara Leaf-nosed Bat foraging habitat is likely to occur to the north and north-east of the Paraburdoo Ranges as well as in the plains to the south.

Table 3.7: Approximate percentage of time spent within and outside of the detection range

Bat ID	Sum of all detection event durations (h)	Total estimated time spent outside of roost (h)	% of time spent near towers	% of time spent outside of detection range of towers
37987	2.82	16.83	16.76	83.24
37988	24.15	62.85	38.43	61.57
37989	8.85	29.60	29.91	70.09
38451	4.63	38.76	11.95	88.05
37991	8.72	12.50	69.72	30.28
37992	15.87	39.90	39.77	60.23
37993	11.53	23.35	49.40	50.60
37994	12.20	86.25	14.14	85.86
37995	2.52	9.10	27.73	72.27
37996	25.16	55.00	45.75	54.25
37997	5.82	14.10	41.28	58.72
37998	8.68	34.20	25.38	74.62
37999	13.66	55.00	24.84	75.16
38001	19.71	64.90	30.37	69.63
38455	9.47	40.15	23.58	76.42
38459	13.01	40.90	31.82	68.18
38014	9.28	30.80	30.14	69.86
38015	14.42	52.76	27.33	72.67
38016	2.85	21.60	13.17	86.83
38018	5.94	30.90	19.22	80.78
Average	**10.97**	**37.97**	**30.54**	**69.46**



Roost

VHF Towers

- Directional
- Omni-directional
- Mini Omni-Towers

Watercourse

biologic Environmental Survey

N

1:300,000

0 3.5 7 14 km

Rio Tinto Iron Ore

Western Range PLNB VHF Study

Figure 3.3: Total number of Pilbara Leaf-nosed Bat detection events per tower

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 13/01/2020

Legend

- Roost
- Watercourse

VHF Towers

- Directional
- Omni-directional
- Mini Omni-Towers

biologic Environmental Survey

N

1:300,000

0 3.5 7 14 km

Rio Tinto Iron Ore

Western Range PLNB VHF Study

Figure 3.4: Total duration of Pilbara Leaf-nosed Bat detection events per tower

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A4. Created 13/01/2020

3.3 Bat Movements

3.3.1 General

Emergence patterns and indicative roosting locations of the Pilbara Leaf-nosed Bats during the sampling period are shown in Table 3.7. A bat was considered roosting near a tower if its first detection of the night and its last detection in the previous night were recorded at the same tower. Bats roosted at the Ratty Springs Roost most (74.5%) nights (Table 3.7), confirming the significance of this roost for the local population. One individual (38455) roosted at Mt Truchanas in one night and one individual (37988) roosted near 052F A2 & A3) for six nights (Table 3.7). The latter likely roosted at the Paraburdoo East Roost, a roost thought to represent a second permanent diurnal roosting site at Greater Paraburdoo (Astron, 2018a). Its exact location has yet to be identified, but recent data suggests that it likely occurs north of the Eastern Range mining operations (Astron, 2018a), which aligns spatially with the locations of tower 052F (A2 & A3) in this study. Four bats (37988, 37997, 37998 and 38455) likely also roosted in the western section of the Project Area, with matching first and last detections being recorded by towers B549 A1 and/or 9E15 A2 (Table 3.7). Several caves, including Caves 7, 8, 9, 10, 11 and 12 are located in the vicinity of these towers. In 16.9% of the nights, roosting locations could not be determined, as the towers that recorded the first detection of the night and the last detection in the previous night did not match.

On average, Pilbara Leaf-nosed Bats emerged from their roosts at approximately 8.15 pm each night and returned to the roost approximately 5.25 hours later (Table 3.7). The average nightly activity periods for the bats should be considered a minimum, as some individuals were only detected for a short period upon emerging from their diurnal roost before leaving the Project Area until the following evening.

Table 3.8: Emergence patterns and indicative roosting locations*

Bat ID	4135	5BE8	AC48	B893	B549 A1	9E15 A2	052F (A2 & A3)	F06C	Uncertain	Av. emergence time	Av. nightly activity periods (hours)
	Ratty Springs Roost							Mt Truchanas			
37987	-	5 (100%)	-	-	-	-	-	-	0	21:14	4:13
37988	-	1 (9%)	1 (9%)	-	-	-	6 (54%)	-	3 (27%)	21:39	5:43
37989	-	2 (25%)	1 (12.5%)	-	2 (25%)	-	-	-	3 (37.5%)	20:32	4:32
38451	-	1 (10%)	-	-	-	-	-	-	9 (90%)	20:33	4:19
37991	3 (50%)	1 (17%)	2 (33%)	-	-	-	-	-	0	18:55	2:30
37992	3 (50%)	2 (33%)	-	-	-	-	-	-	1 (17%)	20:46	6:38
37993	2 (40%)	1 (20%)	2 (40%)	-	-	-	-	-	0	20:46	5:51
37994	15 (71%)	4 (19%)	2 (10%	-	-	-	-	-	0	18:33	4:19
37995	1 (33%)	1 (33%)	1 (33%)	-	-	-	-	-	0	19:48	4:32
37996	5 (45%)	4 (36%)	-	-	-	-	-	-	2 (18%)	20:19	5:30

Bat ID	4135	5BE8	AC48	B893	B549 A1	9E15 A2	052F (A2 & A3)	F06C	Uncertain	Av. emergence time	Av. nightly activity periods (hours)
	Ratty Springs Roost							Mt Truchanas			
37997	-	3 (50%)	1 (17%)	-	2 (33%)	-	-	-	0	20:50	2:49
37998	3 (30%)	1 (10%)	-	-	-	2 (20%)	-	-	4 (40%)	20:14	3:48
37999	3 (27%)	5 (45%)	2 (18%)	-	-	-	-	-	1 (9%)	19:44	5:30
38001	2 (22%)	3 (33%)	4 (44%)	-	-	-	-	-	0	19:05	8:06
38455	1 (11%)	4 (44%)		-	1 (11%)	-	-	1 (11%)	2 (22%)	21:00	5:01
38459	5 (71%)	1 (14%)	1 (14%)	-	-	-	-	-	0	20:05	6:50
38014	-	5 (63%)	3 (37%)	-	-	-	-	-	0	19:56	4:25
38015	5 (63%)	2 (25%)		-	-	-	-	-	1 (13%)	20:08	7:32
38016	-	2 (33%)		2 (33%)	-	-	-	-	2 (33%)	19:54	4:20
38018	-	1 (20%)	4 (80%)	-	-	-	-	-	0	20:17	7:42
Total	**123**				**5**	**2**	**6**	**1**	**28**	**20:12**	**5:12**
%	**74.5**				**3**	**1.2**	**3.6**	**0.6**	**16.9**		

* number of nights

Although the 20 individuals visited similar towers throughout the sampling period, they rarely did so at the same time. The data suggests that the Pilbara Leaf-nosed Bats dispersed separately when exiting their roost each night and used multiple foraging areas in the hours after emergence. Although there was no strong relationship between individuals, there was a reoccurring pattern for most individuals, i.e. individuals were regularly detected at the same towers suggesting each individual has preferred foraging grounds and flight paths. Individual Pilbara Leaf-nosed Bat movements are described, in detail, in Section 3.3.2.

3.3.2 Activity per Individual

Individual 37987 - Male

Individual 37987 was recorded over the first five nights of the study, from the evening of the 24th September till the morning of the 29th September 2019. A total of 32 detection events from three towers were received during this time (Table 3.3), comprising 5BE8 (*n* = 14), 4135 (*n* = 8) and AC48 (n = 10). All three towers were located in the immediate vicinity of the Ratty Springs Roost. In all five nights, the first detection event of the night was recorded by 5BE8, suggesting that the individual was exclusively roosting at the Ratty Springs Roost during the sampling period.

The most common movement pattern of this bat was to emerge from the Ratty Springs Roost and to circle back and forth between towers in the immediate vicinity of the roost (4135, 5BE8 and AC48) for short

periods of time. Each night, the individual then disappeared from the detection range of all towers for extended (up to 4.5 hours) periods of time, suggesting that it mostly foraged outside of the detection zone. As only the three towers near the Ratty Springs Roost recorded detections, it is unclear where the main foraging grounds of this individual were located. Some nights, the individual occasionally returned to the Ratty Springs Roost throughout the night, but only for short (up to 10 min) periods of time. On 29/09/2019, the tag became dislodged near tower 4135, and any consecutive detections from this tower were discarded.

Individual 37988 - Female

Individual 37988 was recorded over the first twelve nights of the study, from the evening of the 24th September till the morning of the 6th October 2019. A total of 248 detection events from 18 towers were received during this time (Table 3.3). The individual likely roosted at multiple locations during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (two nights), 6405 (one night, likely reflecting roosting activity at the Ratty Springs Roost) and 520F A2/A3 (five nights). The latter likely represented roosting at the Paraburdoo East Roost.

The majority of detection events (50%) were recorded by towers in the immediate vicinity of the Ratty Springs Roost, comprising 5BE8 (*n* = 44), AC48 (*n* = 56) and 4135 (*n* = 24). 5BE8, AC48 and 4135 were also the towers that recorded the highest total detection event duration for this individual, with the bat spending approximately 13.2 hours near the Ratty Springs Roost.

On five of the nights, the bat emerged from 052F and then flew south west, flying by towers 8AC3, CCD3 and 522B into the minor drainage line to the north of Pirraburdu Creek (6405 A1). After spending some time near the roost, moving up and down the small section of Pirraburdu Creek where it cuts through Paraburdoo Ranges, the bat then flew back north to 052F (via E5CE A2). In the remaining nights, the bat headed south following emergence at the Ratty Springs Roost, flying by tower 6405 (all antennas) before being detected by 9E15 later in the night. This indicates that some foraging also occurred in the plains to the south of Western Range. Therefore, the detection data indicates that this bat foraged extensively near the roost, along Pirraburdu Creek as well as in the plains to the north, the north-east and the south of the Paraburdoo Ranges.

Individual 37989 - Female

Individual 37989 was recorded over the first eight nights of the study, from the evening of the 24th September till the morning of the 2nd October 2019. A total of 123 detection events from 19 towers were received during this time (Table 3.3). The majority of detection events were made at towers B549 (*n* = 24), 5BE8 (*n* = 20) and AC48 (*n* = 15). The individual likely roosted at multiple locations during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers 5BE8 and AC48, three nights) and B549 (two nights). It is uncertain where the individual roosted for three nights as there were no matching first and last detection events recorded.

Next to activities near the Ratty Springs Roost, the bat frequently flew across Western Range, flying by towers 53E7, B8B8, 511AD, 5B80 and FBF3. On some nights, the bat immediately returned to the Ratty Springs Roost (also via flying across Western Range) whereas in at least two of the nights, the bat

remained in the western section of the Project Area, most likely roosting to the north of B549. The bat likely foraged both in the plains to the north of the ranges (between towers B549 and 052FA3, as well as to the south of the ranges (near tower 2EA7 A1).

Individual 38451- Female

Individual 38451 was recorded over the first ten nights of the study from the evening of the 24th September to the morning of the 4th October 2019. A total of 45 detection events from 16 towers were received during this time (Table 3.3). The majority of detections were recorded at tower 6405 (*n* = 10) adjacent to the Ratty Springs Roost. Roosting is suggested for one night at the Ratty Springs Roost from matching first and last detection events (tower 5BE8), however, it is unknown where the individual roosted for the other nine nights as there were no other matching first and last detection events.

During the first night, the bat emerged from the Ratty Springs Roost, spent some time circling between towers in Pirraburdu Creek (near the roost) and then flew north, circling between E5CE A2, 052F A3, B893 and A080 A4. Whilst the individual did not spend a significant amount of time near any of these towers, the circling pattern indicates that the bat foraged extensively in the area between the towers (plains to the north of the Ratty Springs Roost) during that time. The bat was not detected again in the following four nights, indicating that the individual left the Project Area and roosted and foraged elsewhere. In the sixth night, the individual was briefly detected just south of the Ratty Springs Roost (6405 A2 and A3). It then flew west and foraged in the vicinity of B549, CDAD and F05C. On the seventh night, the bat was only briefly detected at B939 (Eastern Range) and then disappeared from the detection range of all towers for the following two nights, suggesting that it was roosting and foraging outside of the Project Area.

Individual 37991 - Female

Individual 37991 was recorded over the first six nights of the study, from the evening of the 24th September to the evening of the 29th September 2019. A total of 107 detection events from nine towers were received during this time (Table 3.3). The majority of detection events were made at towers AC48 (*n* = 22), 5BE8 (*n* = 20), B893 (*n* = 20), E5CE (*n* = 20) and 4135 (*n* = 17). The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded by towers 4135, 5BE8 and AC48.

The individual followed the same movement pattern in each of the six nights. Following emergence from the Ratty Springs Roost, the bat circled between towers AC48, 5BE8, 4135 (near the roost) as well as E5CE A2, B893, 052F A3 and 1E8F in the plains just north of the ranges. Therefore, the bat almost exclusively moved up and down Pirraburdu Creek (where it cuts through the Paraburdoo Ranges) as well as heading further north to the plains during the sampling period.

Individual 37992 - Male

Individual 37992 was recorded over the first seven nights of the study, from the evening of the 24th September to the morning of the 1st October 2019. A total of 195 detection events from 16 towers were received during this time (Table 3.3). The majority of detection events were made at towers AC48

(*n* = 47), 5BE8 (*n* = 41), and 4135 (*n* = 23) adjacent to the Ratty Springs Roost. The individual roosted at the Ratty Springs Roost most nights (towers 4135, 5BE8 and AC48, five nights).

Most nights, the bat emerged from the Ratty Springs Roost and circled back and forth between towers in the immediate vicinity of the roost (4135, 5BE8, AC48) and towers E5CE A2 and 53E7 in the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges. The individual also occasionally moved into the minor drainage line above Pirraburdu Creek (6405 A1, E5CE A1). On two of the nights, there were small (~1 hour) gaps between detection events, suggesting that the individual returned to the roost throughout this time for short periods of time, potentially for night-resting and socialising activities. The bat also commonly foraged in the plains to the north and north-east of the roost, circling between towers 522B, 9869 (Seven Mile Creek), CCD3 (Kelly's Pool), 8AC3 (Paraburdoo Waste Water Plant) and 052F A2, as well as between towers B893, A080 A3 and 052F A2. Whilst the bat did not spend significant amounts of time near any of the towers, the circling pattern indicates that the bat foraged extensively in the area between the towers (plains to the north and north-east of the Ratty Springs Roost) during that time. In one of the nights, the individual also flew south to 6405 (all antennas), indicating that some foraging also occurred in the plains to the south of Western Range (outside of the detection range of the tower).

Individual 37993 - Male

Individual 37993 was recorded over the first five nights of the study, from the evening of the 24th September to the evening of the 28th September 2019. A total of 123 detection events from ten towers were received during this time (Table 3.3). The majority of detection events were recorded at towers E5CE (*n* = 28), AC48 (*n* = 21), 5BE8 (*n* = 21) and B893 (*n* = 20). The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers 4135, 5BE8 and AC48).

The most common flight pattern of this individual was to emerge from the Ratty Springs Roost and to move up and down Pirraburdu Creek where it cuts through the Paraburdoo Ranges (between towers 5BE8, 4135, AC48, 53E7, E5CE A2 and B893). The bat also flew further north each night, circling between towers 1E8F, E5CE A2 and 052F A3 for extended periods of time. Whilst it did not spend a significant amount of time near any of the towers, the circling pattern indicates that extensive foraging occurred in the area between the towers, in the plains to the north of the roost. In four nights, the bat returned to the Ratty Springs Roost once for 3 – 4.5 h hours, indicating that it also occasionally utilised the roost for night-resting and/or socialising.

Individual 37994 - Female

Individual 37994 was recorded for the longest period of time, from the evening of the 24th September to the evening of the 14th October 2019 (21 nights). A total of 171 detection events from eight towers were received during this time (Table 3.3). The majority of detection events were recorded at towers 5BE8 (*n* = 49), AC48 (*n* = 45) and 4135 (*n* = 34) adjacent to the Ratty Springs Roost. The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at towers 4135, 5BE8 and AC48.

In the majority (15) of nights, the individual exclusively moved between towers in the immediate vicinity of the roost (5BE8, AC48 and 4135). Occasionally, the individual was also picked up by 53E7, located approximately 2.5 km to the west of the roost (eastern section of Western Range). Most nights, the bat periodically returned to the Ratty Springs Roost throughout the night, most likely to night-rest and/or socialise. In six of the nights, the individual flew north following emergence from the Ratty Springs Roost, circling between towers B893, E5CE (A1 and A2), A080 A3 and 052F A3. Whilst the bat did not spend a significant amount of time near any of these towers, the data indicates that extensive foraging occurred in the area between the towers (plains to the north of the Paraburdoo Ranges) during this time.

Individual 37995 - Male

Individual 37995 was recorded over the first three nights of the study, from the evening of the 24th September to the evening of the 26th September 2019. A total of 39 detection events from eight towers were received during this time (Table 3.3). The majority of detection events were recorded at towers AC48 (*n* = 11) and 5BE8 (*n* = 11) adjacent to the Ratty Springs Roost. The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at towers 4135, 5BE8 and AC48.

On the first night, the individual circled between towers in the immediate vicinity of the roost (5BE8, AC48 and 4135) for the whole duration of the night. The bat returned to the Ratty Springs Roost for approximately 1 hour during this time, most likely to night-rest and/or socialise. In the following two nights, the individual continued to move up and down Pirraburdu Creek (between towers 5BE8, AC48, and 4135). However, it also occasionally moved into the minor drainage line above Pirraburdu Creek (6405 A1), as well as foraged in the plains to the north of the ranges (between towers E5CE A2 and A1, and tower A080 A3 along Pirraburdu Creek).

Individual 37996 - Female

Individual 37996 was recorded over the first 11 nights of the study, from the evening of the 24th September to the morning of the 5th October 2019. A total of 246 detection events from 17 towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers 5BE8 (*n* = 58), AC48 (*n* = 51) 6405 (*n* = 42) and 4135 (*n* = 38) adjacent to the Ratty Springs Roost. Roosting was suggested for nine nights at the Ratty Springs Roost from matching first and last detection events (towers 4135 and 5BE8). The individual may also have roosted in the very western section of Western Range (near towers 9E15 and B549) for two nights, though data is not conclusive.

In the first three nights, the individual emerged from the Ratty Springs Roost and spent the night circling between towers in the immediate vicinity of the roost (5BE8, AC48, and 4135) as well as occasionally moving into the minor drainage line above Pirraburdu Creek (6405 A1). The individual occasionally returned to the Ratty Springs Roost during this time, suggesting that it used the roost for night-resting and/or socialising. On five of the nights, the bat also moved further north, circling between towers E5CE (all antennas), 1E8F, B893, 53E7, 052F A3 and 522B. Whilst the bat did not spend a significant amount of time near any of these towers, the circling pattern indicates that it foraged extensively in the plains to the north of the ranges during this time. On two of the nights, the bat also headed south, flying by tower

6405 (all antennas) before being detected at 9E15 (both antennas), suggesting that it was also foraging in the plains to the south of Western Range. During the last night, the bat emerged from the very western section of Western Range (9E15) and then headed back east, passing by towers located in the upper ranges of Western Range (all flybys) before returning to the Ratty Springs Roost.

Individual 37997 - Female

Individual 37997 was recorded over the first six nights of the study, from the evening of the 24th September to the morning of the 30th September 2019. A total of 75 detection events from nine towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers B549 (*n* = 15), 5BE8 (*n* = 14) and AC48 (*n* = 11). The individual likely roosted at two locations during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers 5BE8 and AC48, four nights) and B549 (two nights), which is to the west of the Ratty Springs Roost.

On the first two nights, the individual emerged from the Ratty Springs Roost and spent the night circling between towers in the immediate vicinity of the roost (5BE8, AC48, 4135 and 53E7) as well as occasionally moving into the minor drainage line above Pirraburdu Creek (6405 A1). In the third night, the bat immediately flew west following emergence from the Ratty Springs Roost, briefly flew by 53E7 and 1E8F and then headed further north to E5CE A2, 052F A3 before ultimately flying north-west to tower B549 A1 and A2. Whilst the bat did not spend a significant amount of time near any of these towers, it likely spent a significant amount of time foraging in the area in-between. The bat then roosted near B549 and flew back east the following night, circling between towers 052F A3, E5CE (A2 and A1) and 1E8F, suggesting that it was foraging in the plains to the north of the ranges. The movement pattern was repeated int the following two nights, and the bat moved back west to B549 where it roosted and flew back east to Ratty Springs the night after. In both nights, the bat foraged extensively in the plains to the north of the ranges, though mostly outside of detection range of the towers.

Individual 37998 - Female

Individual 37998 was recorded over the first ten nights of the study, from the evening of the 24th September to the morning of the 4th October 2019. A total of 86 detection events from 12 towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers AC48 (*n* = 22), 5BE8 (*n* = 21) and 4135 (*n* = 14), adjacent to the Ratty Springs Roost. The individual likely roosted at multiple locations during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers 4135 and 5BE8, four nights) and 9E15 A2 (two nights). It is uncertain where the individual roosted for four nights as there were no matching first and last detection events recorded.

The bat spent the first night flying up and down Pirraburdu Creek where it cuts through the Paraburdoo Ranges (near the roost), with frequent detections at 5BE8, AC48, 4131, 53E7 and E5CE A2. In the second night it immediately flew south following emergence from the Ratty Springs Roost, passing 6405 A3 before being detected by 9E15 A2 later in the night, suggesting that it was foraging in the plains south of Western Range. It then flew north, crossing Western Range before being last detected by B549 A3. On the third night, it was only detected briefly at 6405 A1 before returning to the Ratty Springs

Roost. In the fourth night, the bat emerged from the Ratty Springs Roost and immediately flew south, passing 6405 A3 before being detected by 9E15 A2 and 2EA7 A1 later in the night, suggesting that it was foraging in the plains south of Western Range. The bat then crossed Western Range near tower 9640, flew north to B549 A3 and disappeared from the detection range of all towers for one night, suggesting that it was roosting outside of the Project Area. The bat remained in the western section of the Project Area during the sixth night but was only briefly detected by B549 (all antennas) in the early morning. In the seventh night, the bat emerged from 9E15 A2, foraged in the plains to the south of Western Range before returning to the Ratty Springs Roost later in the night. In the remaining three nights, the bat mainly foraged in the plains to the south of the Ratty Springs Roost, between towers 6405 A3 and 9E15 A2.

Individual 37999 - Male

Individual 37999 was recorded over the first 11 nights of the study, from the evening of the 24th September to the evening of the 4th October 2019. A total of 188 detection events from five towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers E5CE (*n* = 48) and B893 (*n* = 46) to the north of the Ratty Springs Roost. Roosting is suggested for ten nights at the Ratty Springs Roost from matching first and last detection events (towers 4135, 5BE8 and AC48), however, it is unknown where the individual roosted for one night as there was no matching first and last detection events.

The individual followed the same movement pattern in each of the eleven nights. Following emergence from the Ratty Springs Roost, the bat circled between towers AC48, 5BE8, 4135 (near the roost) as well as E5CE A2 and B893 in the plains just north of the ranges. Therefore, the bat almost exclusively moved up and down Pirraburdu Creek (where it cuts through the Paraburdoo Ranges) during the sampling period, spending the majority of its time at E5CE A2. During five of the nights, the bat intermittently returned to the roost for extended (3 – 8.5 hours) periods of time, suggesting that it was utilising the roost for night-resting and/or socialising activities.

Individual 38001 - Male

Individual 38001 was recorded over the first nine nights of the study, from the evening of the 24th September to the morning of the 3rd October 2019. A total of 179 detection events from six towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers E5CE (*n* = 47) and 53E7 (*n* = 46). The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers AC48, 5BE8 and 4135).

The individual followed the same movement pattern in each of the nine nights. Following emergence from the Ratty Springs Roost, the bat circled between towers AC48, 5BE8, 4135 (near the roost), between E5CE A2 and B893 in the plains just north of the roost as well as 53E7 located in the very eastern section of Western Range. Therefore, the bat almost exclusively moved up and down Pirraburdu Creek (where it cuts through the Paraburdoo Ranges) during the sampling period. Each night at around 9 pm, the bat then returned to the Ratty Springs Roost where it spent up to six hours (most likely night-resting and socialising) before repeating the movement pattern and flying up and down Pirraburdu Creek.

Individual 38455 - Female

Individual 38455 was recorded over the first nine nights of the study, from the evening of the 24th September to the morning of the 3rd October 2019. A total of 180 detection events from 13 towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers A080 (*n* = 46) and E5CE (*n* = 43) to the north of the Ratty Springs Roost. The individual likely roosted at multiple locations during the sampling period, with matching first and last detection events being recorded at the Ratty Springs Roost (towers 5BE8 and 4135, five nights) and B549 A1 (one night) and Mt Truchanas (tower F06C, one night). It is uncertain where the individual roosted for one night.

This individual spent the majority of its time foraging in the plains to the north of the ranges. Most commonly, the bat emerged from the Ratty Springs Roost and headed north, circling between towers B893, 052F (all antennas), E5CE (all antennas), A080 (all antennas) and B549 (all antennas). Whilst the bat did not spend a significant amount of time near any of these towers, the circling between them indicates that the individual was foraging extensively in the plains to the north of the ranges outside of the detection range of the towers. Its foraging ground spanned a large area, as towers visited within a single night were located up to 30 km apart. In one of the nights, the bat also flew to Mt Truchanas, located approximately 40 km north of the Ratty Springs Roost and roosted in the vicinity tower F06C. This individual was the only tagged Pilbara Leaf-nosed Bat that was observed to roost at this location during the sampling period.

Individual 38459 - Female

Individual 38459 was recorded over the first seven nights of the study, from the evening of the 24th September to the evening of the 30th September 2019. A total of 155 detection events from 14 towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers AC48 (*n* = 42), 5BE8 (*n* = 41) and 4135 (*n* = 37), adjacent to the Ratty Springs Roost. The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at towers 4135, 5BE8 and AC48.

The individual spent most nights exclusively circling along the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges, near the Ratty Springs Roost. During this time, the individual occasionally returned to the Roost during the night for 1- 4 hours at a time, suggesting that it was utilising the Ratty Springs Roost for night-resting and socialising. On two of the nights, the bat also flew north following emergence from the roost, circling between towers E5CE and B893 which suggests that it was foraging in the northern plains. In one of the nights, the bat also flew south following emergence from Ratty Springs Roost, passing 6405 A2 and returning to the tower 4.5 later. This suggests that the individual also spent a significant amount of time foraging in the plains to the south of the roost, but outside of the detection range of the towers. Finally, the bat was also observed to briefly fly into the Western section of Western Range, passing by 1E8F, 51AD and B8B8 (all flybys) before heading to the northern plains.

Individual 38014 - Male

Individual 38014 was recorded over the first eight nights of the study, from the evening of the 24th September to the evening of the 1st October 2019. A total of 80 detection events from six towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers AC48 (*n* = 27) and 5BE8 (*n* = 27), adjacent to the Ratty Springs Roost. The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at towers 5BE8 and AC48.

The most common flight path of this individual was to emerge from the Ratty Springs Roost and to circle back and forth between towers in the immediate vicinity of the roost (AC48, 4135, 5BE8), the very eastern section of Western Range (53E7, 1E8F) as well as tower E5CE located in the plains immediately north of the roost, for the whole duration of the night. In three of the nights, the bat returned to the roost during the night for 1 - 5.5 hours, suggesting that it may have utilised the roost for night-resting or socialising activities.

Individual 38015 - Female

Individual 38015 was recorded over the first eight nights of the study, from the evening of the 24th September to the evening of the 1st October 2019. A total of 181 detection events from 20 towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers 5BE8 (*n* = 39), 4135 (*n* = 34) and AC48 (*n* = 32), adjacent to the Ratty Springs Roost. Roosting is suggested for seven nights at the Ratty Springs Roost from matching first and last detection events (towers 4135 and 5BE8). It is unknown where the individual roosted for one night as there was no matching first and last detection events.

On the first five nights, the individual emerged from the Ratty Springs Roost and circled between towers in the immediate vicinity of the roost (in the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges) for the whole duration of the night. Small (~1 hour) gaps between detection events were common, suggesting that the individual frequently returned to the roost throughout this time for short periods of time, potentially for night-resting and socialising activities. During the fifth night, the bat also briefly headed west into Western Range, flying by towers 53E7, 1E8F, 51AD, 5751 and 5B80 (all flybys) before flying to the north of Western Range (most likely to forage) and returning to the Ratty Springs Roost later in the night. On the following two nights, the bat headed south following emergence from the roost, flying by 6405 (A2 and A3) before disappearing for extended periods of time. The bat was occasionally detected by 9E15 A2 and A3 during this time, suggesting that it was foraging in the plains to the south of Western Range. On the last night of the sampling period, the bat emerged from the roost, immediately headed north where it spent the remainder of the night foraging, both in the plains to the north-east of the ranges (near tower 052F) as well as in the plains just north of Western Range (between towers E5CE and B549).

Individual 38016 - Male

Individual 38016 was recorded over the first six nights of the study, from the evening of the 24th September to the evening of the 29th September 2019. A total of 39 detection events from seven towers were received

during this time (Table 3.3). The majority of detection events were recorded at towers B893 (*n* = 10), 5BE8 (*n* = 9), AC48 (*n* = 8) and E5CE (*n* = 7). Roosting is suggested for four nights at the Ratty Springs Roost from matching first and last detection events (towers 5BE8 and B893), however, it is unknown where the individual roosted for two nights as there were no matching first and last detection events.

Whilst the majority of detection events were made in the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges (near the roost), the bat did not spend a significant amount of time in that area. Most frequently, the bat emerged from the Ratty Springs Roost and headed north, circling between towers in the plains immediately north of the roost (B893, E5CE A2), suggesting that its mains foraging grounds were located in the plains just north of the ranges during the sampling period.

Individual 38018 - Male

Individual 38018 was recorded over the first five nights of the study, from the evening of the 24th September to the evening of the 28th September 2019. A total of 82 detection events from ten towers were recorded during this time (Table 3.3). The majority of detection events were recorded at towers 5BE8 (*n* = 20), E5CE (*n* = 16) and AC48 (*n* = 19). The individual likely roosted exclusively at the Ratty Springs Roost during the sampling period, with matching first and last detection events being recorded at towers AC48 and 5BE8.

Most nights, the bat emerged from the Ratty Springs Roost and circled back and forth between towers in the immediate vicinity of the roost (4135, 5BE8, AC48) in the small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges. Small (~1 hour) gaps between detection events were common, suggesting that the individual frequently returned to the roost throughout this time for short periods of time, potentially for night-resting and socialising activities. The bat also commonly foraged in the plains to the north of the roost, spending approximately 3.8 hours at tower E5CE A2 during the sampling period. On one of the nights, the individual flew north-east, circling back and forth between tower B893, CCD3 and 052F. Whilst it did not spend significant amounts of time near any of the three towers, the circling pattern indicates that the bat foraged extensively in the area between the towers (plains to the north-east of the Ratty Springs Roost) during that time. During another one of the nights, the bat was also briefly detected at 1E8F in the eastern section of Western Range. It accessed this area by coming from the plains to the north of Western Range (E5CE A2) where it also returned to after spending 1 minute near tower 1E8F.

3.4 Limitations and Constraints

The EPA (2016) outlines several potential limitations to fauna surveys, which are presented and discussed in Table 3.9. Outside of the VHF component, there were very few limitations and constraints. Following the first study conducted in the dry season of 2018, this study represents the second instance of Motus automated VHF tracking being used to comprehensively investigate Pilbara Leaf-nosed Bat movements at Western Range, and the sixth instance investigating Pilbara Leaf-nosed Bat movements in the Pilbara. Furthermore, this study is one of only a handful to utilise automated VHF tracking systems in Australia, which have been developed using relatively new technology. Despite a large component of the study being considered experimental in its survey design and analysis, the survey was able to replicate broad results similar to the previous season, and the results obtained to date appear to be adequate to address the objectives set for this study. The current study built off the limitations of the first survey and conducted more sampling (i.e. more bats and sampling in a different year), with a refinement in tower positioning and installation of additional towers, to more definitely explain the movements and habitat use of the local bat colonies.

Despite the benefits and broad utility of the system, and the repeated nature of the current survey following Biologic (2019), it is important to recognise that the limitations of this new technology are still present. Firstly, the detection period is relatively restricted (four weeks at best), thus only providing a snapshot of an individual's behaviour. Importantly, detections can only be recorded within the given range of a tower (~79 ha), and thus analysis can only focus on a portion of an area visited (Taylor *et al.*, 2017). Furthermore, the range of a transmitter can vary considerably due to numerous environmental and technical factors, including an individual's height in the landscape (flying low vs. flying high), temperature, obstructions, background noise, speed, flight orientation (Taylor *et al.*, 2017). In some instances, this can impact upon the certainty of a detection (such as those with a low run length; see Section 2.5).

Table 3.9: Study limitations and constraints

Potential limitation or constraint	Constraint	Applicability to this study
Experience of personnel	No	The field personnel involved in the study have an excess of 15 years' experience undertaking fauna surveys in the Pilbara. The team leader (Thomas Rasmussen) has specific experience surveying for Pilbara Leaf-nosed Bats and assisted in development of the Motus system within Australia. Robert Bullen of Bat Call WA, who assisted in the bat catching component, is a regional specialist for the species. Data analysis and interpretation was done so with Motus support.
Proportion of fauna identified	No	The study was focussed on a single species (Pilbara Leaf-nosed Bat) – the species was readily identified upon capture.
Sources of information (recent or historic) and availability of contextual information	Partial	Previous Pilbara Leaf-nosed Bat surveys have been conducted within the Western Range area, and previous reports and resources required to complete the study were made available. However, the detection data suggests that there are other roosts in the area whose exact location is currently unknown, adding a certain degree of uncertainty regarding interpretation of bat movements.
Completeness	No	The study was adequately completed to meet the requirements of the scope of works for this species. Other studies are currently being undertaken to meet similar requirements for other species.
Disturbance	No	Some eastern sections of the Project Area have been cleared for drilling activities, resulting in a loss of vegetation and thus potential foraging habitat. However, these sections are comparatively small, indicating that such disturbances are not a significant barrier to species movements across most of the Project Area. No recent fires occurred at Greater Paraburdoo and therefore impacts of fire on bat movements and habitat use can be excluded.
Timing of survey, weather, seasonality	No	The study was conducted during the dry season when bats are expected to be more reliant on the water resources available in the area, and contract back to important diurnal roost sites and thus use important foraging grounds. For these reasons timing was well suited to understanding the most important habitats within the area.
Remoteness or access issues	Partial	Due to the size and weight of the towers, locations were restricted to those accessible by light vehicle and trailer. The majority of the Project Area was accessible either by vehicle or on foot, thus the equipment setup during this survey were largely unconstrained by accessibility or remoteness.
Tower distribution	Partial	Tower installation was restricted to Rio Tinto Iron Ore held Mining Act and Land Act tenure. Installation of additional towers south of the Project Area would have provided greater coverage and potentially more accurate data of Pilbara Leaf-nosed Bats utilising the foraging grounds to the south.

4 CONCLUSION

This study represents the second instance of VHF tracking being utilised to investigate the habitat use of the local colony of Pilbara Leaf-nosed Bats within the Western Range Project Area, following Biologic (2019). The results were highly comparable to those determined in the original study, and thus further demonstrate that the methods are well suited for this type of study and for this species. As such the key objectives of the study were addressed.

In general, the data suggests that:

- Few bats visited the western and central sections of Western Range and spent comparatively little time in the area. As the detection coverage within the Western Range Development Envelope was very high (>90%), these results indicate that this area did not represent an important foraging ground for the Pilbara Leaf-nosed Bats during the sampling period.
- Pilbara Leaf-nosed Bats were mostly outside of the detection area of the towers, suggesting that their preferred foraging areas were located outside of the Project Area.
- Pilbara Leaf-nosed Bats foraged extensively in the plains to the north and north-east of the Paraburdoo Ranges, and to a minor extent also to the south of the Paraburdoo Ranges, as indicated by repeated detections at towers in these areas.
- The small section of Pirraburdu Creek where it passes through the Paraburdoo Ranges (and where the Ratty Springs Roost is located) not only represents an important diurnal roosting site for the species, but is also a significant area for night-resting, foraging, social interactions as well as being utilised as a water source.
- There is limited regional movement between roosting sites at Western Range and Mt Truchanas and Turee. However, this study is the first to show that Pilbara-Leaf-nosed Bats can move distances of at least 40 km within the dry season (approximately twice as far as previously estimated).
- Kelly's Pool and the Paraburdoo Waste Water Plant did not represent an important water source or foraging ground during the sampling period, despite representing an open waterbody.

The current study was able to address some of the limitations from the first dry season study. In particular, the tower array was considerably expanded to better address specific objectives of the study, such as placing additional towers within the proposed development area at Western Range and further afield in potential foraging areas. Additionally, the overall sampling size was increased by tagging an additional twenty individuals to provide a better understanding of colony-level habitat use within the area. By addressing these limitations, the current study was able to confirm and further refine some broad trends of movement patterns and foraging zones identified in the dry season survey in 2018, providing confidence that the preferred foraging grounds of the local colony o Pilbara Leaf-nosed Bats are located away from the Paraburdoo Range itself.

5 REFERENCES

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6 APPENDICES

Appendix A – VHF Tower Details

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
FBF3	Omni-directional	-	02/09/19	-	-23.171	117.357	
B893 9640	Omni-directional	-	03/09/18 02/09/19	25/08/19 -	-23.171	117.374	
F05C-2	Omni-directional	-	22/02/19	-	-23.173	117.410	
B549	Omni-directional	-	23/02/19	-	-23.173	117.423	No picture available

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
4CB8	Omni-directional	-	25/02/19	-	-23.190	117.433	
C9C8	Omni-directional	-	04/09/18	-	-23.185	117.444	
DD2E	Omni-directional	-	04/09/18	-	-23.185	117.463	

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
2C04	Omni-directional	-	04/09/18	-	-23.187	117.474	
5B80-2	Omni-directional	-	24/02/19	-	-23.189	117.482	
5751-2	Omni-directional	-	22/02/19	-	-23.190	117.491	No picture available
51AD	Omni-directional	-	21/02/19	-	-23.196	117.495	

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
1E8F	Omni-directional	-	02/09/19	-	-23.197	117.510	
B8B8	Omni-directional	-	23/02/19	-	-23.203	117.512	
53E7	Omni-directional	-	21/02/19	-	-23.205	117.520	

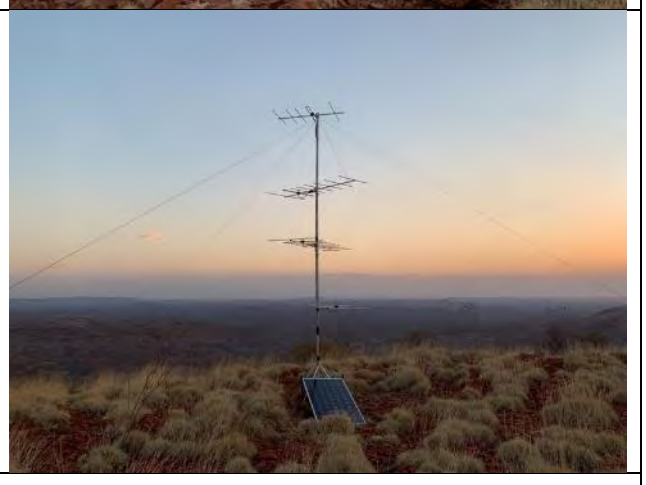
Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
AC48	Omni-directional	-	25/02/19	-	-23.217	117.537	
5BE8-2	Omni-directional	-	21/02/19	-	-23.218	117.543	
CDAD	Omni-directional	-	02/09/19	-	-23.156	117.399	

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
B893-2	Omni-directional	-	02/09/19	-	-23.203	117.557	
4135	Mini Omni-directional	-	02/09/19	-	-23.213	117.544	
72A6	Omni-directional	-	04/09/18	04/05/19	-23.215	117.618	
0101	Omni-directional	-	06/05/19	01/06/19	-23.215	117.618	No picture available

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
CCD3	Mini Omni-directional	-	02/09/19	-	-23.217	117.616	
9869-2	Mini Omni-directional	-	02/09/19	-	-23.213	117.645	
8AC3-2	Omni-directional	-	02/09/19	-	-23.214	117.667	No picture available
9E54	Omni-directional	-	02/09/19	-	-23.317	117.601	

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
B939	Omni-directional	-	02/09/19	-	-23.263	117.733	
E510	Omni-directional	-	02/09/19	-	-23.155	117.939	
7295	Omni-directional	-	02/09/19	-	-22.905	117.621	

Tower ID	Type	Antenna Direction	Date Installed	Date Deactivated	Location		Photograph
					Latitude	Longitude	
F06C	Omni-directional	-	02/09/19	-	-22.889	117.700	
9E15	Directional	153º 9E15 A1	04/09/18	-	-23.169	117.384	
		240º 9E15 A2					
2EA7	Directional	40º 2EA7 A1	04/09/18	-	-23.228	117.362	
		130º 2EA7 A2					
		305º 2EA7 A3					

6405	Directional	43º 6405 A1 158º 6405 A2 226º 6405 A3	04/09/18	-	-23.222	117.551	
E5CE	Directional	120º E5CE A1 197º E5CE A2 300º E5CE A3	04/09/18	-	-23.170	117.542	
A080	Directional	30º A080 A1 66º A080 A2 119º A080 A3 158º A080 A4	24/02/19	-	-23.100	117.506	
052F	Directional	136º 052F A1 173º 052F A2 235º 052F A3 350º 052F A4	25/02/19	-	-23.040	117.695	
4A3E	Directional	41º 4530 A1 308º 4530 A2 343º 4530 A3	02/09/19	-	-23.146	117.910	No picture available