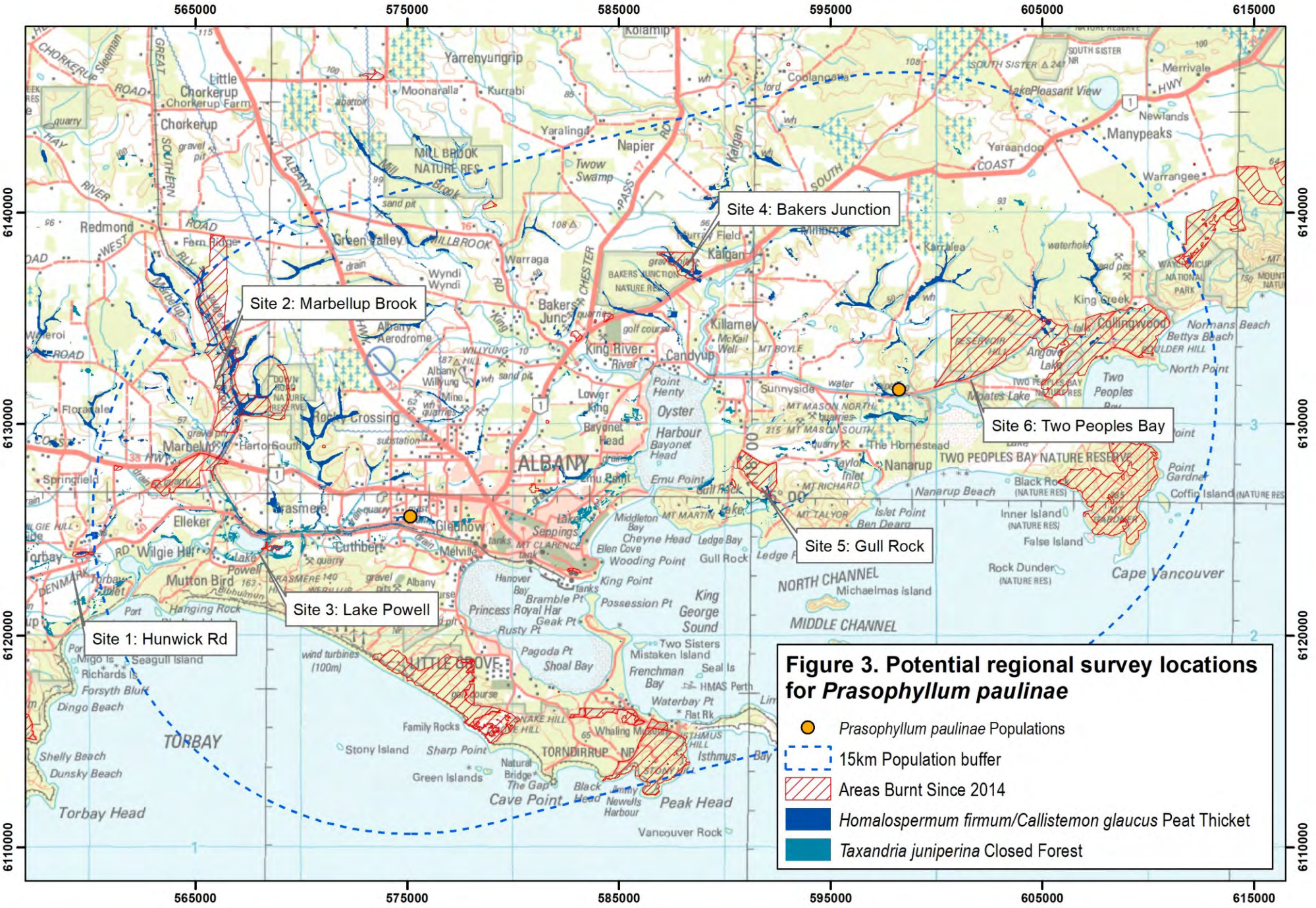
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Site 1: Hunwick Rd
Site 2: Marbellup Brook
Site 3: Lake Powell
Site 4: Bakers Junction
Site 5: Gull Rock
Site 6: Two Peoples Bay
ALBANY
TORBAY
MIDDLE CHANNEL
NORTH CHANNEL
TWO PEOPLES BAY NATURE RESERVE
MILL BROOK NATURE RES
TORNDIRRUP NP
LITTLE GROVE
Figure 3. Potential regional survey locations for Prasophyllum paulinae
Prasophyllum paulinae Populations
15km Population buffer
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest

5 FIELD SURVEY RESULTS

5.1 2019 Field Survey Results

Field assessments of the proposed regional survey sites, a subset of the habitat in the project area and other opportunistic locations were undertaken (six person days) by two senior botanists on the 16-18 of October 2019. Of the 19.25 ha of potentially suitable within the Albany Ring Road project area, only the previously known population and selected areas were revisited. Areas targeted were road edges, slashed areas and dam walls where inter-fire germination of orchids may occur due to localised disturbance.

All of the survey efforts (GPS track log) are shown in Appendix A. A summary of the field observations and habitat suitability for each site are presented in Table 5.

Table 5. Field observations of *P. paulinae* survey sites. Mapping of survey effort and population information provided in Appendix A.

Site	Location	Date	Survey Notes
Gledhow (Population 1) and surrounds (Lot 50 and 53 Frederick St, Lot 64 Cuming Rd, Reserve 46057, Lower Denmark Rd, Link Rd).	Known population in ARR project area and surrounding areas	18th October	No areas recently burnt therefore survey targeted firebreaks and slashed areas. Several *Prasophyllum* collections made for analysis. Collections made from Lot 64 Cuming Rd occur in a large fenced area owned by Broadcast Australia, this area is regularly slashed and is not mapped as remnant vegetation.
Link Rd Wetlands	ARR project area	18th October	Large wetland area mostly long unburnt. Considered suitable habitat if burnt in the future. Survey undertaken of slashed areas, dams and roadsides where inter-fire germination is possible. No *Prasophyllum* species observed.
Two Peoples Bay (Population 2)	Known Population	16th October	Large wetland burnt in 2011. Approximately 100 plants of *P. paulinae* previously observed (prior to 2015). Only several diminutive *P. macrostachyum* observed in 2019 despite intensive survey undertaken.
Hunwick South	Regional survey site (Site 1)	18th October	Large wetland burnt in 9/11/2017. Relatively drier than other sites with prolific *Evandra aristata*, not considered suitable for *P. paulinae*. No *Prasophyllum* species observed.
Marbellup Brook	Regional survey site (Site 2)	17th October	Extensive wetland system upper regions burnt 24/05/2018, lower regions burnt 18/01/2017. Large areas of potentially suitable habitat. Multiple *Prasophyllum* collections taken for analysis.
Lake Powell	Regional survey site (Site 3)	17th October	Large wetland burnt in 1/02/2018. Relatively dry and heavy weed infestation in *Taxandria juniperina,* saline/brackish conditions near lake edge. Considered only partially suitable for *P. paulinae*. No *Prasophyllum* species observed.
Bakers Junction	Regional survey site (Site 4)	16th October	Large wetland burnt in 25/10/2016. Considered to be potentially suitable habitat, however dense regeneration suggests optimal period or survey has past. Multiple *Prasophyllum macrostachyum* observed.
Gull Rock	Regional survey site (Site 5)	16th October	Multiple wetland areas burnt 2/06/2017 and 20/03/2019. Relatively dry in *Taxandria juniperina* and many wetlands with narrow incised gullies. Considered only partially suitable for *P. paulinae*. No *Prasophyllum* species observed.
Two Peoples Bay, Angove Reserve entrance	Regional survey site (Site 6)	16th October	Large wetland burnt in 1/01/2016. Considered ideally suitable habitat and fire age adequate for detection. No *Prasophyllum* species observed despite intensive survey undertaken.

Site	Location	Date	Survey Notes
Wright St, Elleker	Opportunistic site (Presented in map of regional site 3)	17th October	Small wetland area burnt adjacent to fire shed, exact date unknown. No *Prasophyllum* species observed.
Old School Rd Elleker	Opportunistic site (Presented in map of regional site 3)	17th October	Small wetland area between lower Denmark Rd and Old School Rd. Not burnt recently and no *Prasophyllum* species observed.
Lake Seppings	Opportunistic site	16th October	Patchy wetlands mostly long unburnt and generally too dry for *P. paulinae.* No *Prasophyllum* species observed.
Norwood Rd	Opportunistic site	16th October	Small wetland area adjacent to Norwood Rd. Not burnt recently and no *Prasophyllum* species observed.

5.2 Morphological Trait Assessment

The taxonomy of the genus *Prasophyllum* R. Br. is reported (Jones and Clement 1996) to be one of the most difficult of Australian orchid genera and considerable problems with identification of taxa occur due to the similarity of floral morphology between taxa and the difficulty of identifying dried herbarium specimens. Orchid experts (Andrew Brown pers. comm.) have also noted the potential limitation of the published description of *Prasophyllum paulinae*, which is derived from only one specimen.

The regional surveys undertaken as part of this study represent the largest systemic survey known for *Prasophyllum paulinae*. This provided an opportunity to make collections of fresh specimens of *Prasophyllum* species over a range of populations and habitat types, and to assess the application of the published description by David Jones (Jones and Clement 1996).

The key diagnostic morphological characters that distinguish *P. paulinae* from the allied *P. macrostachyum* are listed in Table 6. It was noted that several characters were defined only by qualitative judgments (i.e. thick or thin), which can be difficult to determine without any reference point. Ovary length was described to differ between taxa, however actual measurements for each taxon in their description are identical (i.e. 4 mm).

A subset of 22 fresh specimens that superficially resembled *P. paulinae* were assessed against the nine characters. The representative collections were from four wetland habitats, two from within Albany Ring Road Project area and two from outside the Project area. The assessment determined that five specimens (from one location) exhibited all of the characters that align with *P. paulinae*. However, many specimens showed a combination of characters from both species and several of the qualitative characters could potentially be influenced by the environment as follows:

- Two of the quantitative characters varied across a range of measurements expected in both taxa (i.e. *no. of flowers, ovary length*).
- Labellum characters were constant across all specimens (i.e. *labellum shape* was obtuse and *callus texture* was consistent in all specimens).
- Three of the qualitative characters separated the specimens into two groups (*flower arrangement, plant statue, flower separation*). However, these traits can potentially be influenced by plant age and site productively (i.e. flowers become more separated as the stem grows longer, young plants often have bud clusters at the apex and plants can be more robust on productive sites).

In summary, conflicting conclusions can be drawn, depending on which set of characters are used to base the specimen identification. A conservative approach was taken in identification in this analysis,

which determined the presence of extant plants of *P. paulinae* from one location. Plants attributed to *P. paulinae* had sub-pyramidal, clustered flowers on thick stems (>2mm) and generally had long ovaries and > 25 flowers. Other specimens attributed to *P. macrostachyum* had distinctly spaced, fewer flowers and were generally more diminutive. However, some of the labellum characters were consistent with the *P. paulinae* and some specimens showed intermediate characters (determined as *?P. paulinae*).

Concordant with the findings of other experts (Andrew Brown pers. comm.), the analysis here demonstrates inconsistences in the taxonomy of this taxon and highlights that a broader reassessment of the group may be warranted. Andrew Brown (ex. DBCA expert in Orchidaceae) viewed the specimens collected in this study and supported the interpretation of the taxonomy (Andrew Brown pers. comm.).

Table 6. Summary of morphological characters from Jones and Clement (1996) to distinguish the allied species *Prasophyllum paulinae* and *P. macrostachyum* and notes on how these were categorised or measured in the analysis.

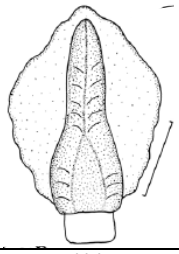
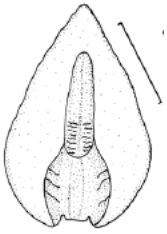
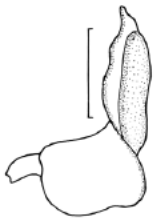
Key Characters	*P. paulinae*	*P. macrostachyum*	Notes
Overall flowers size (mm)	6	9	Vertical overall height of flowers measured to 1mm accuracy.
Flower arrangement	sub-pyramidal 	evenly spaced 	Qualitative judgement on shape, classified into two groups.
Plant statue	stout	slender	Diameter of flower stem measured as >2mm, or <2mm.
Flower separation on spike	strongly overlapping	widely spaced	Qualitative judgement on degree of overlap, classified into three groups: strongly overlapping, moderately overlapping and widely spaced.
No. of Flowers	25-70	15-30	Count of all flowers, including unopened buds.
Ovary length	4mm x 2.5mm	4mm x 1.5mm	*P. paulinae* noted to have longer ovaries. However, descriptions for both taxa are identical. Measured as overall length and width.
Lateral sepals	shorter broader	longer thinner	Qualitative judgement on shape. Measured as overall length and width.
Labellum shape	obtuse (wide point at 1/2) 	ovate (wide point at 1/3) 	Qualitative judgement on shape. Measured as position of widest point (either ½ or 1/3 from base of labellum).
Callus texture (viewed from side on)	thick 	thin 	Qualitative judgement on shape. Estimated as thick or thin without any reference point.

Table 7. Assessment of morphological characters of *Prasophyllum* species from four wetland locations. Two occur within the Albany Ring Road Project area (Lower Denmark Road Reserve (574963mE 6125156mN), Lot 53 Frederick St (574585mE, 6125551mN)) and two occur outside the Project area (Lot 64 Cuming Rd (574964mE, 6125349mN) and Marbellup Brook, Regional survey site 2 (566759mE, 6131584mN). *Collection Reference Number - these five specimens were dried and forwarded to the Western Australian Herbarium for vouchering.

Sample No.	Flowers size (mm)	Plant statue/stem diameter (mm)	Flower arrangement	Flower separation on spike	No. of flowers	Ovary length	Lateral sepals	Labellum shape	Callus texture	Determination
Lot 64 Cuming Rd (Population 1 and surrounding area)										
1	6	>2	sub-pyramidal	strongly overlapping	36	8	2.5x1	obtuse	?thick	*P. paulinae* *DAR1052
2	5	>2	sub-pyramidal	moderately spaced	32	7	3x1	obtuse	thick	*P. paulinae*
3	6	>2	sub-pyramidal	moderately spaced	20	5	2.5x1	obtuse	?thick	*?P. paulinae* *DAR1054
4	6	>2	sub-pyramidal	moderately spaced	24	5	2.5x1	obtuse	?thick	*?P. paulinae*
5	5	>2	sub-pyramidal	moderately spaced	27	6	4x1	obtuse	?thick	*P. paulinae*
6	6	>2	sub-pyramidal	moderately spaced	24	6	3x1	obtuse	?thick	*?P. paulinae*
7	5	>2	sub-pyramidal	moderately spaced	25	6	3x1	obtuse	?thick	*P. paulinae*
8	5	>2	sub-pyramidal	moderately spaced	22	5	2.5x1	obtuse	?thick	*?P. paulinae*
9	6	>2	sub-pyramidal	moderately spaced	35	4	3x1	obtuse	?thick	*P. paulinae* *DAR1053
10	5	>2	sub-pyramidal	moderately spaced	15	4	2.5x1	obtuse	?thick	*P. macrostachyum*
Lot 53 Frederick St (Population 1 and surrounding area)										
11	6	<2	evenly spaced	widely spaced	12	4	2.5x1	obtuse	?thick	*P. macrostachyum*
12	6	<2	sub-pyramidal	widely spaced	23	3	2.5x1	obtuse	?thick	*P. macrostachyum*
Marbellup Brook, Regional survey site 2										
13	5	<2	evenly spaced	moderately spaced	21	6	3x1	obtuse	?thick	*P. macrostachyum* *DAR1055
14	5	<2	evenly spaced	widely spaced	34	6	2.5x1	obtuse	?thick	*P. macrostachyum*
15	5	<2	evenly spaced	moderately spaced	24	6	2.5x1	obtuse	?thick	*P. macrostachyum*
16	5	<2	evenly spaced	moderately spaced	19	5	2.5x1	obtuse	?thick	*P. macrostachyum* *DAR1056
17	5	<2	evenly spaced	widely spaced	24	5	2.5x1	obtuse	?thick	*P. macrostachyum*
18	5	<2	evenly spaced	widely spaced	18	6	2.5x1	obtuse	?thick	*P. macrostachyum*
19	5	<2	evenly spaced	widely spaced	15	5	2.5x1	obtuse	?thick	*P. macrostachyum*
20	5	<2	evenly spaced	widely spaced	12	5	2.5x1	obtuse	?thick	*P. macrostachyum*
Lower Denmark Rd (Population 1 and surrounding area)										
21	5	<2	evenly spaced	widely spaced	10	4	2.5x1	obtuse	?thick	*P. macrostachyum*
22	5	<2	evenly spaced	widely spaced	12	4	2.5x1	obtuse	?thick	*P. macrostachyum*

5.3 Population Estimate of *Prasophyllum paulinae*

The analysis in this assessment determined the presence of five extant plants of *P. paulinae* (Plate 3) from one location (Lot 64 Cuming Rd), which occurs outside the Albany Ring Road Project area. However, this population was also composed of some specimens with intermediate characters between *P. paulinae* and *P. macrostachyum*. Therefore, an accurate population assessment is limited due to the inherent ambiguity in the taxonomy and the impracticality of assessing each individual specimen by microscopy. A population estimate determined by field observation quantified 50 individuals attributable to *P. paulinae* to be present within the wetland habitat, which occupied 0.45 ha (population mapped in Appendix A).

The habitat at this site is composed of an unburnt, but regularly slashed, ground cover of predominantly native plants within a large fenced area owned by Broadcast Australia that houses an AM radio tower (Plate 4). The site has restricted access and the low groundcover is maintained to manage the needs of the tower and infrastructure. Importantly, this area is not mapped as remnant vegetation therefore highlights a limitation of using desktop spatial data to guide regional surveys. The presence of *P. paulinae* in this habitat is potentially due to the seasonal slashing that mimics burning (i.e. creates an open habitat without competition) and is facilitated by a reduction of browsing pressure.

Plate 3. *Prasophyllum paulinae*.

Plate 4. *Prasophyllum paulinae* habitat, Lot 64 Cuming Rd, Gledhow.

6 CONCLUSIONS

Suitable habitat of *P. paulinae* is most likely associated with recently burnt vegetation that aligns with two Albany Regional Vegetation Mapping Units (*Taxandria juniperina* Closed Forest (ARVS Unit 59) and *Homalospermum firmum/Callistemon glaucus* Peat Thicket (ARVS Unit 47). These units occupy 19.25 ha of the Albany Ring Road Project area and a total of 2,861 ha are mapped within the Albany Region. Of the 2,861 ha, 12% occurs within IUCN conservation reserves.

One previously known population of *P. paulinae* is recorded from the Albany Ring Road Project area (population one). Historical photos indicate population one occupies approximately 1.04 ha of the Albany Ring Road Project area. No extant individuals of *P. paulinae* were recorded at this location during the targeted survey (and during previous surveys in spring 2017 and 2018). Whilst no individuals of *P. paulinae* have been recorded from this location despite extensive survey effort, there remains the possibility for the taxon to emerge in future years, particularly after a fire event.

Targeted searches in areas containing suitable habitat for *P. paulinae* within the Albany Ring Road Project area did not identify any individuals of the taxon. These areas have been subject to survey effort in 2017, 2018 and 2019, however are long-unburnt and some are highly degraded.

Targeted searches of regional survey areas (including population two, sites 1-6 and four opportunistic sites), identified a new previously unknown population of *P. paulinae*, outside the Albany Ring Road Project area. This population is estimated to comprise 50 plants within the wetland habitat and occupies 0.45 ha. The habitat at this site is composed of an unburnt, but regularly slashed, ground cover of predominantly native plants that occurs within a large fenced area. No individuals of *P. paulinae* were located at the other surveyed locations, which had suitable habitat of variable fire ages.

The regional surveys undertaken as part of this study represent the largest systemic survey known for *P. paulinae*. This provided an opportunity to make collections of fresh specimens of *Prasophyllum* species over a range of populations and habitat types, and to assess the application of the published description by David Jones (Jones and Clement 1996). Many specimens showed a combination of characters from species (*P. paulinae* and *P. macrostachyum*) and several of the qualitative characters could potentially be influenced by the environment. Concordant with the findings of others (Andrew Brown pers. comm.), the analysis demonstrated inconsistences in the taxonomy and highlights the need for a broader reassessment of the group.

7 REFERENCES

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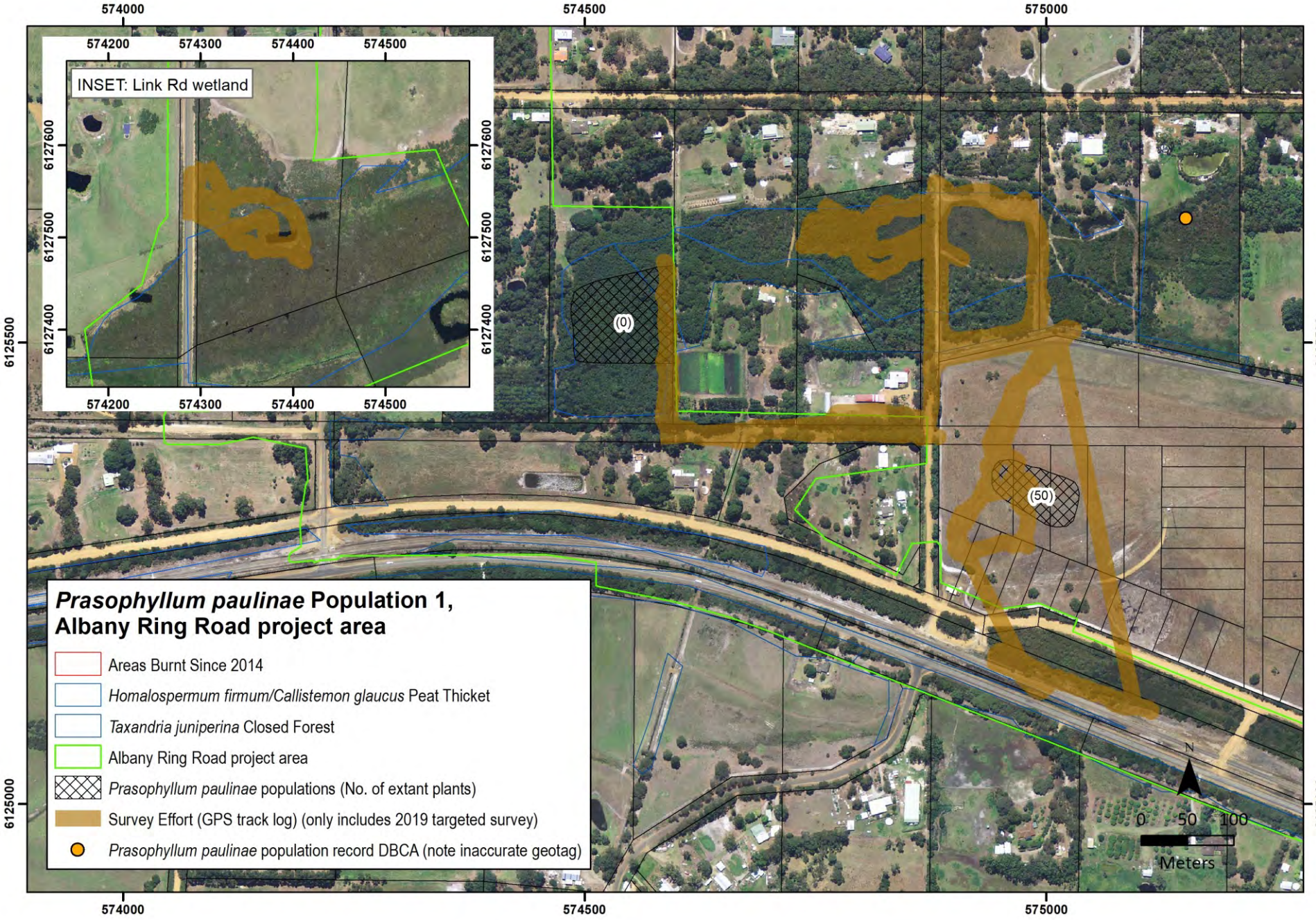
8 Appendix A - Survey Site Maps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INSET: Link Rd wetland
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Prasophyllum paulinae Population 1,
Albany Ring Road project area
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Albany Ring Road project area
Prasophyllum paulinae populations (No. of extant plants)
Survey Effort (GPS track log) (only includes 2019 targeted survey)
Prasophyllum paulinae population record DBCA (note inaccurate geotag)
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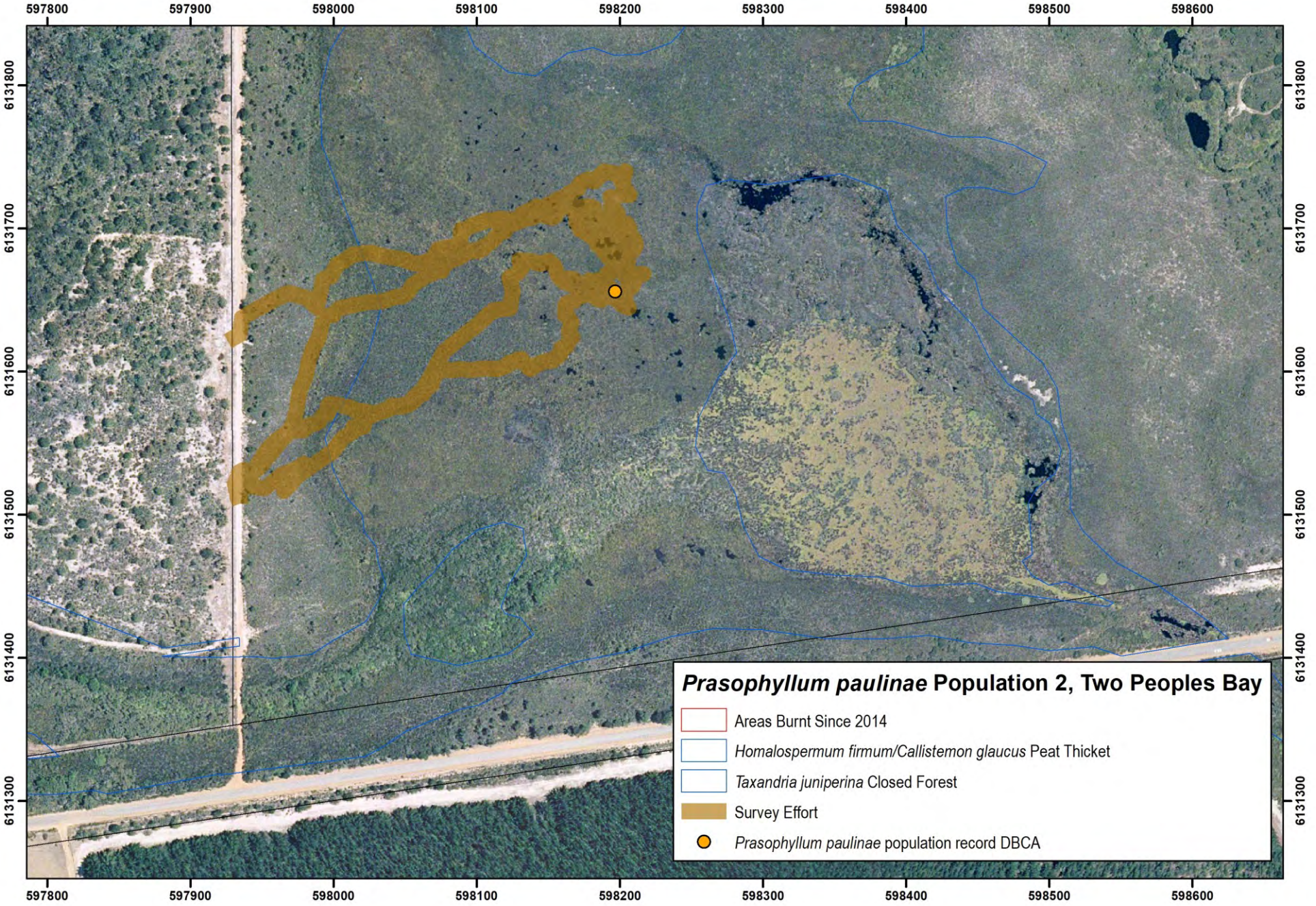
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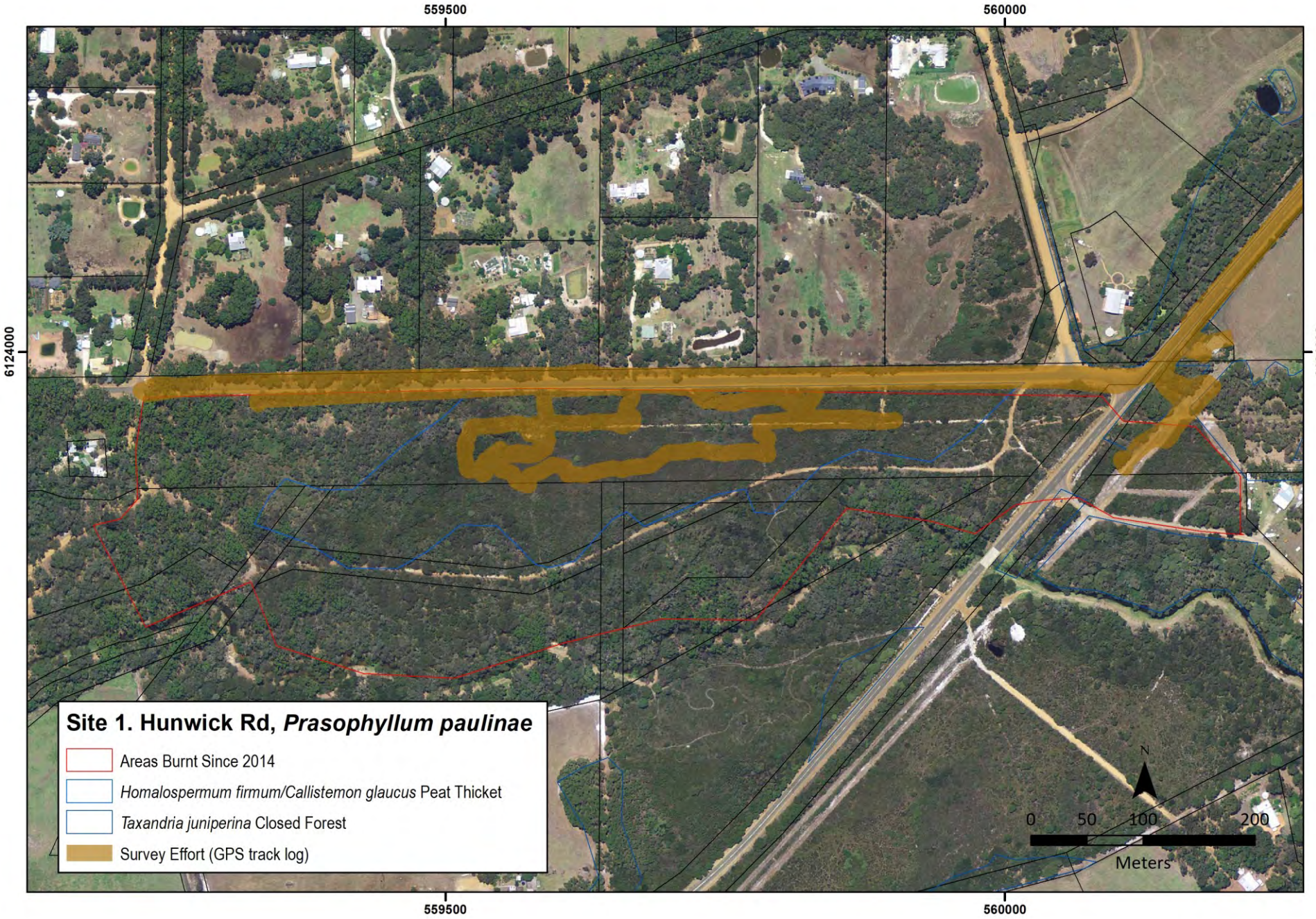
Prasophyllum paulinae Population 2, Two Peoples Bay
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort
Prasophyllum paulinae population record DBCA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Site 1. Hunwick Rd, *Prasophyllum paulinae*
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)
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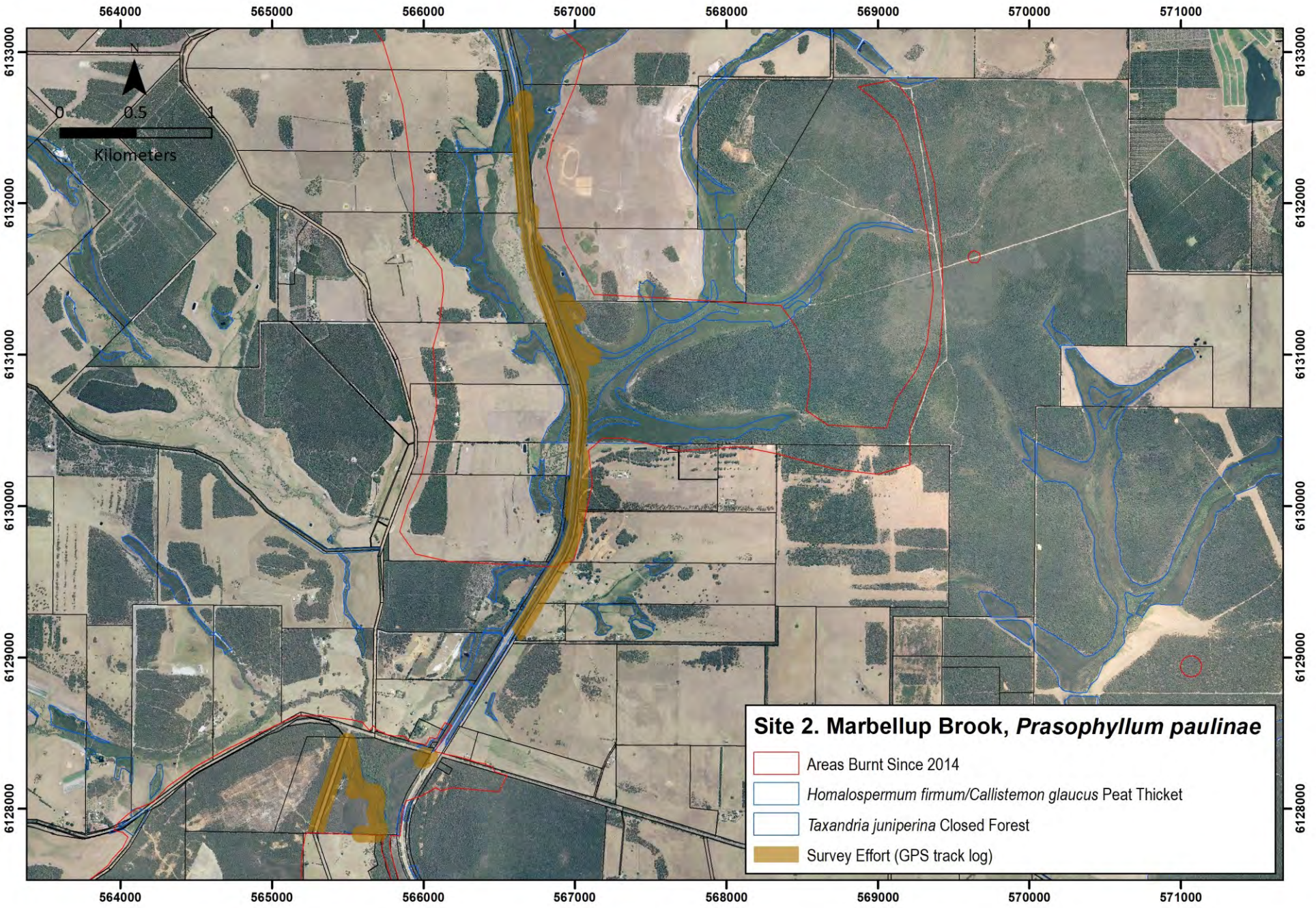
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Site 2. Marbellup Brook, *Prasophyllum paulinae*
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)


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Site 3. Lake Powell, *Prasophyllum paulinae*
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)
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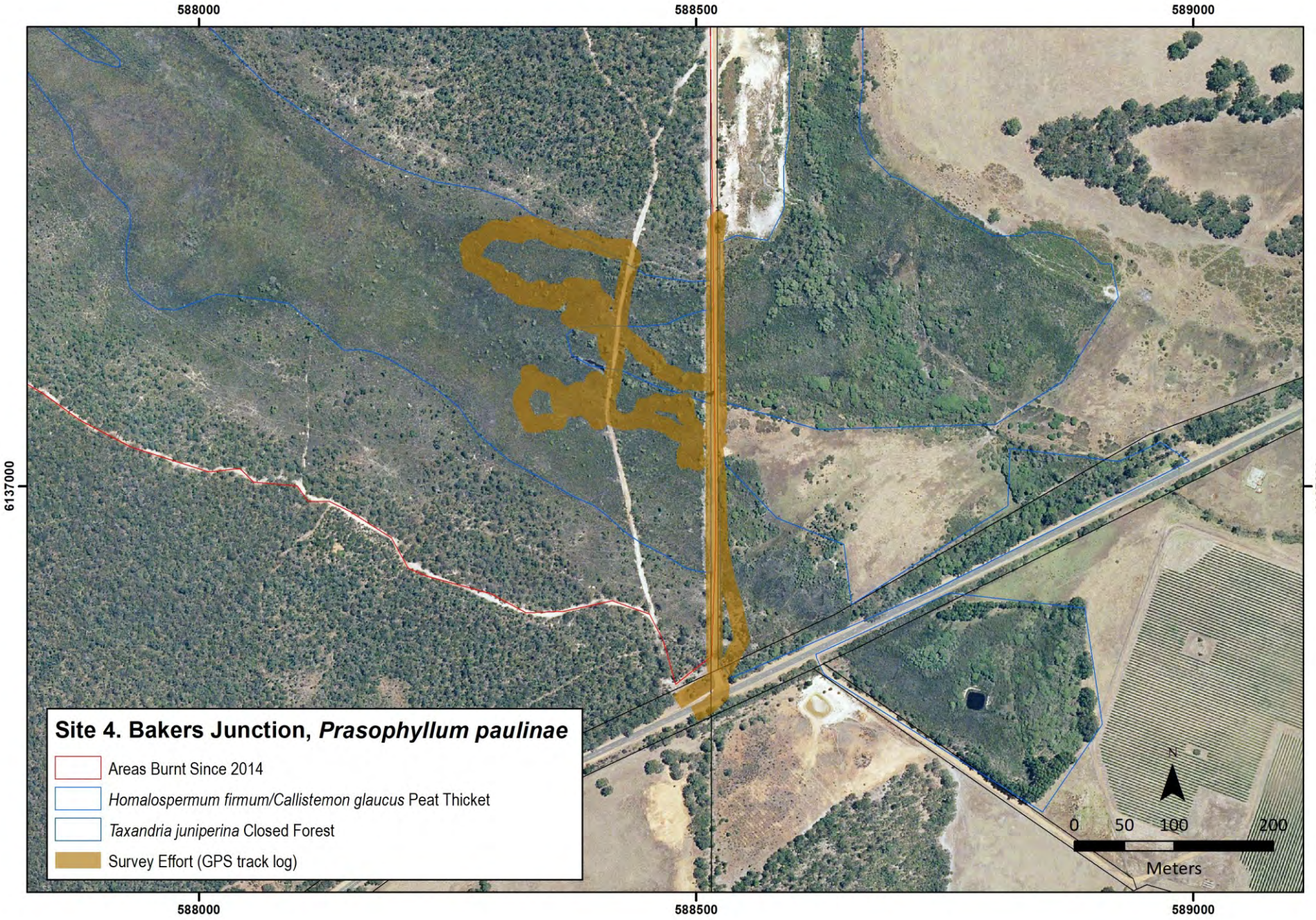
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Site 4. Bakers Junction, Prasophyllum paulinae
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)
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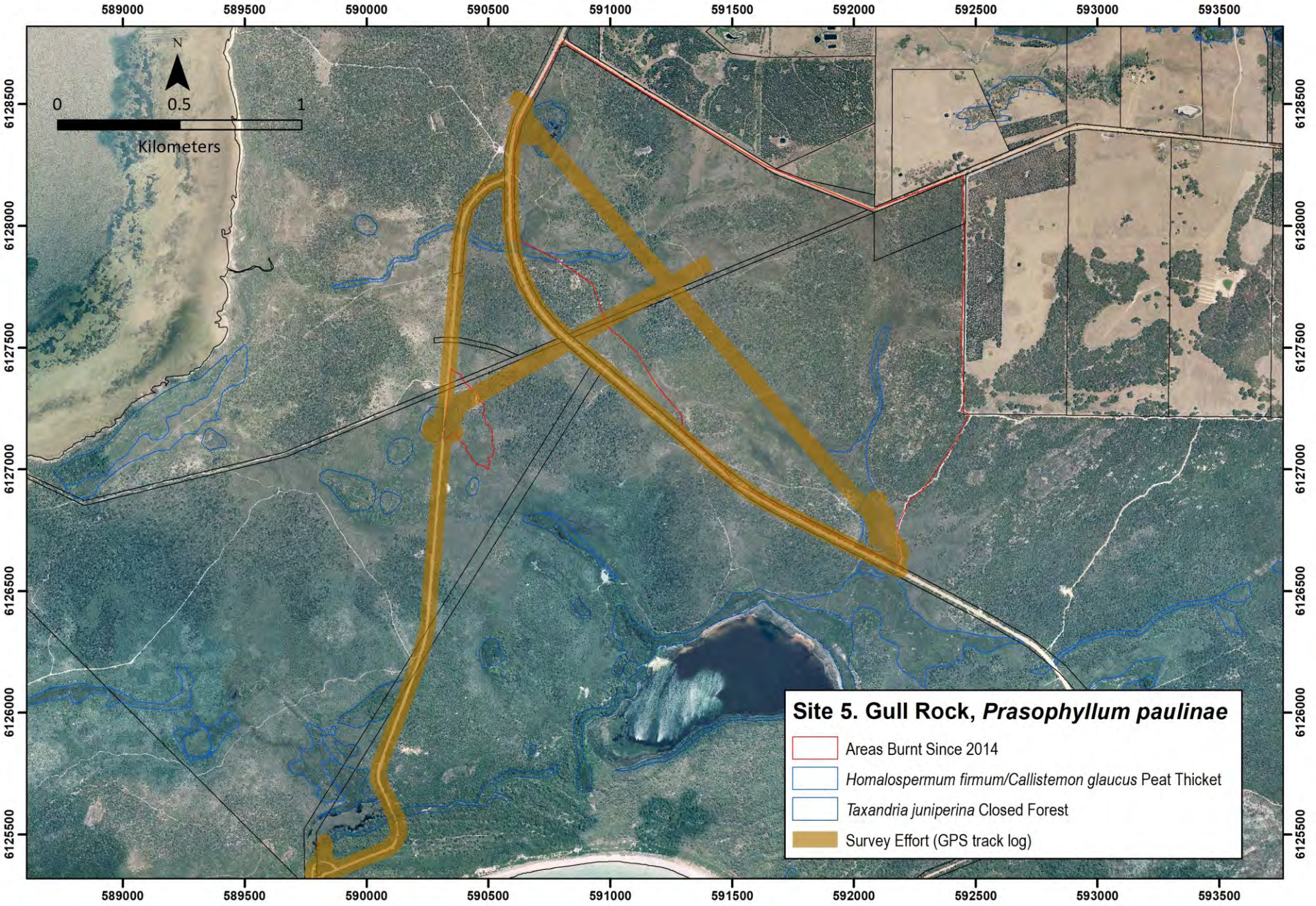
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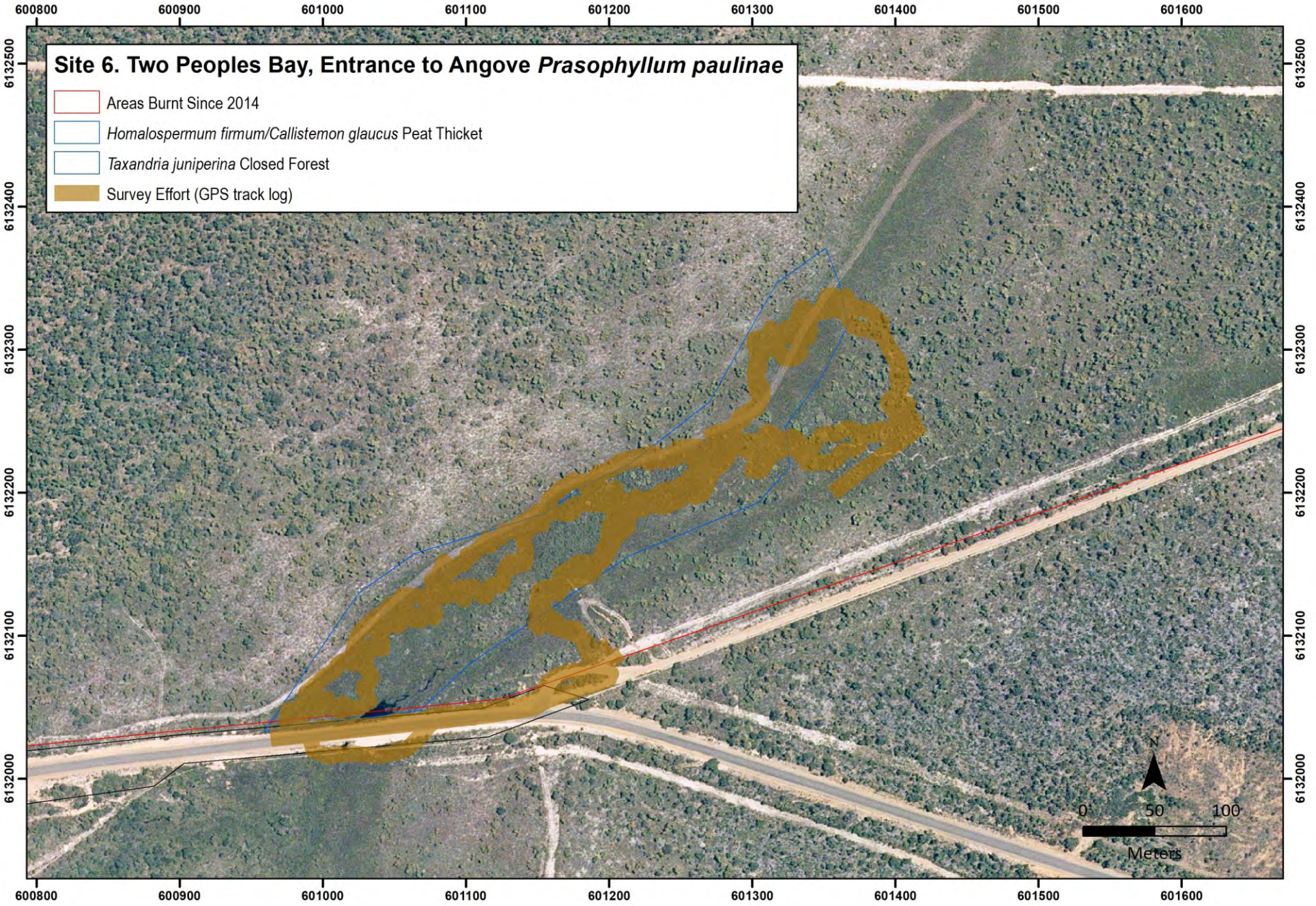
Kilometers
Site 5. Gull Rock, *Prasophyllum paulinae*
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)


Site 6. Two Peoples Bay, Entrance to Angove *Prasophyllum paulinae*
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)
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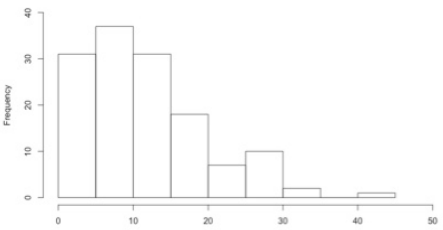
582600
6132800
6132700
6132600
Opportunistic Sites, Lake Seppings and Norwood Rd (inset)
Areas Burnt Since 2014
Homalospermum firmum/Callistemon glaucus Peat Thicket
Taxandria juniperina Closed Forest
Survey Effort (GPS track log)

Appendix C: Biota Environmental Sciences, Albany Ring Road, Western Ringtail Possum Assessment, Main Roads Western Australia May 2020

Biota Environmental Sciences

Albany Ring Road Project Western Ringtail Possum Assessment



Main Roads Western Australia

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Approved for issue: Roy Teale

Albany Ring Road WRP Assessment

Contents

Tables

Figures

1.0 Summary

The Albany Ring Road project is a proposed staged development to support freight growth in the City of Albany, by creating an alternative route for heavy vehicles accessing Albany Port and remove the necessity for these vehicles to travel through built up urban areas of the City. Stage 1 is complete and Stage 2 and Stage 3, the focus of this study, will connect Albany Highway, South Western Highway, Lower Denmark Road and Hanrahan Road allowing access to the port.

This report presents the results of sampling for the Western Ringtail Possum within the Albany Ring Road Project Area (the "Project Area" hereafter) as well as local and regional contextual sampling. Central to the overall assessment of the significance of the Western Ringtail Possum habitat encompassed by the Project Area is the provision of local and regional context. To provide local context, distance sampling was undertaken in the Down Road Nature Reserve located approximately 4 km north-west of the Project Area. The contextual assessment is extended further by comparison with abundance estimates derived for Bakers Junction Nature Reserve, Mt Melville, Mt Clarence and Mt Adelaide. Finally, the assessment extrapolates the density estimates to the extent of the Albany Regional Vegetation Survey to provide an 'Around Albany' sub-population estimate. Assumptions are presented that provide caveats relevant to this extrapolation of density estimates.

Two sampling methods were used within the Project Area: (i) strip sampling was employed in areas where the habitat comprised individual isolated trees or narrow strips of vegetation, and (ii) distance sampling was used over larger remnants (the Old Tip site and CSBP site). At the Down Road Nature Reserve context site, distance sampling was applied to the entire site.

Within the Project Area 16.2 km of strip transects yielded 13 observations of Western Ringtail Possums and, when the expected number of individuals based on distance sampling in the Old Tip site and CSBP site are included, the abundance estimate for the Project Area increased to between 20 and 37 individuals. For the area of habitat sampled (92.2 ha) this represents a density estimate ranging between 0.22 – 0.40 individuals per hectare.

The sampled area of Down Road Nature Reserve (363 ha) was estimated to support 452 ± 85 (95% CI 312 – 656) individuals for a density estimate of 1.246 ± 0.234 individuals per hectare.

At a regional scale, further distance sampling effort has been applied to three other remnant habitat sites, at Bakers Junction Nature Reserve, Mt Melville, Mt Clarence and Mt Adelaide where a combined estimate of 1,480 (95% CI 894 – 2,465) Western Ringtail Possums in an area of 4,400 ha was calculated.

If an average density estimate of 0.8 individuals per hectare (derived from the two largest areas surveyed: Down Road Nature Reserve and Bakers Junction Nature Reserve) is extrapolated to the mapped extent of the vegetation units surveyed within the Albany Regional Vegetation Survey boundary (a combined area of 21,633 ha), an estimate of 17,306 Western Ringtail Possums is obtained. Not all of this habitat would necessarily be utilised by Western Ringtail Possums, due either to land clearing that has occurred since 2010 (when the mapping was completed), recent fires or degradation from a variety of pressures. Nor is it necessarily accurate to apply a uniform density across the region encompassed by the mapping. However, the approach does indicate that the population estimate for the 'Around Albany' sub-population is considerably larger than the 500 reported in the IUCN assessment, perhaps by an order of magnitude.

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2.0 Introduction

2.1 Project Background

The Albany Ring Road project is a proposed staged development to support freight growth in the City of Albany, by creating an alternative route for heavy vehicles accessing Albany Port and remove the necessity for these vehicles to travel through built up urban areas of the City. Stage 1 is complete and Stage 2 and Stage 3, the focus of this document, will connect Albany Highway, South Western Highway, Lower Denmark Road and Hanrahan Road allowing access to the port (Figure 2.1).

A biological assessment of Stages 2 and 3 was undertaken in late 2017 (Rathbone and Gilfillan 2018) and determined that the Western Ringtail Possum *Pseudocheirus occidentalis,* which is listed as Critically Endangered at both State and Commonwealth levels, utilised a large proportion of the study area. Rathbone and Gilfillan (2018) categorised habitat as either Core, Supporting, Linkages or Likely Linkages. They subsequently identified areas of Core habitat in the southern section of their survey area, coincident with reserves and some remnants on private property. Supporting habitat included large areas in the east of their survey area predominantly within land owned by CSBP. Important habitat linkages were identified along the rail reserve, between Elleker Road and the railway line and along Link Road, south of Lancaster Road and on George Street. Much of the remaining habitat was identified as Likely Linkages.

2.2 Current IUCN Conservation Ranking of the Western Ringtail Possum: Rationale and Threats

The most recent assessment of the conservation status of the Western Ringtail Possum took place in 2014 and was published in 2017 (Burbidge and Zichy-Woinarski 2017). This re-assessment determined that the conservation ranking should be Critically Endangered under the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. The key elements of the justification for the ranking were:

- An area of occupancy of <500 km^2 (area of occurrence 40,000 km^2).
- Small severely fragmented populations.
- A continuing decline (threats being a drying climate, urban development, inappropriate fire regime, predation by foxes and cats).
- The upper Warren sub-population, which was identified as the largest prior to 2002, underwent a severe decline (>95%) between 1998 and 2009 (from >10,000 individuals to near extirpation).
- Remaining fragmented populations in coastal habitats also rapidly declining (equating to an overall population decline of >80% in the past 10 years).
- Predicted further decline of >80% within the next 10 years.

The following 2015 abundance estimates are quoted within the IUCN Red List for the five recognised subpopulations of Western Ringtail Possum with Dr B. Jones cited as the source:

- Southern Swan: 2,000
- Cape to Cape: 500
- Other Forest Rivers: 300
- Upper Warren: 100
- Around Albany: 500

These subpopulation estimates yield a 2015 total of about 3,400 adult Western Ringtail Possums (Burbidge and Zichy-Woinarski 2017). At the time of assessment they were considered to occur "*….patchily in coastal areas from near Bunbury to the Leeuwin-Naturaliste National Park and near Albany (B. Jones pers. comm).*" The authors go on to say that "*Most of these fragmented habitat remnants are on private land*" (Burbidge and Zichy-Woinarski 2017).

2.3 Study Purpose

This study details the results of targeted sampling for the Western Ringtail Possum within the Project Area as well as at a context site, the Down Road Nature Reserve (Figure 2.1). These results are also placed in further regional scale context by comparison with density estimates for Bakers Junction Nature Reserve, Mt Melville, Mt Clarence and Mt Adelaide which have been reported on separately (Figure 2.2). Finally, results of this local and regional work are placed in the wider "Around Albany" context.

2.4 Scale of Consideration

Four scales of geographic context are applied in this study (Project Area, Down Road Nature Reserve, Regional Scale and 'Around Albany sub-population') as defined in Table 2.1 and shown in Figure 2.1 and Figure 2.2.

To define the 'Around Albany' Western Ringtail Possum subpopulation identified (but undefined) in the IUCN conservation ranking published in 2017 (Burbidge and Zichy-Woinarski 2017), we have considered it to be equivalent to the extent of the Albany Regional Vegetation Survey (Sandiford and Barrett 2010). This is considered an appropriate definition for the 'Around Albany' sub-population as Sandiford and Barrett (2010) provides a detailed (67 native vegetation units mapped) thematic layer within which potential Western Ringtail Possum habitat can be identified, and for which density estimates can be extrapolated from the aforementioned distance sampling programs.

Table 2.1: Description of project tiers used to provide context for the Albany Ring Road Western Ringtail Possum Assessment.

Tiers	Description
Project Area	Various polygons along the length of the proposed Albany Ring Road route encompassing an area of 92.2 hectares (ha) (Figure 2.1).
Down Road Nature Reserve	The area adjacent to the Project Area within which a local context was ascertained. Specifically, the context is provided by a distance sampling program undertaken in the Down Road Nature Reserve that surveyed 21.8 kilometres (km) of line transects over seven nights. The reserve encompasses approximately 777.3 ha of which approximately 363 ha encompasses vegetation units sampled by the survey. Approximately one third of the reserve was burnt one month prior to the survey and this area has been estimated and excluded from all calculations.
Regional Scale	Extends context to include results of distance sampling programs in Bakers Junction Nature Reserve, Mt Melville, Mt Clarence and Mt Adelaide (Biota 2018a).
'Around Albany' sub-population	The IUCN species account for the Western Ringtail Possum (Burbidge and Zichy-Woinarski 2017) identifies 'Around Albany' as one of five sub-populations for the species. The geographic extent of this sub-population is not described any further by the IUCN account. This study recommends that for the purpose of this assessment, an area coincident with the boundary of the Albany Regional Vegetation Survey (ARVS) (Sandiford and Barrett 2010) be used to circumscribe the range of the 'Around Albany' subpopulation. The ARVS provides a description and extent of vegetation types encompassing 124,415 ha, bounding the Albany town site by 30 km to the east and west and 20 km to the north.

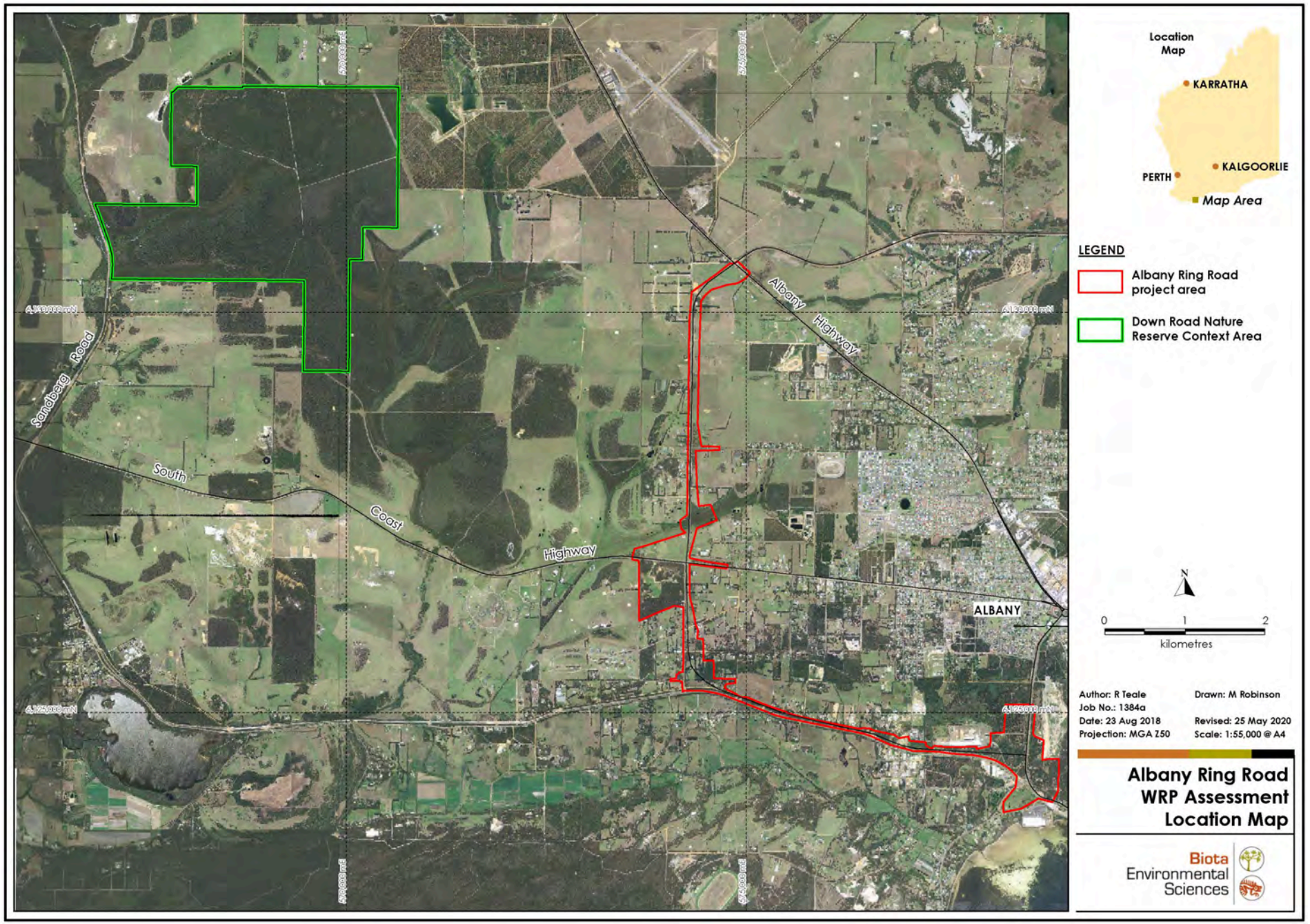

Figure 2.1 The Albany Ring Road Project Area and Down Road Nature Reserve Study Area.

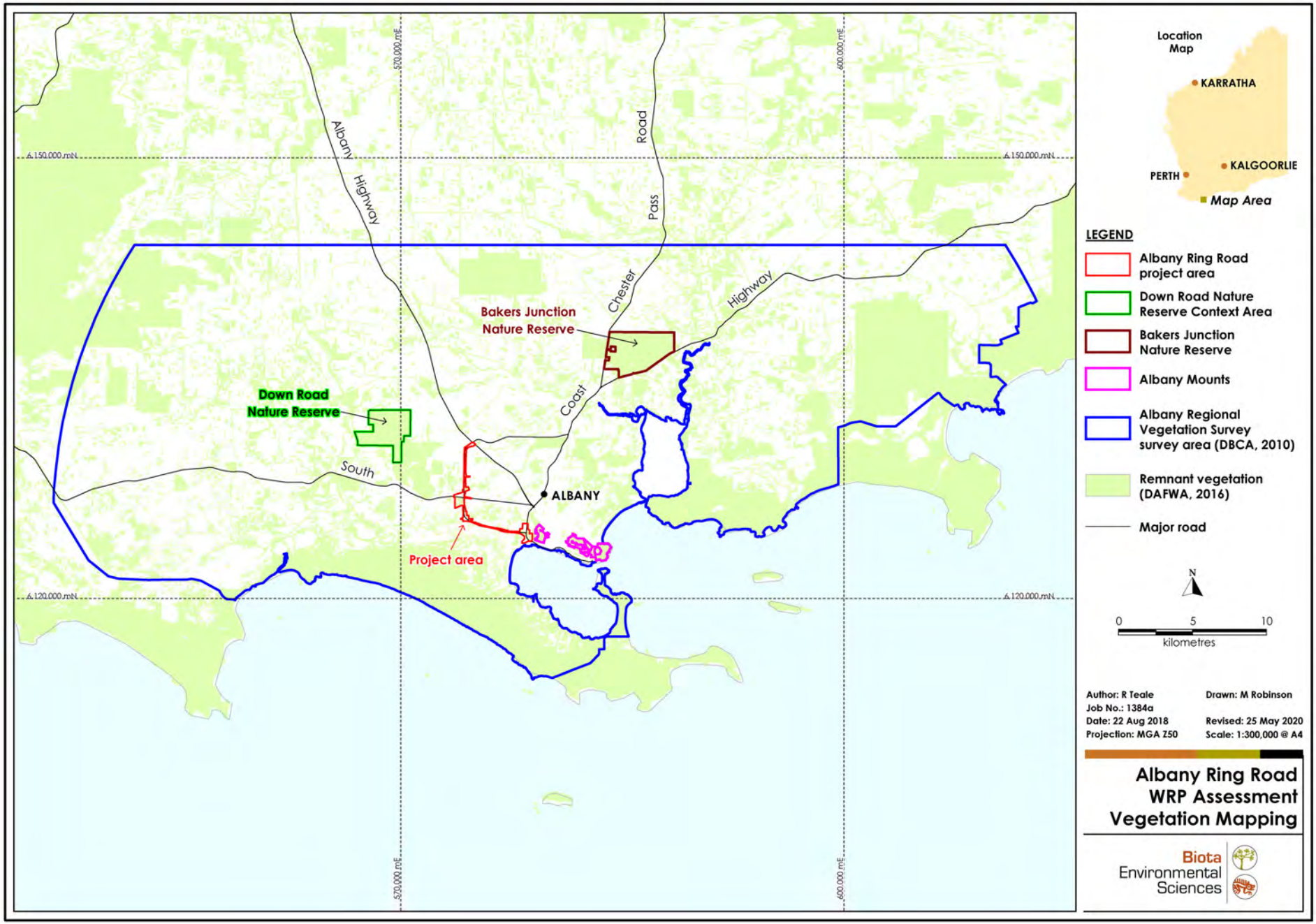

Figure 2.2: Locations of the Project Area, Down Road Nature Reserve and additional contextual sites (Bakers Junction Nature Reserve, Mt Clarence, Mt Adelaide and Mt Melville).

3.0 Methods

3.1 Survey Timing, Personnel and Permits

The survey was undertaken over 11 nights between 5 July and 21 July 2018 by Roy Teale, Stewart Ford, Victoria Ford and Zoe Hamilton all of Biota Environmental Sciences under a Department of Biodiversity, Conservation and Attractions (DBCA) Regulation 17 Licence to take fauna for scientific purposes (08-002410-1).

3.2 Survey Design

3.2.1 Project Area: Strip Transects and Line Transect Distance Sampling

Areas of scattered trees and shrubs and narrow vegetation remnants within the Project Area were surveyed using strip transects (Figure 3.1 - Figure 3.4). Each transect was at most 20 m in width and varied in length between 35 m and 1,376 m. The total length of strip transects in the Project Area was 16.2 km. The 20 m width was selected to yield greater than 90% probability of detection as derived from modelled detection functions fitted to perpendicular distances of Western Ringtail Possum sightings data from other studies (see Section 4.1).

Each 20 m wide strip transect was systematically searched for Western Ringtail Possums by a zoologist using a high-powered head torch. Survey work commenced at approximately 30 min after sunset and ended by 12:30 am. In some areas where the Road Reserve comprised scattered single trees, spotlighting was conducted from a vehicle. In all cases, the location of an observed possum was recorded using a handheld GPS while standing directly below the possum.

When complete detectability is less certain (i.e. probability of detection is less than 1.0, such as when surveying over large areas) other approaches must be adopted that allow the probability of detection and the effective survey area to be estimated. Distance sampling is one such method and is a robust and well documented approach to estimating density. Line transect distance sampling was undertaken at two locations within the Project Area; the George Street Old Tip site and the CSBP Fertiliser site. The Old Tip site encompassed approximately 35 ha and was sampled by ten line transects spaced at 75 m intervals yielding a total effort (combined transect length) of 3.9 km. The CSBP site encompassed approximately 17 ha and was traversed by nine line transects spaced at 75 m intervals with a combined effort of 2.3 km. Distance sampling of these sites followed the methodology in Section 3.3.2.

3.2.2 Down Road Nature Reserve: Line Transect Distance Sampling

To provide local context for the assessment of the habitat within the Project Area, a distance sampling approach (Buckland et al. 2001) was used to estimate the density and abundance of Western Ringtail Possums within the Down Road Nature Reserve (Study Area). Down Road Nature Reserve is a large habitat remnant (777.3 ha) that lies approximately 4 km to the west of the Project Area (see Figure 2.1) and was considered likely to support Western Ringtail Possums.

A total of 50 km of transect was initially proposed for survey (Biota 2018b) however, a fire burnt approximately one third of the Reserve one month prior to the survey and these burnt sections were excluded. The Study Area sampling program was subsequently designed around 17 north-south and 47 east-west oriented parallel line-transects spaced 75 m apart and spanning the entire extent of unburnt sections of the Nature Reserve (Figure 3.5). However, transects generally took longer to complete than initially anticipated, especially those transects within the *Hakea* spp. Shrubland / Woodland Complex vegetation unit (of the ARVS by Sandiford and Barrett (2010)), and the majority of the transects within this vegetation unit were not sampled. Of the initial 50 km of planned transects (Biota 2018b), 21.8 km were actually sampled during this study.

Sandiford and Barrett (2010) define 11 vegetation units within the Down Road Nature Reserve, of which three (considered to represent primary habitat for Western Ringtail Possum) were surveyed as part of the distance sampling program (Table 3.1).

Table 3.1: Vegetation units (after Sandiford and Barrett 2010) surveyed as part of the Western Ringtail Possum distance sampling program in the Down Road Nature Reserve.

Vegetation unit / wetland feature	Area in Reserve (prior to the May 2018 fires)
Jarrah/Marri/Sheoak Laterite Forest (Unit 12)	302.3 ha
Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland (Unit 13)	65.4 ha
Hakea spp. Shrubland / Woodland Complex (Unit 31)	258.1 ha

Two zoologists (Roy Teale and Stewart Ford) undertook the survey within the Down Road Nature Reserve. Each transect was walked by one observer using a high-powered head torch (Led Lenser XEO 19R model) to detect animals. The location of each observation was recorded using a Hemisphere R330 Differential GPS, typically providing accuracy to within 1.5 m. The following data were recorded for each observation:

- species (Western Ringtail Possum or Common Brushtail Possum);
- observer;
- animal location using GPS standing directly underneath;
- time;
- number of individuals;
- cue: Seen (eyeshine), seen (no eyeshine), heard or silhouette; and
- tree type.

Walking pace along transects was generally equivalent to approximately 0.5 km per hour.

3.2.2.1 Data Analysis

There were sufficient observations of Western Ringtail Possums (n=80) yielded by the Down Road Nature Reserve distance sampling program to independently model a detection function (required to derive animal density estimates using distance sampling approaches; Buckland et al. (2001)). However, the number of observations yielded by the distance sampling program within the Old Tip and CSBP sites (n = 7 after truncation) was fewer than the number generally recognised as being suitable for modelling a detection function (n=60 to 80) (Buckland et al. 2001). Hence, observations from these two small remnants (CSBP site and the old George Street Tip site) were pooled with observations from Down Road Nature Reserve and Bakers Junction Nature Reserve to yield a global detection function with derived parameter estimates which were then stratified by Reserve and remnant.

Perpendicular distances to each observation from the transect were calculated using MapInfo Professional Geographical Information System (GIS) v12.5 from the GPS location taken at the point of observation. Perpendicular distance data were analysed using the the 'mrds' (Laake et al. 2013) and 'Distance' (Miller 2013) packages in R statistical software (R Core Team 2013). Probability Detection Functions were modelled based on the histogram of perpendicular distance measurements to individuals and pairs (clusters). Perpendicular distance data were plotted as histograms with customised cut-points and examined to determine whether evasive movement of animals was occurring prior to detection. Stepped lower initial intervals that increase away from the centreline can indicate movement away from the observer, while initially high then decreasing intervals indicate relatively little movement away from the observers (Buckland et al. 2001). Both can lead to bias in density estimation.

Histograms were right truncated as necessary to achieve better model fit, optimally at the distance at which detection probability was 0.15 as recommended by Buckland et al. (2001), but other truncation distances were tested as part of the model selection phase. Akaike's Informative Criterion (AIC) is a quantitative method of model selection and was used to select between potential models (Buckland et al. 2001). In addition to AIC, candidate models were also compared using visual inspection of their fit to histograms of the perpendicular distance, goodness of fit quantile-quantile (Q-Q) plots, Kolmogorov-Smirnov (K-S) and Cramér-von Mises

(CvM) test statistics (Buckland et al. 2004). The half-normal and hazard rate keys were used for modelling the Probability Detection Function, with or without adjustment terms (Buckland et al. 2001).

The selected model was used to estimate the following parameters:

1. the encounter rate (n/L), where n was the number of observed clusters and L was the total length of the transect;
2. the average probability of detection (p);
3. a density estimate (D); and
4. an estimate of the number of animals in the specified area (N).

Variation in the Probability Detection Function caused by observers (factor covariate: observer) and study area (factor covariate: study area) were modelled. The effect of time elapsed since survey commencement (minutes past 18:30) was also examined to see if observer fatigue played a role in affecting detection rates. Only the results from the preferred model are discussed here.

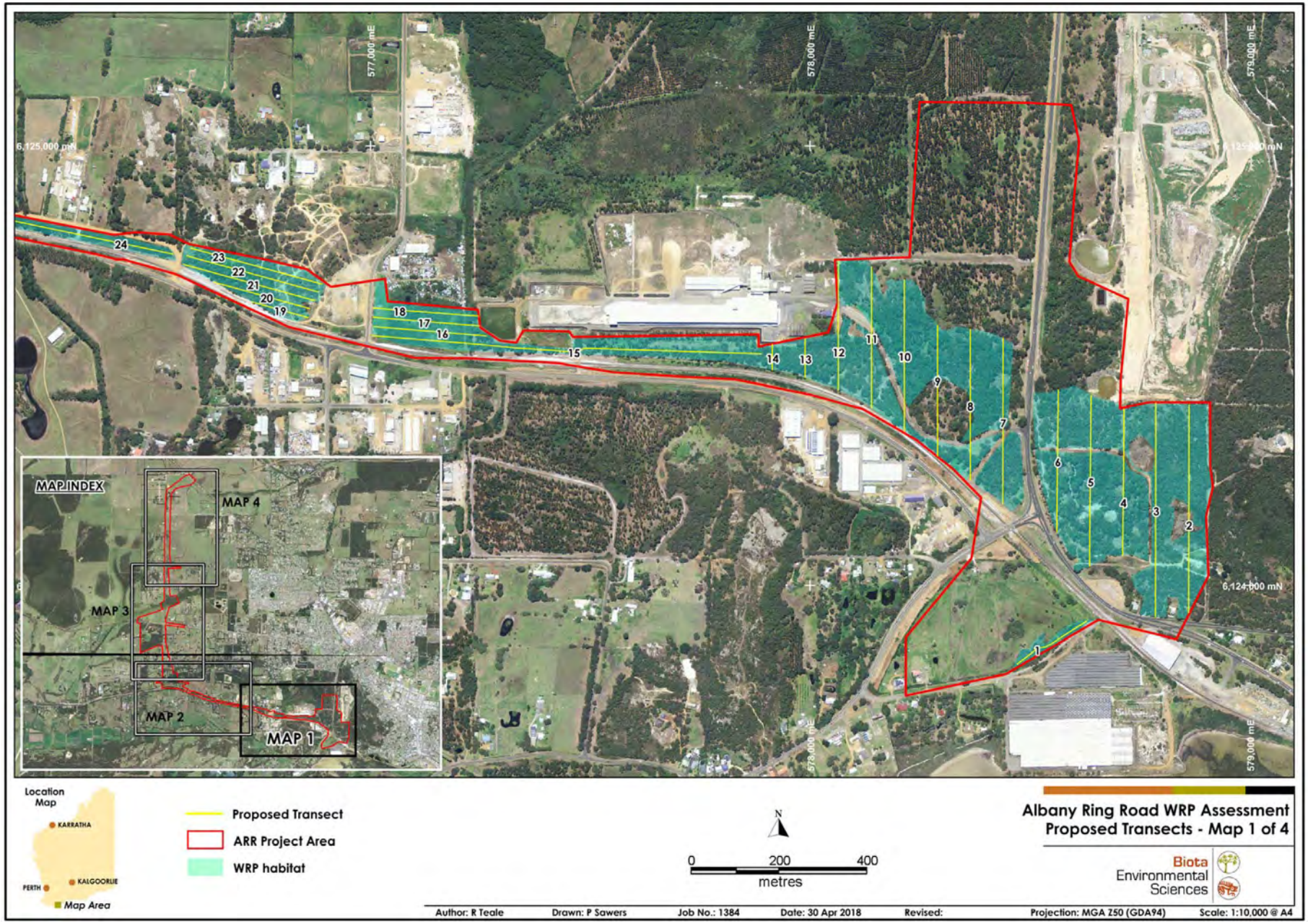

Figure 3.1: Distance sampling transects (Transects 2 – 14) within the CSBP site and strip transects (Transects 15 to 24) within the Albany Ring Road Project Area.

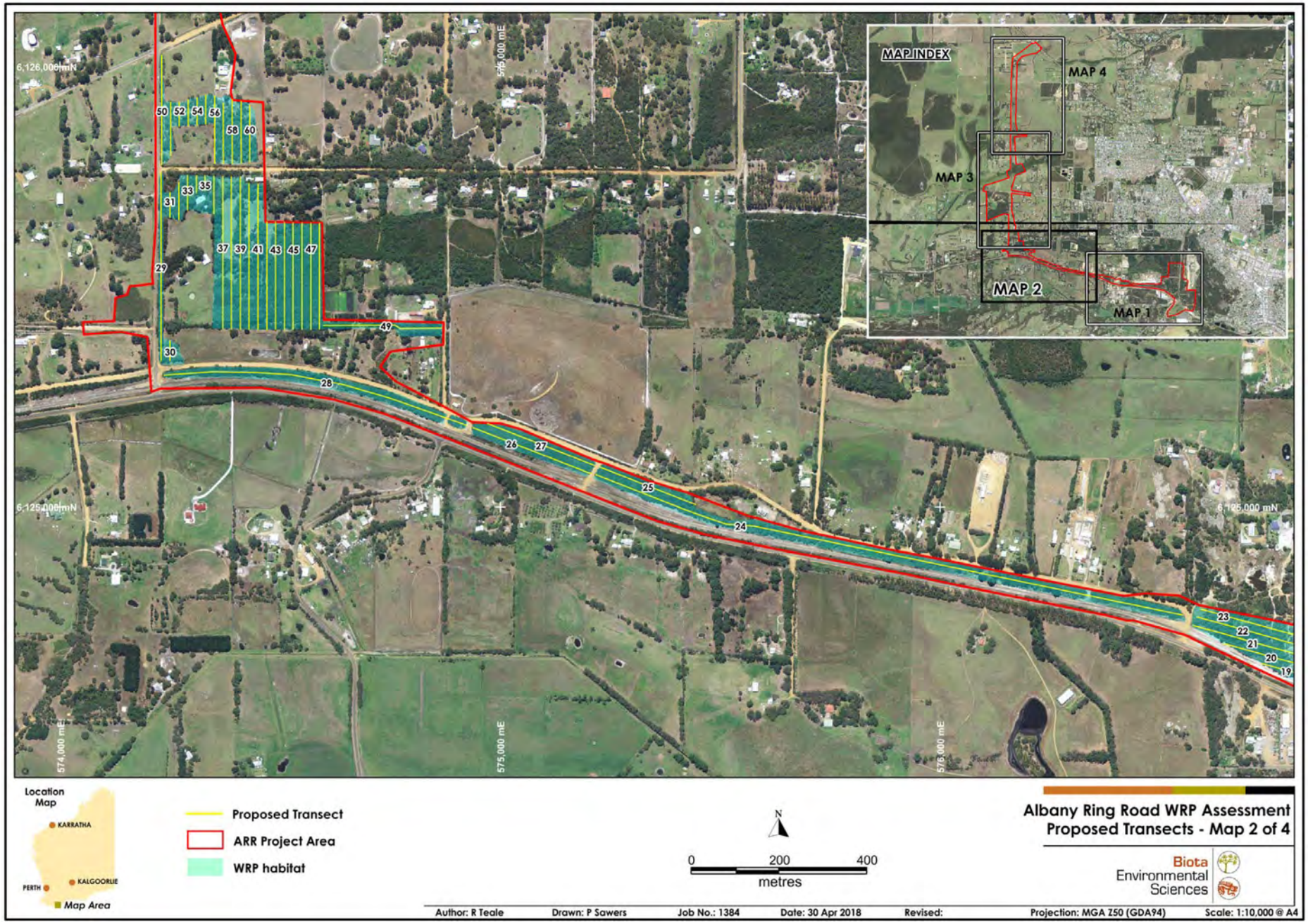

Figure 3.2: Strip transects (Transects 19 to 60) within the Albany Ring Road Project Area (continued).

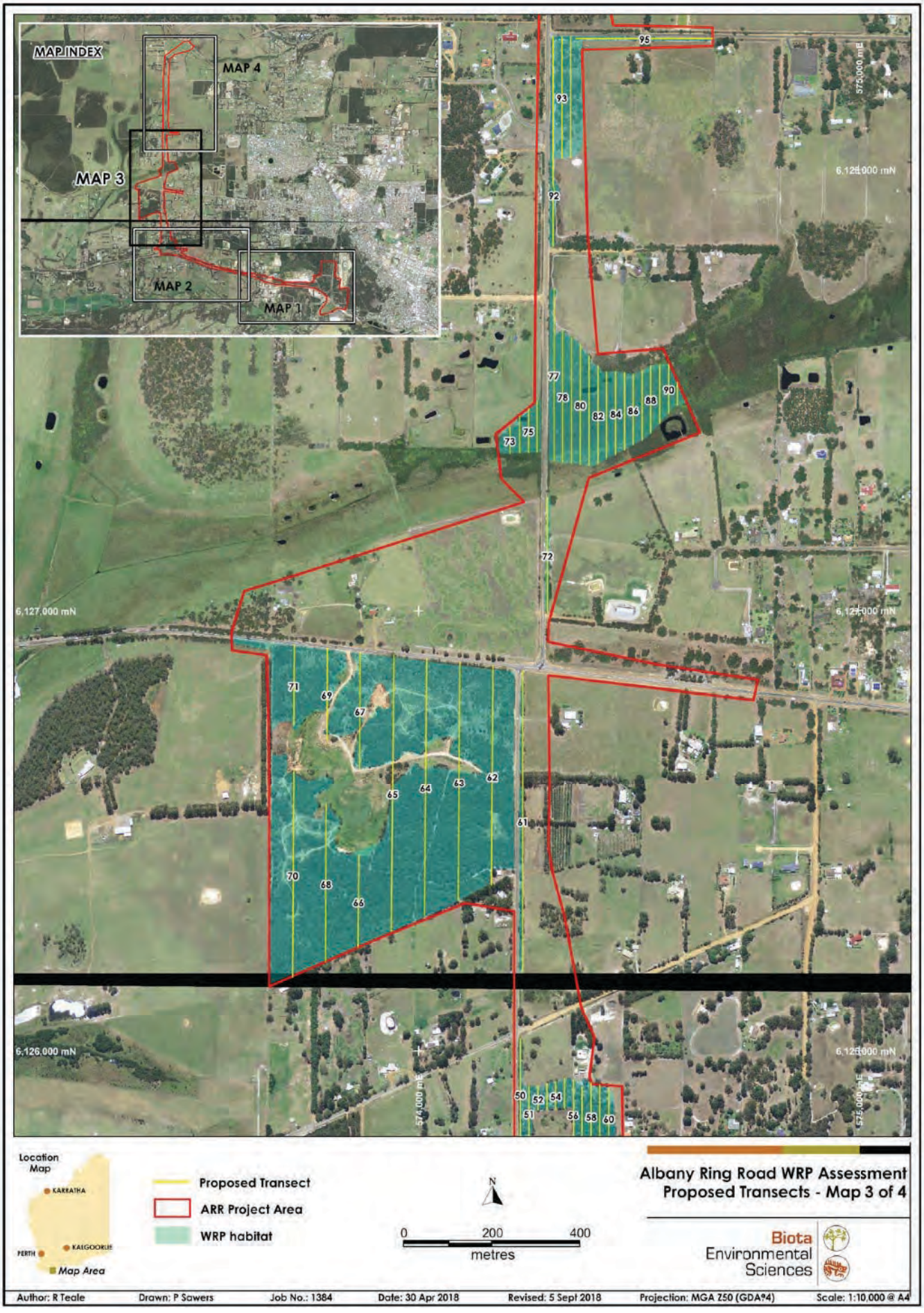

Figure 3.3: Distance sampling transects (Transects 52 – 61) within the Old Tip site and strip transects (Transects 50 to 95) within the Albany Ring Road Project Area (continued).

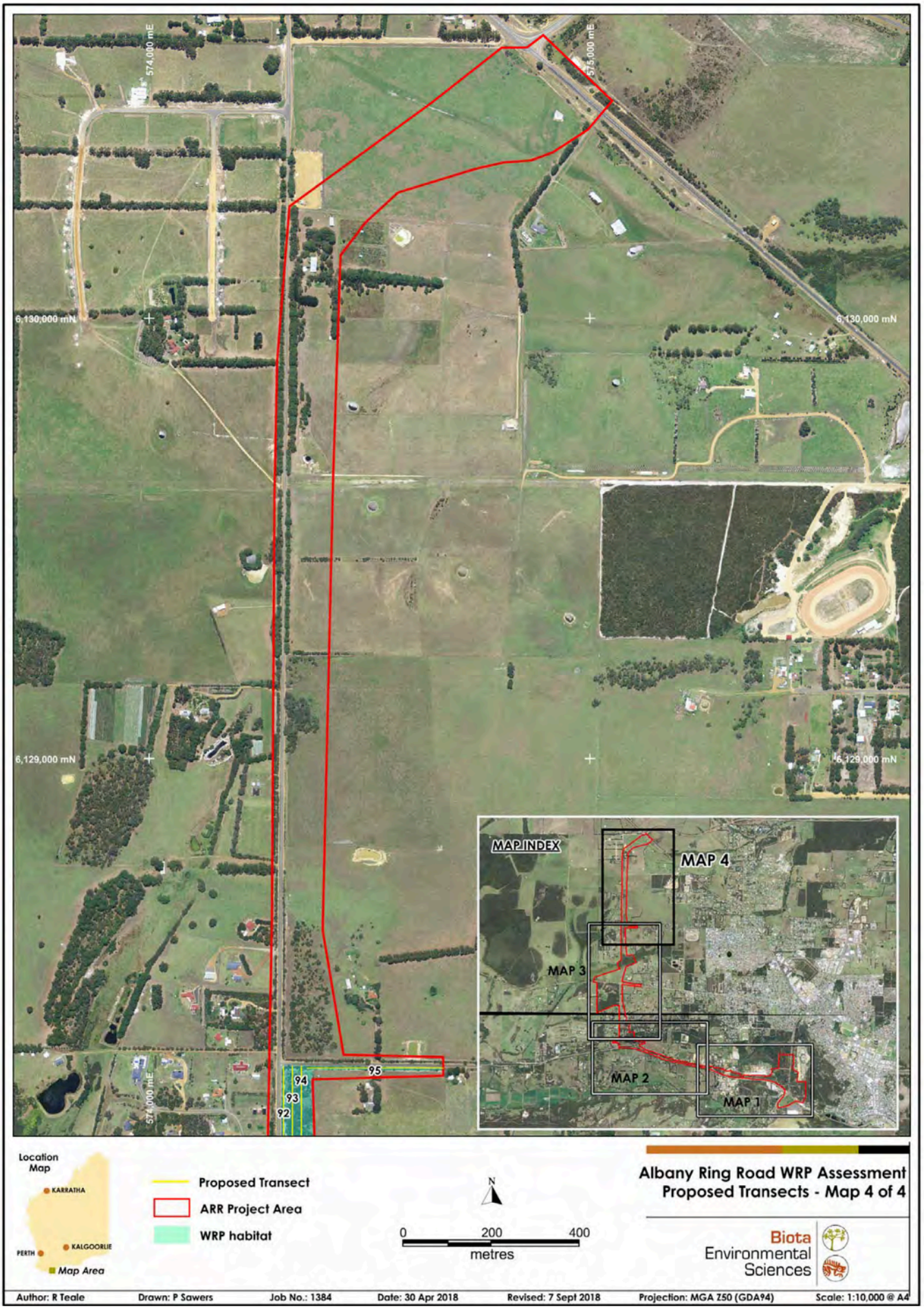

Figure 3.4: Strip transects (Transects 92 to 95) within the Albany Ring Road Project Area (continued).

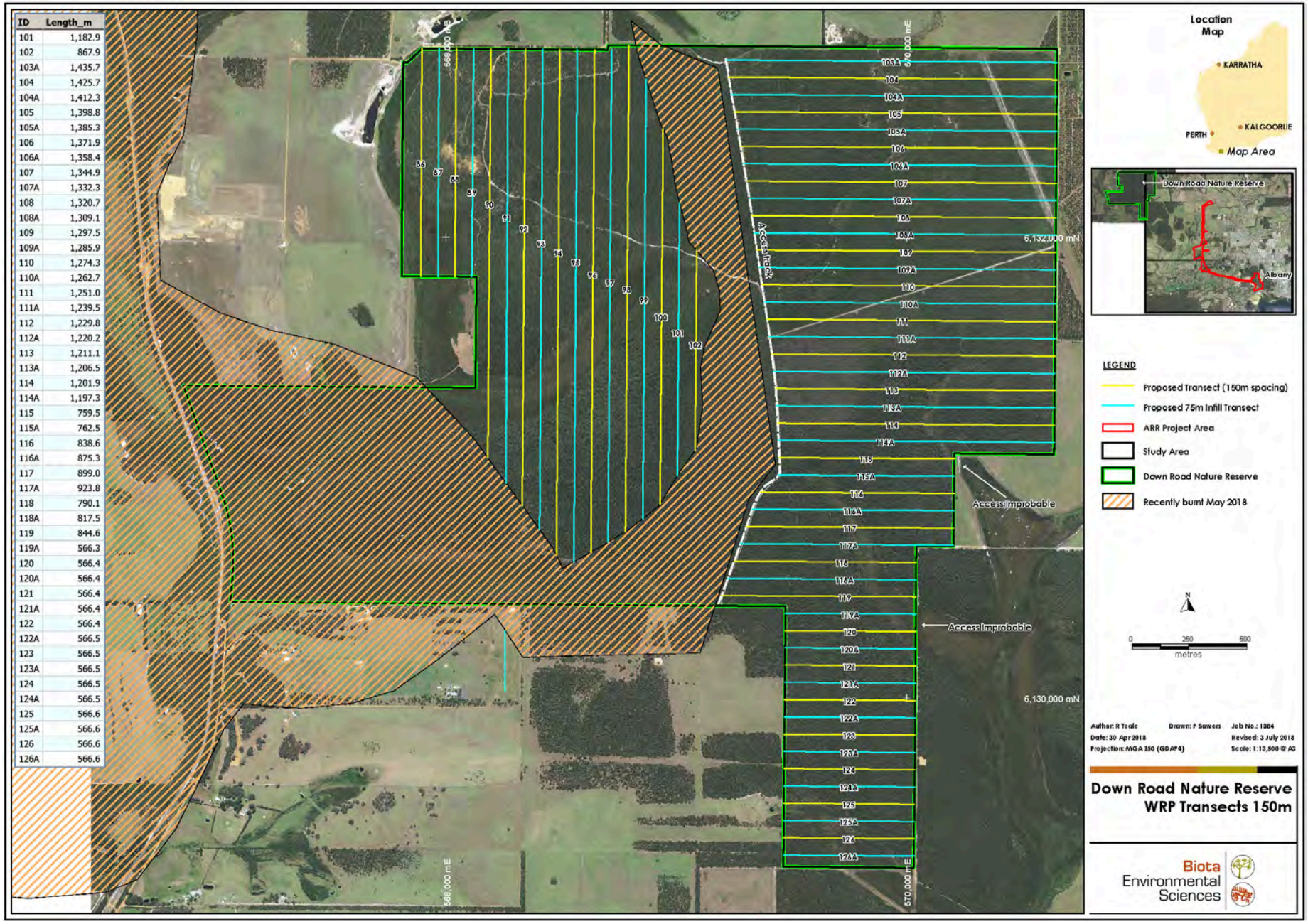

Figure 3.5: Proposed transects layout for the Western Ringtail Possum distance sampling program in the Down Road Nature Reserve study area.

4.0 Results

4.1 Project Area

The area of mapped Western Ringtail Possum habitat within the Project Area comprises approximately 92.2 ha (as per Rathbone and Gilfillan 2018), consisting of 30.89 ha of core Habitat, 31.95 ha of supporting habitat, 9.32 ha of linkage habitat and 20.04 ha of linkage likely habitat. Within this area, a total of 20 sightings of Western Ringtail Possums were recorded from 20 locations and records came from the entire length of the Project Area (Figure 4.5). The tally comprises 13 observations from the strip transects, four observations from the Old tip and three from the CSBP sites (within which distance sampling was conducted). Individuals were recorded from a variety of tree species including Sydney Wattle *Acacia longifolia*, Peppermint *Agonis flexuosa*, eucalypts, *Melaleuca* spp., and a Cypress Pine.

Within those areas sampled by strip transects, we are confident that most, if not all individuals present were recorded during the survey. This assertion is supported by the distance sampling program undertaken in the Down Road Nature Reserve (see Section 4.1.1) that yielded an average probability of detection of p=0.99 from the detection function at a truncation distance of 10 m (i.e. consistent with the 20 m strip transects used). The more open habitat of the road reserve areas likely afforded greater visibility than was possible in the larger vegetation fragments resulting in a higher probability of detection.

Population estimates for the two larger remnants (Old Tip site and the CSBP site) were derived using a distance sampling approach rather than being directly observed as was the case for the strip transects. As noted earlier (Section 3.3.2), the number of observations yielded by the distance sampling surveys within the CSBP and Old Tip sites (n= 7) was too few to adequately model a stand-alone detection function and hence observations were combined across the Down Road and Bakers Junction Nature Reserves. The combined total of 63 transects across the four survey areas yielded 137 observations of Western Ringtail Possums prior to truncation, comprising 50 in Bakers Junction Reserve, 80 in the Down Road Nature Reserve, three in the CSBP site and four in the George Street Tip site.

4.1.1 Model Selection

The histogram of detection distances was indicative of Western Ringtail Possum movement away from the observer (Figure 4.1). An alternative explanation for the initial stepped increase in the number of observations is that insufficient attention was being spent observing along the transect, largely as a result of a requirement to navigate around trees and shrubs, removing the attention of the observer from along the transect. The consequence of the stepped increase is a negative bias in the estimate of Western Ringtail Possums (i.e. an underestimate). Methodological changes were developed to correct the observers' technique from the fifth night onwards and this markedly improved the histogram, supporting our suspicion that the cause of the spike was not animal movement away from the transect (and observer).

The best overall model fit was a hazard rate key with no adjustment terms and no covariate on the detection process (truncation = 20 m, n = 117, K-S p = 0.80, CvM p = 0.96) (Figure 4.2). Key summary statistics are presented in Table 4.1.

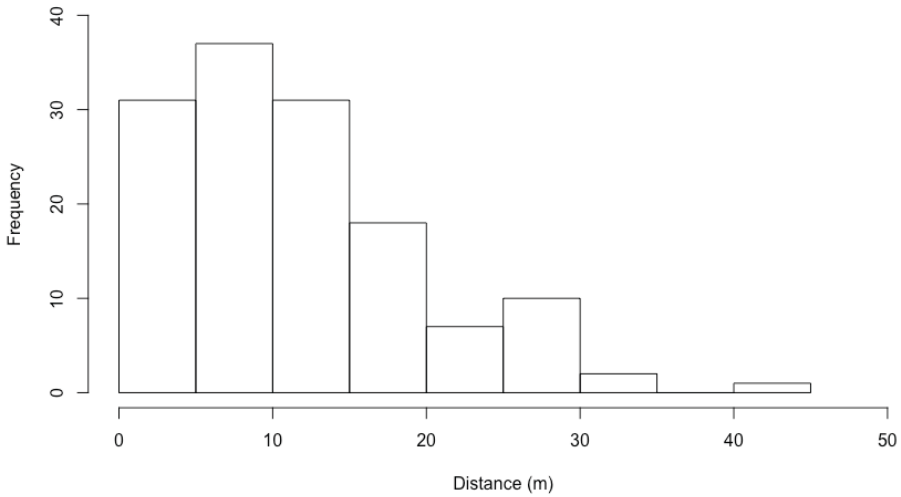

Figure 4.1: Histogram of all Western Ringtail Possum observations from Down Road Nature Reserve, Bakers Junction Nature Reserve, the Old Tip site and the CSBP site (n=137) (n.b. observations include occasions where two individuals were seen together. The tally of individuals was 156).

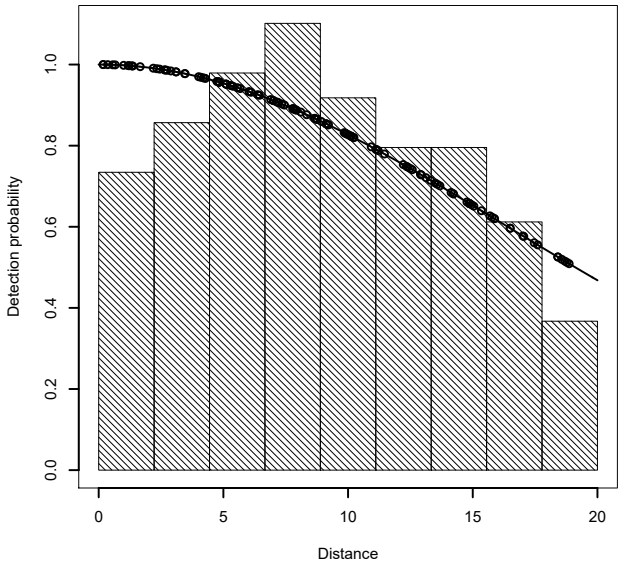

Figure 4.2: Histogram of Western Ringtail Possum observations from Down Road Nature Reserve, Bakers Junction Nature Reserve, the Old Tip site and the CSBP site with hazard-rate Probability Detection Function and truncation at 20 m.

Density estimates derived from the observation data were post-stratified by Reserve / Remnant to provide parameter estimates for the two remnants (namely the Old Tip site and the CSBP site) and then used to obtain abundance estimates. Density estimates of 0.36 ± 0.087 and 0.14 ± 0.101 Western Ringtail Possums per hectare were derived for the CSBP and Old Tip sites respectively (Table 4.2). The density estimates translate to abundance estimates of 6.1 ± 2.5 and 5.0 ± 3.6 individuals for the CSBP and Old Tip sites respectively (Table 4.3).

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Table 4.1: Key summary statistics from the Distance Sampling program for Western Ringtail Possum observations (equals clusters) in the CSBP and Old Tip sites (ER = Encounter Rate, n = number of observations, k = number of transects, cv = coefficient of variation).

	Region Area (ha)	Covered Area (ha)	Effort (km)	n	k	ER km^{-1}	se.ER Rate km^{-1}	cv.ER
CSBP site	17	9.3	2.3	3	9	1.29	0.53	0.41
Old Tip site	35	15.6	3.9	2	10	0.51	0.36	0.71

Table 4.2: Density estimates for Western Ringtail Possums (individuals) in the CSBP and Old Tip sites (cv = coefficient of variation, lcl = lower confidence limit, ucl = upper confidence limit).

	Estimate (per ha)	se (per ha)	cv	lcl (per ha)	ucl (per ha)
CSBP site	0.36	0.087	0.41	0.14	0.90
Old Tip site	0.14	0.101	0.71	0.03	0.61

Table 4.3: Abundance estimates for Western Ringtail Possums (individuals) in Bakers Junction Nature Reserve (cv = coefficient of variation, lcl = lower confidence limit, ucl = upper confidence limit).

	Estimate	se	cv	lcl	ucl
CSBP site	6.1	2.5	0.42	2.4	15.3
Old Tip site	5.0	3.6	0.71	1.2	21.3

When the distance sampling abundance estimates (rather than the direct observations) from the Old Tip site and the CSBP site are added to the tally for the Project Area, then the number of expected individuals increases to 25 and ranges between 20 and 37 individuals, yielding a range of densities between 0.22 – 0.40 individuals per ha.

While the Project Area boundary may intersect the home ranges of more individual Western Ringtail Possums than the 20 to 37 estimated above (given that sections abut larger contiguous habitat remnants), we believe it is reasonable to state that the Project Area encompasses habitat that could support the equivalent of 20 to 37 individuals. The local and regional significance of this habitat is in part understood by placing it into a local and regional context by direct comparison with habitat in other nearby remnants, in this case the Down Road Nature Reserve.

4.2 Local Context Area: Down Road Nature Reserve

The histogram of detection distances for the 80 observations (Figure 4.3) shows a clear "shoulder" out to 10 m indicating relatively even detectability to at least this distance from the transect. The best overall model fit for the observation data from the surveyed vegetation units of the Down Road Nature Reserve was a half-normal with no adjustment terms and no covariate on the detection process (truncation = 20 m, n = 75, K-S p = 0.99, CvM p = 0.98) (Figure 4.4). Key summary statistics derived from this model are presented in Table 4.4. An encounter rate of 3.45 ± 0.47 Western Ringtail Possums per kilometre of transect was estimated from a truncation distance of 20 m.

The Jarrah/Marri/Sheoak Laterite Forest and Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland vegetation units of the Down Road Nature Reserve yielded a density estimate of 1.246 ± 0.234 individuals per hectare (Table 4.5), which translates to approximately 452.3 ± 85 (95% CI 311.7 – 656.3) individuals for these vegetation units in the Reserve (Table 4.6).

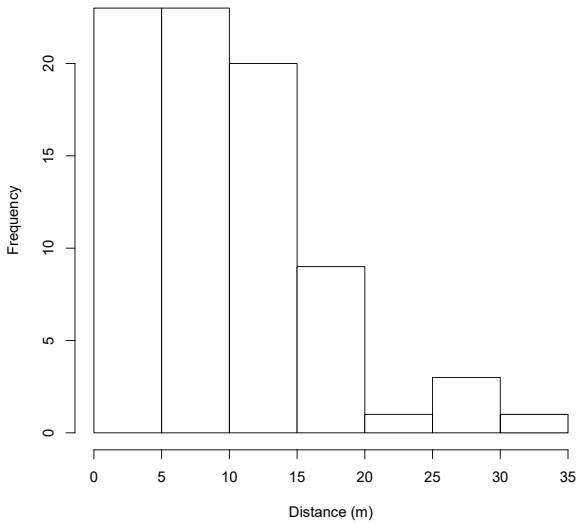


Figure 4.3: Histogram of all Western Ringtail Possum observations from the Down Road Nature Reserve (n=80) (note: observations include occasions where two individuals were seen together. The tally of individuals was 86).

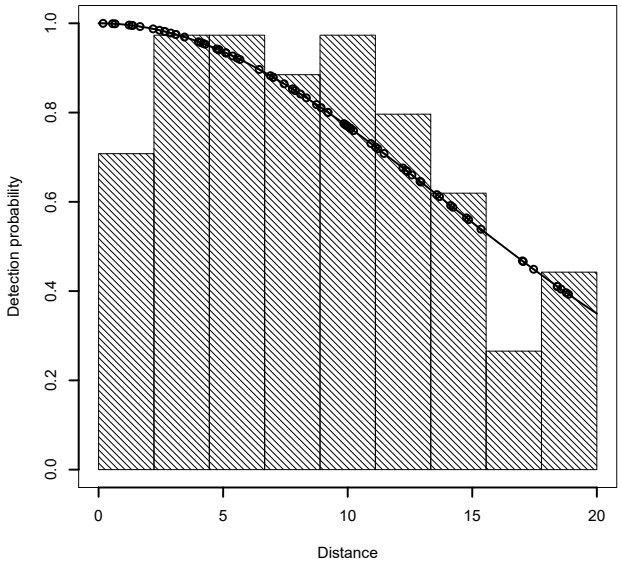


Figure 4.4: Histogram of Western Ringtail Possum observations from the Down Road Nature Reserve with half-normal Probability Detection Function and truncation at 20 m.

Table 4.4: Key summary statistics from the Distance Sampling program for Western Ringtail Possum observations (equals clusters) in Down Road Nature Reserve (ER = Encounter Rate, n = number of observations, k = number of transects, cv = coefficient of variation).

	Region Area (Ha)	Covered Area (Ha)	Effort (km)	n	k	ER km^{-1}	se.ER Rate km^{-1}	cv.ER
Down Road NR	363	87.1	21.8	75	29	3.45	0.47	0.136

Table 4.5: Density estimates for Western Ringtail Possums (individuals) in Down Road Nature Reserve (cv = coefficient of variation, lcl = lower confidence limit, ucl = upper confidence limit).

	Estimate (per ha)	se (per ha)	cv	lcl (per ha)	ucl (per ha)
Down Road NR	1.246	0.234	0.19	0.858	1.808

Table 4.6: Abundance estimates for Western Ringtail Possums (individuals) in Down Road Nature Reserve (cv = coefficient of variation, lcl = lower confidence limit, ucl = upper confidence limit).

	Estimate	se	cv	lcl	ucl
Down Road NR	452.3	85.0	0.18	311.7	656.3

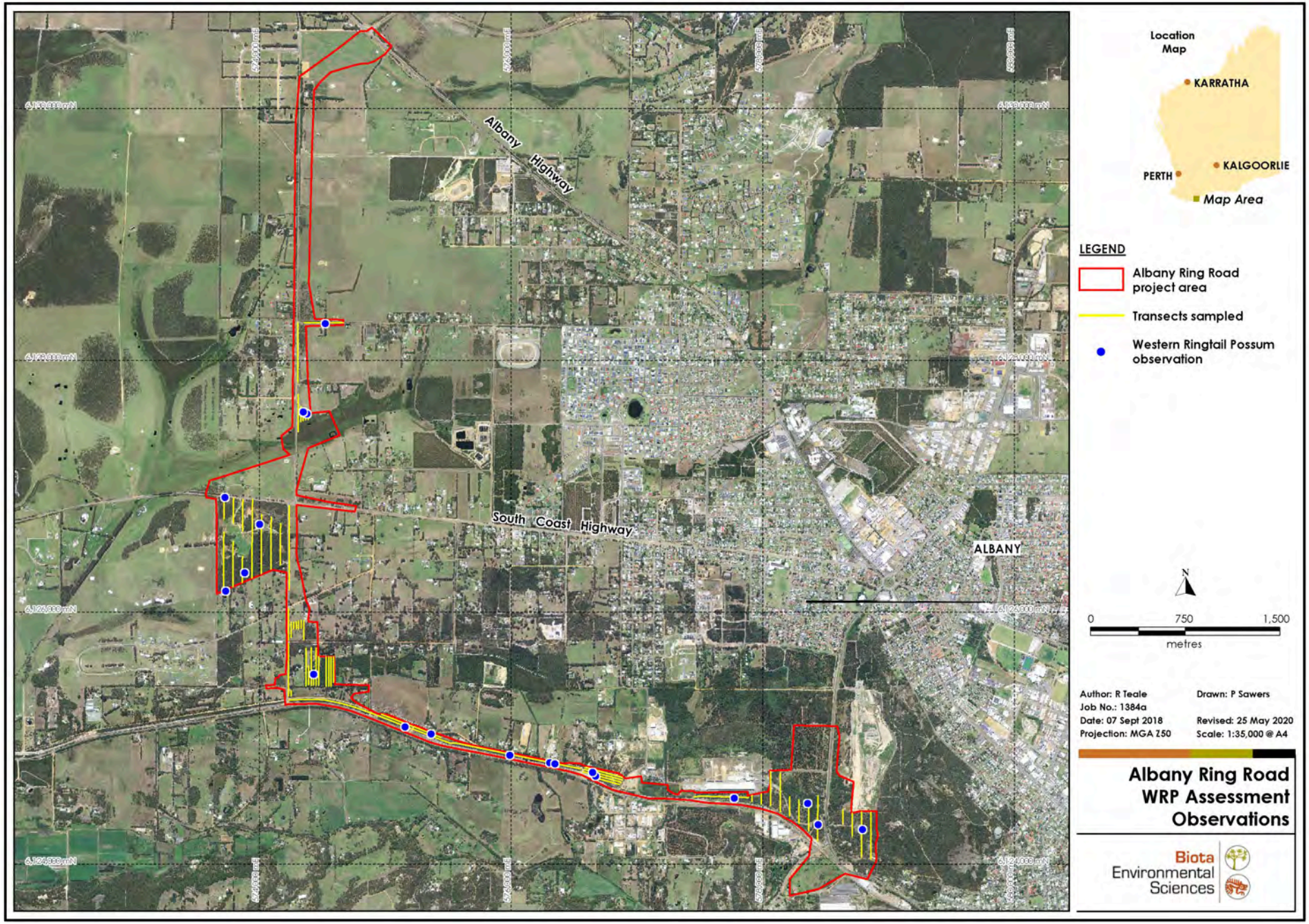
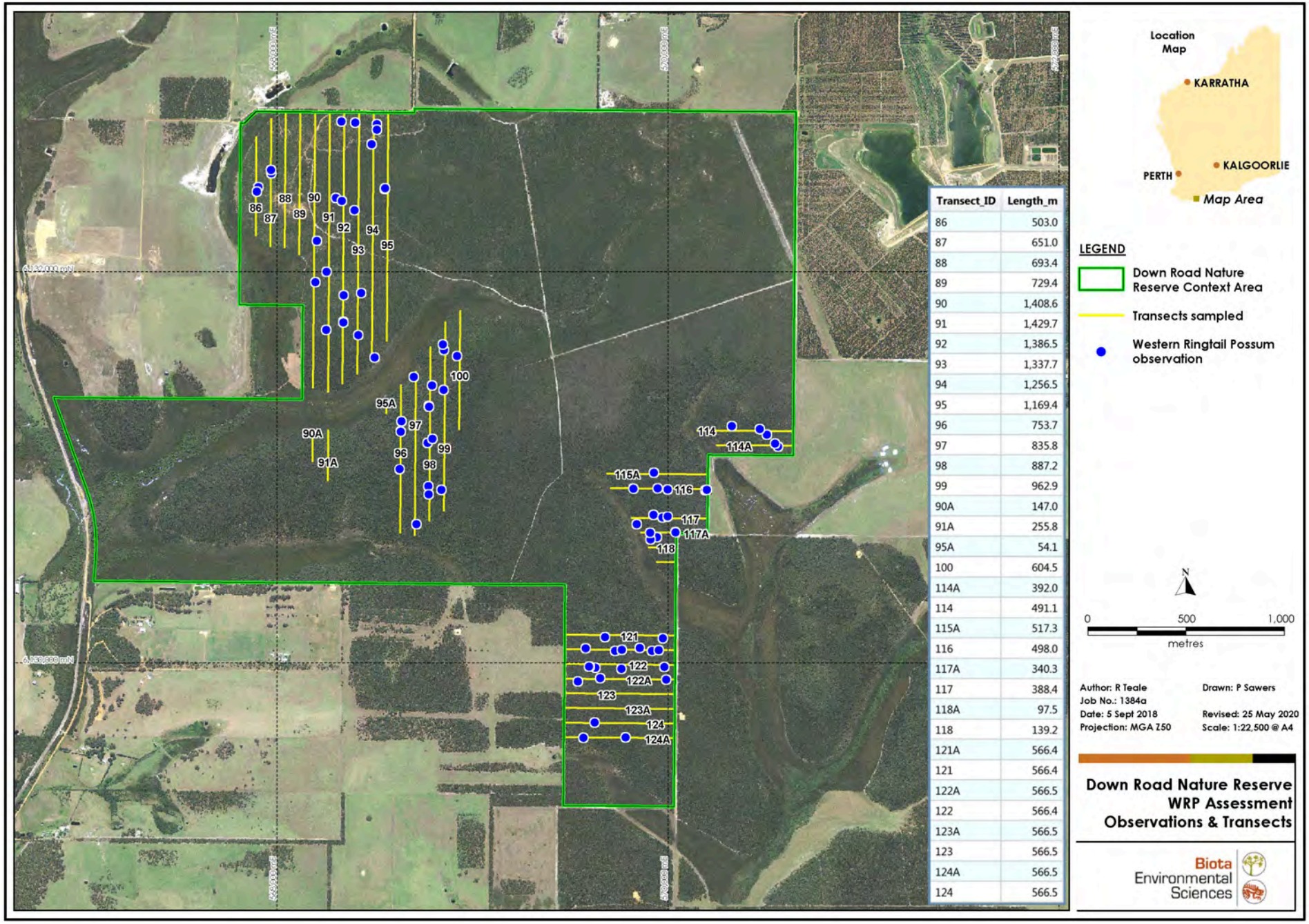


Figure 4.5: Observations of the Western Ringtail Possum within the Project Area from both Distance Sampling and Strip Sampling.



Transect_ID	Length_m
86	503.0
87	651.0
88	693.4
89	729.4
90	1,408.6
91	1,429.7
92	1,386.5
93	1,337.7
94	1,256.5
95	1,169.4
96	753.7
97	835.8
98	887.2
99	962.9
90A	147.0
91A	255.8
95A	54.1
100	604.5
114A	392.0
114	491.1
115A	517.3
116	498.0
117A	340.3
117	388.4
118A	97.5
118	139.2
121A	566.4
121	566.4
122A	566.5
122	566.4
123A	566.5
123	566.5
124A	566.5
124	566.5

Figure 4.6: Locations from which Western Ringtail Possums were recorded within the Down Road Nature Reserve.

5.0 Discussion

The purpose of this study was to assess the importance of the identified Western Ringtail Possum habitat within the Albany Ring Road Project Area (as per Rathbone and Gilfillan 2018) by direct comparison with habitat in a local (the Down Road Nature Reserve) and wider contexts including the extent of the ARVS (Sandiford and Barrett 2010). Density was identified as the preferred metric for making such comparisons and was estimated using either strip transects or a distance sampling approach depending on the extent of habitat. Within the Albany Ring Road Project Area, Western Ringtail Possum habitat ranged from isolated individual habitat trees (both native and exotic), through remnant vegetation strips (between 10 and 80 m wide) surrounded by cleared land, to larger remnants; either isolated from or broadly contiguous with, much larger remnants. Narrow habitat corridors were not amenable to undertaking a distance sampling program and to obtain density estimates in such sections, the strip transect approach was adopted. Strip transects were considered a suitable method for estimating density given that the probability of detection was essentially 1.0 (see Section 3.1) and that in most instances the area of habitat was clearly demarcated. Distance sampling was used to estimate density within two larger remnants of the Project Area (Old Tip site and the CSBP site) as well as the Jarrah/Marri/Sheoak Laterite Forest and Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland vegetation units of the Down Road Nature Reserve.

The strip transects within the Project Area yielded 13 observations of Western Ringtail Possums and, when the expected number of individuals based on the distance sampling exercises in the Old Tip site and CSBP site were included, the estimate for the Project Area increased to between 20 and 37 individuals. The 20 to 37 individuals and an area of habitat of 92.2 ha (encompassed by the Project Area boundary and as mapped by Rathbone and Gilfillan (2018) yielded a density estimate ranging between 0.22 – 0.40 individuals per ha.

At the local scale, the estimate of 20 – 37 individuals supported by the 92.2 ha of mapped habitat within the Project Area compares to an estimate of 452.3 ± 85 individuals from the Jarrah/Marri/Sheoak Laterite Forest and Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland vegetation units (encompassing 363 ha) of the Down Road Nature Reserve for a density estimate of 1.246 ± 0.234 individuals per ha, more than three times that of the Project Area.

At a 'Around Albany' scale, an original estimate of approximately 500 individuals was ascribed to the 'Around Albany' sub-population as presented in the IUCN re-assessment of the conservation status of the Western Ringtail Possum (Burbidge and Zichy-Woinarski 2017). However, since the 2017 publication (initiated in 2014) (Burbidge and Zichy-Woinarski 2017), several programs (including this study) have been implemented in the Albany Region to more robustly estimate the density of Western Ringtail Possums using a distance sampling approach and these have provided additional data to re-evaluate the IUCN estimate.

The Down Road Nature Reserve study reported here was also run in conjunction with a distance sampling program within the Bakers Junction Nature Reserve (Biota 2018a). Neither reserve has previously been surveyed for Western Ringtail Possums and both were previously highlighted as regional gaps in determining the likely distribution of Western Ringtail Possums in the greater Albany region (Gilfillan 2008). The two programs involved walking a combined total of 51.7 km of transects across 13 nights, which yielded 130 individual Western Ringtail Possums (an encounter rate of 2.51 km^{-1}) and yielded population estimates of 306 ± 75 for Bakers Junction Nature Reserve and 452 ± 85 for Down Road Nature Reserve (Table 5.1).

A third program (with Natural Resource Management funding) implemented by the Oyster Harbour Catchment Group (OHGC) and using volunteers to collect the observation data, conducted distance sampling at Mt Clarence, Mt Adelaide and Mount Melville. This program involved repeated monthly sampling of six groups of four transects yielding a total effort of 51.8 km and has been in operation since 2016. The observation data were provided to Main Roads Western Australia for the purpose of providing additional regional context. These data were also analysed as part of the current study, and density for the Mt Clarence and Mt Adelaide sites was estimated to be 3.48 ± 0.91 individuals per ha yielding a population estimate of 767 ± 201,

whilst the density estimate for the Mt Melville site was 1.54 ± 0.38 individuals per ha, yielding a population estimate of 156 ± 39 (Table 5.1).

Table 5.1: Density and population estimates for four sites at which distance sampling has been undertaken in the Albany region.

Reserve / Remnant Bushland (Area of Surveyed habitat)	Number of individuals recorded	Density (ha)	CV	Abundance Estimate (95% CI)
Bakers Junction Nature Reserve (843 ha)	54	0.363 ± 0.088	24%	306 ± 75 (185 – 507)
Down Road Nature Reserve (363 ha)†	80	1.246 ± 0.234	17.9%	452 ± 85 (311 – 656)
Mt Clarence / Mt Adelaide (2,211.7 ha)	Repeat Sampling	3.478 ± 0.908	26.2%	767 ± 201 (441 – 1335)
Mt Melville (1,012.9 ha)	Repeat Sampling	1.54 ± 0.381	24.7%	156 ± 39 (92 – 263)

† Excludes habitat burnt in June 2018 fires. The area is an approximate estimate only as the exact area burnt was not known at the time of reporting.

The distance sampling campaigns at Bakers Junction Nature Reserve, Down Road Nature Reserve, Mt Clarence / Mt Adelaide and Mt Melville yielded in excess of 135 distinct Western Ringtail Possums. These three studies yielded a combined population estimate of 1,681 individuals from a combined area of approximately 4,400 ha. The population estimate for these areas alone is therefore three times the estimate provided for the 'Around Albany' sub-population in the IUCN assessment.

By drawing on the population estimates obtained from recent studies employing a systematic distance sampling approach in the Albany Region (i.e. 1. Biota: Bakers Junction Nature Reserve and Down Road Nature Reserve and 2. OHGC: Mt Clarence, Mt Adelaide and Mount Melville), and placing them in the context of regional vegetation mapping (Sandiford and Barrett 2010) of the same habitat sampled in these studies, it is possible to calculate an approximate population size for these vegetation units in the broader Albany region.

The ARVS (Sandiford and Barrett 2010) provides a description and extent of vegetation types that encompasses 124,415 ha in an area bounded to the east and west of the Albany town site by 30 km and to the north by 20 km (shown in Figure 2.1).

The distance sampling program within the two Bakers Junction Nature Reserve and Down Road Nature Reserve primarily sampled two vegetation Units:

i) Jarrah/Marri Sheoak laterite forest (Unit 12); and

ii) Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland (Unit 13).

Sandiford and Barrett (2010) mapped 13,144 ha of the Jarrah/Marri Sheoak laterite forest (Unit 12) within the ARVS boundary and noted that 1,273 ha was encompassed by IUCN I-IV reserves, a further 3,991 ha occurred on other Crown reserves and 7,879 ha was on non-reserve land. The mapped extent of Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland (Unit 13) occurred on 5,148 ha including 1,334 ha on IUCN-IV reserves, 1,878 ha on other Crown Reserves and 1,936 ha on non-reserved land. The combined area of both vegetation units occurring on reserved land is 8,477 ha, with 9,815 ha on non-reserved land (at the time of mapping). The mean Western Ringtail Possum density across Bakers Junction Nature Reserve and Down Road Nature Reserve was estimated to be approximately 0.80 individuals per hectare. Using this density across the 8,477 ha of reserved land yields over 6,820 individuals and, if the entirety of the 2010 mapped extent is used, the estimate increases to over 14,600 individuals. Clearly not all of this habitat would currently be available either due to land clearing that has occurred since 2010, recent fires or degradation from a variety of pressures. Nor is it necessarily appropriate to apply a uniform density across the region encompassed by the mapping. However, there are a variety of other vegetation types considered likely to support Western Ringtail Possums occurring in the ARVS boundary but not surveyed as part of this study. Conservatively, these include *Hakea* spp. Shrubland/Woodland Complex (2,366 ha), *Banksia coccinea* Shrubland / *Eucalyptus staeri* / Sheoak Open Woodland (1,330 ha) and Peppermint Low Forest (1,232 ha). In addition, Western

Ringtail Possums have been documented to inhabit the urban environment within Albany utilising narrow road reserves and residential gardens (this study and Gilfillan 2008).

Further extrapolation can be obtained with a similar approach, including the additional vegetation units sampled during the studies at Mt Clarence / Mt Adelaide and Mt Melville, and applying the conservative density estimate of 0.8 individuals per hectare (lower than actually recorded during those studies). The vegetation units included in the surveys conducted at Mt Clarence / Mt Adelaide and Mt Melville were as follows:

i) Coastal *Banksia ilicifolia* / Peppermint Low Woodland (Unit 4);

ii) Marri / Jarrah Forest / Peppermint Woodland (Unit 10); and

iii) Marri / Jarrah Coastal Hills Forest (Unit 17).

When an average density estimate of 0.8 individuals per hectare (as derived from the two Nature Reserves) is extrapolated to the mapped extent of all five vegetation units surveyed by distance sampling within the ARVS boundary (a combined area of 21,633 ha; Table 5.2), an estimate of 17,306 Western Ringtail Possums is yielded. Again, not all of this habitat would necessarily be utilised by Western Ringtail Possums and nor is it necessarily accurate to apply a uniform density across the region encompassed by the mapping. However, the approach does indicate that the population estimate for the 'Around Albany' sub-population is considerably larger than the 500 reported in the IUCN assessment, perhaps by an order of magnitude.

Table 5.2: Broader extent of the sampled vegetation units within the ARVS (Sandiford and Barret 2010) and the estimated abundance of Western Ringtail Possum given an average density of 0.5 ha^{-1}.

Vegetation Unit	ARVS Occurrence	Abundance Estimate at 0.8 ha^{-1}
Coastal *Banksia ilicifolia* / Peppermint Low Woodland (Unit 4)	506 ha (411 ha in Reserves)	405 (329 in Reserves)
Marri / Jarrah Forest / Peppermint Woodland (Unit 10)	1,597 ha (516 ha in Reserves)	1,278 (413 in Reserves)
Jarrah/Marri Sheoak laterite forest (Unit 12)	13,144 ha (5,264 ha in Reserves)	10,515 (4,211 in Reserves)
Jarrah/Sheoak/*Eucalyptus staeri* Sandy Woodland (Unit 13)	5,148 ha (3,212 ha in Reserves)	4,118 (2,570 in Reserves)
Marri / Jarrah Coastal Hills Forest (Unit 17)	1,238 ha (990 ha in Reserves)	990 (792 in Reserves)
All units	21,633 ha (10,393)	17,306 (8,314 in Reserves)

Reserve equates to IUCN I-IV Reserves and Other Crown Reserves after Sandiford and Barrett (2010).

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Appendix 1

Raw Observation Data

Appendix A1: Distance Sampling Raw Data (Project Area and Down Road Nature Reserve)

Site	Abundance	Date	Time	Easting	Northing	Dominant Veg
ARR Strip sampling	1	20/7/18		574362	6127591	
ARR Strip sampling	1	20/7/18		574379	6127579	Jarrah/Marri
ARR Strip sampling	1	20/7/18		574347	6127595	Jarrah/Marri
ARR Strip sampling	1	16/7/18		574524	6128298	Cypress pine
ARR Strip sampling	1	16/7/18		577776	6124531	Jarrah/Marri
ARR Strip sampling	1	16/7/18		576673	6124705	Melaleuca
ARR Strip sampling	1	16/7/18		576650	6124735	Melaleuca
ARR Strip sampling	1	16/7/18		575989	6124871	Sydney Wattle
ARR Strip sampling	1	16/7/18		575366	6125041	Melaleuca
ARR Strip sampling	1	16/7/18		576309	6124811	Melaleuca
ARR Strip sampling	1	16/7/18		576350	6124802	Melaleuca
ARR Strip sampling	1	12/7/18		575158	6125098	Melaleuca
ARR Strip sampling	1	12/7/18		574432	6125514	
CSBP_ARR Distance sampling	1	16/7/18	21:41	578359	6124488	Melaleuca
CSBP_ARR Distance sampling	1	16/7/18	21:23	578443	6124319	Jarrah/Marri
CSBP_ARR Distance sampling	1	14/7/18	19:01	578795	6124282	
Tip_ARR Distance sampling	1	13/7/18	21:17	573733	6126174	
Tip_ARR Distance sampling	1	13/7/18	23:54	574001	6126704	Jarrah/Marri
Tip_ARR Distance sampling	1	13/7/18	22:35	573726	6126916	Allocasuarina
Tip_ARR Distance sampling	1	13/7/18	21:32	573883	6126322	Allocasuarina

Appendix A2: Down Road Nature Reserve Distance Sampling

Distance	Size	Person	Date	Time	Easting	Northing	Zone	Dominant_Veg
14.223	1	Stewart Ford	10/7/18	7:54	568205	6132162	50	Allocasuarina
14.766	1	Stewart Ford	15/7/18	10:46	568553	6132426	50	Allocasuarina
12.576	1	Stewart Ford	15/7/18	10:51	568555	6132431	50	Allocasuarina
17.046	1	Roy Teale	15/7/18	11:44	568512	6132759	50	Allocasuarina
18.412	1	Roy Teale	15/7/18	11:59	568513	6132730	50	Allocasuarina
8.749	1	Roy Teale	15/7/18	11:52	568485	6132656	50	Allocasuarina
2.667	1	Roy Teale	20/7/18	6:40	570565	6131108	50	Allocasuarina
12.902	1	Roy Teale	20/7/18	6:43	570550	6131124	50	Allocasuarina
20.571	1	Roy Teale	20/7/18	8:53	569928	6130761	50	Jarrah/Marri
7.789	1	Roy Teale	20/7/18	9	569974	6130748	50	Allocasuarina
12.34	1	Roy Teale	20/7/18	9:05	570001	6130752	50	Jarrah/Marri
7.007	1	Roy Teale	20/7/18	7:58	570041	6130672	50	Jarrah/Marri
18.566	1	Roy Teale	18/7/18	9:23	569763	6129973	50	Jarrah/Marri
13.684	1	Roy Teale	18/7/18	9:36	569629	6129979	50	Jarrah/Marri
7.789	1	Roy Teale	18/7/18	9:40	569602	6129985	50	Allocasuarina
7.889	1	Roy Teale	18/7/18	9:41	569597	6129985	50	Allocasuarina
12.939	1	Roy Teale	10/7/18	7:26	567906	6132436	50	Jarrah/Marri
5.564	1	Roy Teale	10/7/18	7:35	567899	6132413	50	Jarrah/Marri
4.831	1	Roy Teale	10/7/18	8:42	567973	6132508	50	Jarrah/Marri
2.189	1	Roy Teale	10/7/18	8:48	567971	6132524	50	Hakea
14.132	1	Roy Teale	15/7/18	6:53	568331	6132773	50	Jarrah/Marri
34.082	1	Roy Teale	15/7/18	7:38	568302	6132381	50	Allocasuarina
9.21	1	Roy Teale	15/7/18	7:49	568333	6132365	50	Jarrah/Marri
4.008	1	Roy Teale	15/7/18	8:32	568343	6131884	50	Jarrah/Marri

Distance	Size	Person	Date	Time	Easting	Northing	Zone	Dominant_Veg
2.642	1	Roy Teale	15/7/18	8:50	568340	6131748	50	Jarrah/Marri
4.099	1	Roy Teale	15/7/18	8:53	568342	6131744	50	Allocasuarina
14.856	1	Roy Teale	15/7/18	9:29	568501	6131564	50	Allocasuarina
5.383	1	Roy Teale	17/7/18	8:31	568778	6131316	50	Jarrah/Marri
3.095	1	Roy Teale	17/7/18	8:32	568780	6131312	50	Jarrah/Marri
13.58	1	Roy Teale	17/7/18	8:52	568796	6131151	50	Jarrah/Marri
9.202	1	Roy Teale	17/7/18	8:56	568773	6131129	50	Jarrah/Marri
4.823	2	Roy Teale	17/7/18	9:22	568775	6130906	50	Jarrah/Marri
1.366	1	Roy Teale	17/7/18	9:29	568779	6130865	50	Allocasuarina
10.93	1	Roy Teale	18/7/18	0:26	568795	6131422	50	Jarrah/Marri
12.395	1	Roy Teale	17/7/18	10:17	568843	6130889	50	Allocasuarina
5.103	1	Roy Teale	17/7/18	11:13	568854	6131398	50	Jarrah/Marri
4.831	1	Roy Teale	17/7/18	11:36	568856	6131603	50	Jarrah/Marri
9.934	1	Roy Teale	17/7/18	11:41	568851	6131632	50	Jarrah/Marri
12.214	1	Stewart Ford	17/7/18	11:00	568923	6131573	50	Jarrah/Marri
17.012	1	Stewart Ford	20/7/18	6:44	570508	6131169	50	Allocasuarina
11.458	1	Stewart Ford	20/7/18	6:51	570471	6131198	50	Melaleuca
25.232	1	Stewart Ford	20/7/18	7:01	570328	6131213	50	Allocasuarina
10.235	1	Stewart Ford	20/7/18	7:51	569929	6130976	50	Jarrah/Marri
3.108	1	Stewart Ford	20/7/18	8:26	569825	6130894	50	Allocasuarina
5.674	1	Stewart Ford	20/7/18	8:43	569949	6130896	50	Jarrah/Marri
0.662	1	Stewart Ford	20/7/18	8:47	569999	6130891	50	Allocasuarina
9.894	1	Stewart Ford	18/7/18	7:35	569580	6130078	50	Jarrah/Marri
1.223	2	Stewart Ford	18/7/18	7:48	569731	6130066	50	Jarrah/Marri
3.448	1	Stewart Ford	18/7/18	8:40	569993	6129919	50	Jarrah/Marri
8.341	1	Stewart Ford	18/7/18	9:13	569655	6129926	50	Allocasuarina
10.005	2	Stewart Ford	18/7/18	9:20	569542	6129909	50	Allocasuarina
8.107	1	Stewart Ford	10/7/18	8:16	568197	6131951	50	Allocasuarina
11.12	1	Stewart Ford	10/7/18	9:29	568254	6131705	50	Jarrah/Marri
18.412	1	Stewart Ford	15/7/18	7:28	568401	6132767	50	Jarrah/Marri
18.774	1	Stewart Ford	15/7/18	8:07	568398	6132319	50	Allocasuarina
18.865	2	Stewart Ford	15/7/18	8:37	568433	6131895	50	Jarrah/Marri
4.28	1	Stewart Ford	15/7/18	9:05	568417	6131679	50	Allocasuarina
4.741	1	Stewart Ford	17/7/18	7:38	568639	6131238	50	Jarrah/Marri
0.181	1	Stewart Ford	17/7/18	7:44	568634	6131187	50	Allocasuarina
4.198	1	Stewart Ford	17/7/18	8:13	568628	6130994	50	Allocasuarina
9.844	1	Stewart Ford	17/7/18	9:01	568714	6130712	50	Allocasuarina
8.93	1	Stewart Ford	17/7/18	10:06	568701	6131466	50	Jarrah/Marri
28.239	1	Roy Teale	20/7/18	8:36	569843	6130713	50	Jarrah/Marri
17.463	1	Roy Teale	20/7/18	8:09	569946	6130648	50	Jarrah/Marri
29.904	2	Roy Teale	20/7/18	8:15	569912	6130636	50	Allocasuarina
5.113	1	Roy Teale	20/7/18	8:19	569910	6130671	50	Allocasuarina
6.897	1	Roy Teale	18/7/18	7:44	569679	6130136	50	Jarrah/Marri
10.125	1	Roy Teale	18/7/18	8:14	569975	6130130	50	Allocasuarina
7.448	1	Roy Teale	18/7/18	8:39	569983	6129983	50	Allocasuarina
7.007	1	Roy Teale	18/7/18	11:31	569626	6129700	50	Allocasuarina
1.664	1	Stewart Ford	20/7/18	8:58	570193	6130887	50	Allocasuarina

Distance	Size	Person	Date	Time	Easting	Northing	Zone	Dominant_Veg
1.333	1	Stewart Ford	20/7/18	8:59	570200	6130887	50	Jarrah/Marri
5.113	1	Stewart Ford	18/7/18	7:55	569766	6130072	50	Allocasuarina
15.348	1	Stewart Ford	18/7/18	8:02	569858	6130081	50	Allocasuarina
0.561	2	Stewart Ford	18/7/18	8:08	569920	6130066	50	Allocasuarina
2.897	1	Stewart Ford	18/7/18	8:13	569955	6130068	50	Allocasuarina
6.446	1	Stewart Ford	18/7/18	11:09	569784	6129623	50	Allocasuarina
2.446	1	Stewart Ford	18/7/18	11:28	569568	6129621	50	Jarrah/Marri
11.21	1	Stewart Ford	10/7/18	9:57	568255	6132003	50	Jarrah/Marri
10.1	1	Roy Teale	15/7/18	-	-	-	50	-
21	1	Zoe Hamilton	13/7/18	9:17	-	-	50	-
25.1	1	Zoe Hamilton	13/7/18	11:54	-	-	50	Jarrah/Marri
2.33	1	Zoe Hamilton	13/7/18	10:35	-	-	50	Allocasuarina
7.34	1	Zoe Hamilton	13/7/18	9:32	-	-	50	Allocasuarina

Appendix D: Memorandum to Main Roads Western Australia, Defining habitat categories for Western Ringtail Possum in the South Coast Population (Southern Ecology, 31 October 20

Memorandum to Main Roads Western Australia:

Defining habitat categories for Western Ringtail Possum in the South Coast population

31st October 2019
Dr Sandra Gilfillan (Southern Ecology)
gilfillansandra@gmail.com

Introduction

Current Environment Protection and Biodiversity Conservation (EPBC) Significant Impact Guidelines for the Western Ringtail Possum pertain only to the population occurring on the southern Swan Coastal Plain (DEWHA 2009). No guidelines have yet been developed for the South Coast population, which can be defined as a significant population under these guidelines (DEWHA, 2009). Recently a significant amount of work has been carried out on the South Coast population.

These recent data indicate that the South Coast population is quite different to the Swan Coastal Plain population in some aspects of its ecology. For example, the presence of Peppermint (*Agonis flexuosa*) is not necessary for the presence the species; habitats with high densities are largely confined to Marri/Jarrah/Sheoak communities within 20 km of the coast; diet can be quite broad and a small percentage of individuals use refugia on the ground (Van Helden et al. 2018; Van Helden unpub. data; Van Helden and Close pers com.; Mathieson et al. in review; Gilfillan 2008 and S.Gilfillan pers. obs.). The EPBC Significant Impact Guidelines for the Swan Coastal Plain may therefore have limited application to the South Coast population.

The EPBC Significant Impact Guidelines identified three areas as important for the Western Ringtail Possums within the southern Swan Coastal Plain: *Core habitat, Primary corridors* and *Supporting habitat*. As the definitions in themselves are not Swan Coastal Plain specific they can be used interchangeably to some degree. Using these habitat categories as a guide, plus current available data on Western Ringtail Possum ecology, habitat categories can be defined for the South Coast population and then identified within the Albany Ring Road project area. NB: the defined categories should be considered DRAFT and should be presented to the WRP Recovery Team for discussion and review.

Methods

Habitat category definitions were defined for the South Coast population by:

1. correlating available data on densities and home ranges of WRP with vegetation type (outlined in Table 1) and;
2. gathering expert opinion of what constitutes habitat categories.

Once habitat categories were defined the occurrence of these categories within the Albany Ring Road project area was mapped. In addition, the habitat categories were mapped (desktop assessment only) within a 5km buffer of the project area to give a regional context. This mapping is presented and summarised in a separate memo to Main Roads Western Australia. Details of methods will be provided in a final Biological Survey report for the Albany Ring Road Project (Southern Ecology December 2019).

Results

1. Core Habitats

Definition

- native vegetation with high canopy continuity (>3 canopy connections per tree) between trees >2 m high (Jones *et al.* 1994b; Van Helden *et al.* 2018)
- gardens with high cover of native and/or exotic plants/trees
- large enough to contain multiple home ranges
- long unburnt (if native vegetation)
- high densities (> 1/ha) OR high abundance >50
- breeding by a high % of individuals (if known)
- high recruitment (if known)
- can be connected OR isolated or largely isolated. However, poorly connected areas should be targeted for restoration work to restore connectivity, considering that the Effective Population Size for South Coast populations is not known.

Core Habitats within the South Coast population

Core Habitats occur within 20km of the coast in an area approximately from West Cape Howe NP in the west to Two Peoples Bay NR in the east (Van Helden,B. and Close, P. (*pers com.*). At this point in time the east and west extent of this area is not as clear and requires further survey.

Habitats that should be considered Core Habitats, based on the above definition are:

- Any remnant with an established density of > 1/ha;
- OR
- Any remnant with an established abundance of >50.
- As a precautionary principal, any Jarrah, Marri or Sheoak forest or woodland, or Peppermint Low Forest remnant that is >50 ha in size until densities are established.

  supporting information:

  - Surveyed remnants that are largely comprised of these vegetation types and with these other characteristics have densities ranging from 0.36 – 17/ha (Table 1). Remnants with measured densities at the lower end of this range (Bakers Junction and Down Rd. NR's) are however large and contain estimated abundances of 306 +/-75 and 251 +/-45, respectively.
  - Average home range in Albany bushland (marri / jarrah communities is 0.88 (Van Helden et al. 2018); A population of 50 individuals is generally seen as large enough to avoid inbreeding (Franklin 20018) and with a estimate of 0.88ha home range 50 individuals would conservatively require 50ha to maintain viability, thus Core Habitats are defined as >50ha in size.

- Urban areas (core)

  supporting information: Urban areas with gardens generally having a high % of plant cover and higher densities (Van Helden, pers com.). Average home range in garden areas of Albany are 0.51ha (Van Helden unpub data) with evidence of overlapping HR. Average density within gardens of Albany (averaged across seasons) is 3.4 possums/ha (Van Helden unpub data).

2. Supporting Habitats

Definition

- any area with an established density of <1/ha;

OR

- any area with an established abundance of <50.
- may be breeding occurring or not
- can be native or non-native vegetation, including urban gardens.

Supporting habitats within the South Coast Population

- Jarrah, Marri or Sheoak or Peppermint woodlands or forests that is < 50ha, or has an established density of <50.
- any remnant that has possums present.
- urban areas with gardens generally having a low % of plant cover and lower densities (Van Helden, pers com.)

3. Linkages

Definition

- any structure that allows movement of individuals at a small to medium scale (eg. street-scape/road-side non-native plantings, wind-breaks, plantations, fencelines)
- no resident individuals, movement of animals only
- do not need to be continuous, but can contain small gaps, as Western Ringtail Possums can come to the ground to move short distances.

Linkages within the South Coast Population
As linkages function on a local scale, they have not been identified at the scale of the population as a whole.

4. Primary Corridors

Definition

- provide major connectivity between areas of occupation,
- regional scale,
- containing multiple home ranges,
- breeding occurs,
- provides movements and habitat (residents)

Linkages within the South Coast Population

There are three primary corridors within the South Coast Population:

- King River
- Kalgan River
- Coastal Corridor (from West Cape Howe NP to Cheynes Beach – this may extend either east or west with new records).

Table 1: Densities determined by systematic methods of surveying WRP in various remnants and associated vegetation types.

Remnant/reserve and vegetation association (ARVS # in brackets)	Density	Source and method
Bakers Junction NR Jarrah/Marri Sheoak laterite forest (12) and Jarrah/Sheoak/Eucalyptus staeri Sandy Woodland (13)	**0.483/ha, se = 1.182**	**Biota (in prep)** **Distance Sampling**
Down Rd NR Jarrah/Marri Sheoak laterite forest (12) and Jarrah/Sheoak/Eucalyptus staeri Sandy Woodland (13)	**0.795/ha, se = 1.145**	**Biota (in prep)** **Distance Sampling**
Gull Rock	**0.786/ha, se = 0.373**	**Biota (in prep)** **Distance Sampling**
King River	**0.115/ha, se = 0.213**	**Biota (in prep)** **Distance Sampling**
Marbellup NR	**0.106/ha, se = 0.223**	**Biota (in prep)** **Distance Sampling**
Millbrook NR	**0.142/ha, se = 0.451**	**Biota (in prep)** **Distance Sampling**
Redmond West	**0.000**	**Biota (in prep)** **Distance Sampling**
Simpson Rd	**0.400/ha, se = 0.700**	**Biota (in prep)** **Distance Sampling**
Walmsley East	**0.223/ha, se = 0.356**	**Biota (in prep)** **Distance Sampling**
Walmsley South	**0.175/ha, se = 0.339**	**Biota (in prep)** **Distance Sampling**
Walmsley West	**0.395/ha, se = 0.480**	**Biota (in prep)** **Distance Sampling**
Mt Clarence and Adelaide 3 different vegetation types pooled; Marri/Jarrah Coastal Hills Forest (17), Jarrah Woodland Marri/Jarrah Forest/Peppermint Woodland (10) Coastal *Banksia ilicifolia* Peppermint Low Woodland (4)	**1.60/ha - 2.25/ha (depending on season)**	**Gilfillan and Comer (2018)** **Distance Sampling**
Mt Melville 3 different vegetation types pooled; Marri/Jarrah Coastal Hills Forest, (17) Jarrah/Sheoak/*E. staeri* Sandy Woodland (13), Marri/Jarrah Forest/Peppermint Woodland (10)	**2.90/ha - 3.16/ha (depending on season)**	**Gilfillan and Comer (2018)** **Distance Sampling**

Remnant/reserve and vegetation association (ARVS # in brackets)	Density	Source and method
Mt Clarence and Adelaide Marri/Jarrah Coastal Hills Forest (17), Marri/Jarrah Forest/Peppermint Woodland (10) Jarrah Woodland (11)	**4.13/ha (average density) – up to 5.5/ha in these vegetation types**	**Biota (2019)** **Distance Sampling**
Remnant bushland in urban areas of Albany Marri, jarrah or Sheoak vegetation communities	**4.5/ha (averaged across seasons):**	**Van Helden (unpub data)** **Based on Home Range size**
Urban gardens of Albany Various (exotic and native)	**3.4/ha (averaged across seasons)**	**(Van Helden unpub data)** **Based on Home Range size**
Albany Ring Road Survey Area - CSBP site mix of exotics/Marri/ Jarrah/and Peppermint	**0.36/ha**	**(Biota 2018)** **Distance Sampling**
Albany Ring Road Survey Area - George st. tip site Jarrah/Marri Sheoak laterite forest (12)	**0.14/ha**	**(Biota 2018)** **Distance Sampling**
Albany Ring Road Survey Area - roadside vegetation all vegetation types combined	**< 1/km (14 individuals in 19 km**	**Biota (2018)** **Strip transects**
Albany remnants Peppermint (*Agonis flexuosa*) Woodland	**1.6/ha (av);** **8/ha (max)**	**(Mathiesen et al. in review)** **Systematic,** **exhaustive spotlight searches in multiple 20 m x 20 m quadrats over 20 days**
Albany remnants Sheoak (*Allocasuarina fraseriana*) Woodland	**7.0/ha(av); 12/ha (max)**	**(Mathiesen et al. in review)** **Systematic,** **exhaustive spotlight searches in multiple 20 m x 20 m quadrats over 20 days**
Albany remnants Marri-eucalypt (*Corymbia calophylla*, *Eucalyptus marginanta* and *Eucalyptus staerii*) woodlands	**6.5/ha (av); 17/ha (max)**	**(Mathiesen et al. in review)** **Systematic,** **exhaustive spotlight searches in multiple 20 m x 20 m quadrats over 20 days**

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Appendix E: Biota Environmental Sciences, Albany Ring Road, Black Cockatoo Habitat Assessment, Prepared for Main Roads, October 2019

Biota Environmental Sciences

Albany Ring Road Black-Cockatoo Habitat Assessment

Prepared for Main Roads WA

October 2019

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Albany Ring Road Black-cockatoo Habitat Assessment

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1.0 Summary

Main Roads Western Australia (Main Roads) is proposing to construct the Albany Ring Road, a staged development with the purpose of redirecting heavy vehicle traffic bound for the Port away from built up urban areas of the City of Albany. With Stage 1 completed in 2017, Main Roads is now proposing to undertake construction of Stages 2 and 3 of the Albany Ring Road project. The survey area for Stages 2 and 3 is known as the Ultimate Footprint (the area to which this report pertains). It is 12 km in length and consists of 185 ha, of which 144.7 ha are vegetated.

Habitat for black-cockatoos was assessed by foot-traversing as much of the woodland habitat in the study area as practicable. In larger vegetation fragments, a systematic approach was applied, whereby transects of 25 m spacing were overlain on the study area in GIS. A zoologist then walked down the middle of two 25 m transects, effectively using them as the boundary of a strip-search, and recorded the location of all trees within the strip. This was continued until the entire fragment had been searched. In small fragments or where there were singular trees, foot traverses were also undertaken and recorded via a track file. Foraging habitat descriptions were recorded while conducting foot traverses. For any tree supporting hollow/s, details of the hollows were taken, and a differential GPS was used to record an accurate location of the tree. These trees were also subject to a dedicated breeding hollow assessment, which included the use of a remotely piloted aircraft (RPA) to obtain images of the hollows.

A total of 516 'suitable diameter at breast height (DBH) trees' (>50 cm DBH) were recorded in the Ultimate Footprint during the survey. From these trees, a total of 48 hollows with entrance diameters of 10 cm or greater were recorded, 37 of which were considered to warrant further investigation during a dedicated hollow assessment. This follow-up hollow assessment included the use of an RPA with a camera mounted to take photographs of the hollows. This assessment indicated that none of the hollows were suitable for black-cockatoo breeding, primarily due to inadequate chamber size.

Potential foraging habitat within the study area was assessed using the detailed vegetation mapping of the study area (Rathbone and Gilfillan 2018). This comprised 17.4 ha of predominantly Jarrah and/or Marri woodland with varying mid- and under-storeys, in some places included foraging plants. Individual planted *Pinus radiata* were also recorded throughout the study area and represent foraging plants for white-tailed black-cockatoos.

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2.0 Introduction

2.1 Project Background

Main Roads is proposing to construct the Albany Ring Road (ARR), a staged development with the purpose of redirecting heavy vehicle traffic bound for the Port away from built up urban areas of the City of Albany. When complete, the ARR will link four major roads (Albany Highway, South Western Highway, Lower Denmark Road and Hanrahan Road), allowing alternative access to the Port and developing industrial area. With Stage 1 completed in 2017, Main Roads is now proposing to undertake construction of Stages 2 and 3 of the ARR project. The survey area for Stages 2 and 3 is known as the Ultimate Footprint. This is the subject of this report and is referred to as the study area throughout. It is 12 km in length and consists of 185 ha, of which 144.7 ha are vegetated.

Three species of black cockatoo are known to inhabit the Albany area, and all have been recorded within 10 km of the study area: Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*), Baudin's Black-Cockatoo (*Calyptorhynchus baudinii*) and the Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*) (DSEWPaC 2012). All three species represent threatened fauna and are protected under both the Western Australian *Biodiversity Conservation Act 2016* (BC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The area contains old growth remnant Jarrah (*Eucalyptus marginata)* and Marri (*Corymbia calophylla*) trees, which have the potential to represent foraging and nesting habitat for all three species (DSEWPaC 2012). As part of a Biological Survey of the Albany Ring Road in 2017, Southern Ecology assessed threatened black-cockatoo habitat covering an area of 247 ha (Rathbone and Gilfillan 2018), of which 117.2 ha overlapped the Ultimate Footprint study area. During the 2017 survey, 265 habitat trees were identified within the area that intersects with the Ultimate Footprint survey area, and 53 hollows with diameters greater than 10 cm were recorded.

Since some sections of the study area had not been surveyed, and the status and value of some of the habitat trees that were surveyed may have changed since 2017, Main Roads commissioned Biota Environmental Sciences (Biota) to complete an updated assessment of black-cockatoo breeding habitat trees across the entire Ultimate Footprint study area.

Figure 2.1: Location of the study area.

2.2 Scope and Purpose of the Study

The aim of the survey was to re-assess black cockatoo habitat values within the Ultimate Footprint (hereafter 'the study area'). This was undertaken by identifying trees suitable for black-cockatoo nesting, which represent breeding habitat as defined in the EPBC Act referral guidelines (DSEWPaC 2012)

Specifically, this was achieved by undertaking the following scope:

- assessment of black-cockatoo habitat trees (diameter at breast height (DBH) >500 mm) within the Ultimate Footprint study area, including a re-assessment of those trees previously identified by Southern Ecology (Rathbone and Gilfillan 2018);
- identification of habitat trees containing hollows >100 mm and corresponding measurements of diameter, depth and angle, as well as details on suitability/evidence of use by black-cockatoos;
- further investigation using a drone for hollows deemed suitable based on risk assessment criteria; and
- recording evidence of roosting or feeding and any physical observations of black-cockatoo species during the survey.

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3.0 Target Species Overview

All three species of black-cockatoo are endemic to the southwest of Western Australia and have documented breeding areas overlapping the study area (Johnstone and Storr 1998, DSEWPaC 2012). Black-cockatoos require tree hollows with suitable dimensions for nesting and breeding, which typically occur in larger trees over 200 years old (DSEWPaC 2012). As such, breeding habitat trees are defined in the Federal guidelines as any tree with DBH equal to or greater than 500 mm (DSEWPaC 2012). Activities such as logging and deforestation for agriculture have contributed to a decline in abundance and range of black-cockatoos, hence their listing as conservation significant species.

3.1 Carnaby's Cockatoo (*Calyptorhynchus latirostris*)

Carnaby's Black-Cockatoo is listed as threatened under both the State BC Act (Schedule 2 - Endangered) and the Commonwealth EPBC Act (Endangered).

This species is distributed from Kalbarri to Esperance. During the breeding season, between July and November, they have been historically concentrated in the Wheatbelt region (Johnstone and Storr 1998, Saunders et al. 2014b). Here, they primarily nest in Salmon Gum (*E. salmonophloia*) and Wandoo (*E. wandoo*) but are also known to nest in Tuart (*E. gomphocephala*), Marri (*Corymbia calophylla*), Red Morrel (*E. longicornis*) and York Gum (*E. loxophleba*) (Johnstone and Storr 1998).

Expansion in breeding range further south and west towards the Jarrah - Marri forests of the Darling Scarp and Tuart forests of the Swan Coastal Plain has occurred in the past 10 to 30 years (Johnstone et al. 2010). Long term studies show that Carnaby's Black-Cockatoos utilise hollows ranging from 10 – 65 cm in diameter (average 26 cm) and approximately 130 cm deep (Saunders et al. 2014a, 2014b). They also frequent coastal areas outside of the breeding season where they forage in large flocks (Saunders et al. 2011), feeding on the seeds of *Banksia*, *Dryandra* and *Eucalyptus* species such as Jarrah, Marri and Karri (*E. diversicolor*).

3.2 Baudin's Cockatoo (*Calyptorhynchus baudinii*)

Baudin's Black-Cockatoo is listed as threatened under both the State BC Act (Schedule 2 - Endangered) and the Commonwealth EPBC Act (Vulnerable).

Baudin's Black-Cockatoo occurs in the humid and subhumid areas of the Southwest, distributed from Gidgegannup in the north to Naturaliste National Park and Augusta; also occurring in the Stirling and Porongurup Ranges and east along the south coast to Waychinicup (Johnstone and Storr 1998). Between March and September, the majority of the population migrates north from the cooler Karri forest to the central and northern Darling Range and eastern Swan Coastal Plain (Johnstone et al. 2010). They feed mainly on the seeds of Marri trees, as well as various species of *Banksia* and *Hakea* (Johnstone and Storr 1998).

Although the breeding requirements of this species are still poorly known, breeding has been recorded in the Southwest, north to Serpentine and east to Kojonup and Albany (Johnstone et al. 2010). They nest mainly in hollows of Karri, Marri and Wandoo trees. Breeding typically occurs between March and October, but egg laying has also been reported less frequently in November and December (Johnstone and Storr 1998, 1998, Johnstone et al. 2010). Specific dimensions of hollows used for breeding have not previously been studied for Baudin's Black-Cockatoo, but are likely to be similar to those hollows used by Carnaby's Black-Cockatoo.

3.3 Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso)*

The Forest Red-tailed Black-Cockatoo is listed as threatened under both the State BC Act (Schedule 3 - Vulnerable) and the Commonwealth EPBC Act (Vulnerable).

This species occurs from Gingin in the north across to near Albany in the south (Johnstone and Storr 1998), typically nesting in Marri, Jarrah and Karri tree hollows with entrance diameters ranging from 10 x 12 cm to 44 x 150 cm (mean 28 x 30 cm), and depths of between 100 cm and 500 cm (average 144 cm) (Johnstone and Storr 1998, Johnstone et al. 2013). This species lays eggs between October and November and incubation is approximately 29 – 31 days, during which time the female stays with the egg and is fed by the male (Johnstone and Storr 1998). They feed mainly on Jarrah and Marri seeds but also Sheoak (*Allocasuarina fraseriana*), Snottygobble (*Persoonia longifolia*) and Swan River Blackbutt (*E. patens*) (Johnstone et al. 2010).

4.0 Survey Methodology

4.1 Desktop Review

The following sources of information were reviewed in relation to the study area:

1. A search of NatureMap, carried out on 9th September 2019 in relation to the three black-cockatoo species using a line search with a 10 km buffer on the following points: (i) 34° 57' 52.5168" S, 117° 49' 14.2968" E; (ii) 34° 59' 47.6592" S, 117° 48' 49.7844" E; (iii) 35° 0' 51.1164" S, 117° 49' 24.2292" E; and (iv) 35° 1' 23.9988" S, 117° 51' 44.3268" E;
2. Results of the Great Cocky Count Report (Peck et al. 2018), particularly in relation to known roosting areas for black-cockatoos;
3. The vegetation and fauna report of Southern Ecology (Rathbone and Gilfillan 2018), which addressed an overlapping study area. Detailed vegetation mapping over the study area was completed by Southern Ecology and provided to Biota as shapefiles;
4. Southdown Magnetite Project Summary of studies and impact assessment for Carnaby's Black-Cockatoo (Rev 12.7) (Everard and Bamford 2016)
5. Revised draft referral guideline for three threatened black cockatoo species: Carnaby's Cockatoo (Endangered) *Calyptorhynchus latirostris,* Baudin's Cockatoo (Vulnerable) *Calyptorhynchus baudinii* and Forest Red-tailed Black Cockatoo (Vulnerable) *Calyptorhynchus banksii naso* (DotEE 2017).

4.2 Field Survey

The field survey methodology was performed in accordance with the Commonwealth referral guidelines for threatened black cockatoos (DSEWPaC 2012, DotEE 2017).

4.2.1 Breeding Habitat Assessment

The field assessment aimed to determine whether suitable breeding habitat for black-cockatoos was present within the Ultimate Footprint study area. This included the reassessment of the 663 habitat trees identified by Southern Ecology during earlier assessments (Rathbone and Gilfillan 2018), which were relocated during the survey using a GPS.

The Commonwealth *Revised draft referral guideline for three black cockatoo species* (DotEE 2017) defines breeding habitat as those species of trees known to support breeding within the range of the species, which either have a suitable nest hollow or are of a suitable DBH to develop a nest hollow (being greater than 50 cm DBH for most Eucalypts, or 30 cm in the case of Wandoo and Salmon Gum).

The aim was to assess, as far as practicable, all potential breeding trees within the study area. Two approaches were taken:

1. Larger areas of continuous vegetation were identified from aerial imagery and overlain with 25 m spaced transects in GIS. Using a GPS, a biologist walked up the middle of each 25 m wide transect, assessing all trees within it;
2. In smaller treed areas (e.g. roadside verges and paddocks containing singular trees), a biologist would maintain a GPS track file while using aerial imagery to visit as many trees as possible.

All individual trees of species with the potential to form hollows (primarily Jarrah, Marri and Tuart) and with sufficient diameter to be considered breeding habitat trees (i.e. DBH >50 cm) were recorded using a GPS with accuracy equivalent to that of a differential GPS (i.e. accurate to within 1.5 m).

For trees that were observed to contain hollows potentially suitable for black-cockatoo nesting, the following information was recorded:

- DBH (approximately 1.3 m above the ground);
- tree height;
- tree species;
- height above the ground of each hollow;
- the estimated size of entry of the hollow;

Hollows that met the following risk assessment criteria were considered a potential breeding hollow warranting further investigation using a remotely piloted aircraft (RPA), as described in Section 4.2.1.1:

- whether the hollow was suitably open for access (i.e. not covered by branches);
- whether the orientation of the hollow was suitable for access (i.e. horizontal to upright; downward-facing hollows being unsuitable);
- whether the location of the hollow allows for the formation of a nesting cavity (e.g. if on a spout branch, was the branch large enough to support a nesting cavity);
- signs of cockatoo use (including wear around hollows, nut chews, scarring, scratch marks on trunks and branches, secondary evidence of feeding sites and moulted feathers).

Figure 4.1: Effort applied to the recording of black-cockatoo habitat trees within the study area.

4.2.1.1 Black-cockatoo Breeding Hollow Assessment Field Methodology

Black-cockatoos breed in large hollow-bearing trees, generally within woodlands and forests (Johnstone and Kirkby 2011). Hollow formation results from a number of processes including fungal infection, termite activity and fire, and propensity for hollow formation varies between eucalyptus species (Whitford and Williams 2002). Studies on hollow formation in Jarrah/Marri forests identified a minimum tree age of 130 years before a tree would be suitable for hollow-dependent fauna (Whitford and Williams 2002). Habitat destruction, and the subsequent loss of suitable breeding hollows, has been identified as a process leading to population decline of black-cockatoos (Johnstone and Kirkby 2008). Furthermore, increased competition with both native and introduced species (e.g. Galahs, ducks and European honey bees) continues to reduce the availability of such trees for breeding sites (Johnstone et al. 2013).

Studies of the breeding behaviours of the three threatened black-cockatoo species have identified variation between the tree species and characteristics of hollows chosen for nesting (Table 4.1). For example, hollows formed in Jarrah are typically smaller than those in Marri, and Forest Red-tailed Black-Cockatoos breed predominantly in Marri in the Jarrah-Marri forest of the South-west (Johnstone et al. 2013). Breeding records of Carnaby's Black-Cockatoo on the Swan Coastal Plain indicate that the majority of their nests are in Tuart (Johnstone and Kirkby 2011).

Table 4.1: Breeding habitat for the three Threatened black-cockatoo species.

	Baudin's	Carnaby's	Forest Red-Tailed
Specific breeding habitat for the three black-cockatoo species	Nest in hollows in live or dead trees of Karri, Marri, Wandoo and Tuart.	Nest in hollows in live or dead trees of Salmon Gum, Wandoo, Tuart, Jarrah, Flooded Gum, York Gum, Powderbark, Karri and Marri.	Nest in hollows in live or dead trees of Karri, Marri, Bullich, Swan River Blackbutt, Tuart and Jarrah.
Hollow Characteristics			
Aspect	No preference. Does not affect nesting success (Saunders 1979).	No preference. Does not affect nesting success (Saunders 1979).	–
Depth	Ranges from 0.1 to 2.5+ m (Johnstone and Kirkby 2011).	Majority between 0.5 and over 2.0 m, average just over 1 m (Saunders 1979).	1.0 - 5.0 m (Johnstone and Kirkby 2011).
Height above ground	No preference (Serventy and Whittell 1976).	No evidence that higher hollows are preferenced (Saunders 1979).	No preference (Johnstone and Kirkby 2011).
Living or dead	No preference (Saunders 1979).	No preference (Saunders 1979).	No preference (Saunders 1979).
Entrance Diameter	–	–	>12 cm (Johnstone and Kirkby 2011).

For all hollow-bearing trees >50 cm DBH, which also contained hollows greater than approximately 10 cm dimension that were recorded during the black-cockatoo habitat mapping exercise (see Section 4.2.1), a follow-up survey was conducted using an RPA (DJI Mavic Pro). This aimed to assess the likelihood or evidence of black-cockatoo breeding within each hollow, as well as a better assessment of its suitability for breeding.

The RPA exercise was carried out by two biologists, one of whom is also an experienced RPA pilot. A pre-flight assessment of the tree was completed to ensure proper flight conditions and confirm the order in which hollows would be assessed. Prior to flight, the side of the tree was raked with a branch, which will generally cause any black-cockatoo or other bird species within a hollow to emerge. This provides an indication of hollow use and also reduces the likelihood of RPA-fauna collision.

During the flight stage of the RPA survey, the two participants were each tasked with a specific duty: (i) the pilot was responsible for flying the RPA; and (ii) the spotter monitored the surroundings to ensure the aircraft was not in close proximity to branches, and informed the pilot if any birds fled the hollows.

All accessible hollows with an entrance of 10 cm were examined with the RPA. Photographs were also taken as a visual reference and to aid future identification of the tree. These were also assessed in detail to determine if they represented suitable hollows and/or if they showed any signs of current or previous use by black-cockatoos (e.g. chew marks around hollow entrance, presence of chicks, eggs, feathers, chew/scratch marks).

Breeding suitability of the hollows examined was assessed against the criteria detailed in Table 4.2.

Table 4.2: Categories of hollow suitability for black-cockatoo nesting.

Category	Characteristics
Suitable with Evidence of Use	As for "Suitable" above, but also showing evidence of use that may be from black-cockatoos. The following represent the types of use that were searched for: • Fresh chews around the rim and inside of the hollow. • Freshly cleared vegetation around the entrance. • Eggs that were similar in appearance to those of black-cockatoos.
Suitable	• Entrance greater than 10 cm. • Branch width and depth large enough to support a nesting chamber. • Angle of entrance/egress suitable for black-cockatoo. • Entrance is clear of large branches would block access for black-cockatoo.
Not Suitable	Not a hollow, or hollow not suitable for black-cockatoo nesting.
Ground Assessment Only	The hollow could only be assessed from the ground due to limitations with RPA access (e.g. proximity to road traffic, within a prescribed no-fly zone, foliage covering hollow).

4.2.2 Foraging Habitat Assessment

Foraging habitat is defined as areas including plants of species known to support foraging within the range of each black-cockatoo species. While a broader range of species is utilised for foraging (including introduced species such as pines, **Pinus* spp.), Marri and Jarrah woodlands are particularly important to Baudin's Black-Cockatoo and the Forest Red-tailed Black-Cockatoo, while proteaceous heaths (i.e. shrublands dominated by *Banksia, Hakea* and *Grevillea* species) are also utilised by Carnaby's Black-Cockatoo (DSEWPaC 2012). The quality of the foraging habitat was scored using the elements of the habitat scoring tool described in the referral guideline (DotEE 2017) (Appendix 2).

The detailed vegetation mapping of the study area (Rathbone and Gilfillan 2018) was used in conjunction with the on-site breeding habitat assessment in order to apply the Foraging Habitat Scoring Tool (DotEE 2017) to the vegetation of the study area. Consideration was also given to the wider availability of foraging habitat for black-cockatoos by placing the study area in a 12 km context using mapping from the Albany Regional Vegetation Survey (Sandiford and Barrett 2010).

4.3 Survey Team and Timing

The field work was carried out over two phases, with the initial phase consisting of a habitat tree assessment, and the follow-up second phase involving investigation of hollows (>100 mm opening) potentially suitable for cockatoo nesting using a drone. The first phase was carried out over a period of three days from 5 – 7 August 2019 by two Biota biologists, Brandon King and Simon Colwill, together with Shane Priddle from Southwest Environmental. Shane Priddle and Brandon King carried out the assessment using the RPA in the following week, on 15 August 2019.

The survey timing fell within the recommended (DotEE 2017) South Coast regional window for Baudin's Black-cockatoo (March to September), as the species is likely to occur in foraging habitat and may occur in areas of the south coast region if breeding. Carnaby's Black-cockatoo would primarily occur in the Albany area from January to July to forage, following breeding further inland, however the species may also occur after July if breeding in local areas. Forest Red-tailed Black-Cockatoos are known to breed throughout the year.

The timing of the survey overlapped the beginning of the breeding period for the Carnaby's and Baudin's Black Cockatoo species, taking place near the end of winter, but was not within the usual peak breeding times.

A total of 46.2 mm of rainfall was recorded over the survey period from 5 – 14 August and temperatures were mild, ranging from a minimum of 8°C to a maximum of 21.6°C (data from the Bureau of Meteorology's Albany recording station (No. 9500)).

4.4 Legislation and Policy Conformance

All surveys were completed as far as practicable in accordance with relevant State and Commonwealth policy, and to a standard that would provide adequate information to assess the Proposal against principles and environmental aims relating to the environmental factor 'Terrestrial Fauna' (EPA 2016a).

Table 4.3 provides a summary of the most important and relevant legislation, policy and guidelines relating to this study.

Consistent with the most practically applicable and current policy in relation to the three black-cockatoo species occurring within South-west Western Australia, the current study primarily represents a habitat assessment, and as recommended under DSEWPaC (2012) the following was undertaken:

> *"Assess the extent, type and quality of the vegetation present, including the presence and extent of plants known to be used by the black cockatoos. In potential breeding habitat, measurements of the diameter at breast height of trees in the patch of woodland/forest must be made to determine whether the habitat meets the definition of 'breeding habitat'. Surveys for black cockatoo foraging habitat should be done in any remaining vegetation containing proteaceous heath/woodland, eucalypt woodlands or forest (particularly marri and jarrah forest) and in areas dominated by Pinus spp. Any area within the range of the black cockatoos that contains known food or nesting plant species is considered to be potential habitat for the species."*

While in draft form, the current assessment was conducted to the standard of "Revised draft referral guideline for three threatened black cockatoo species: Carnaby's Cockatoo (Endangered) *Calyptorhynchus latirostris* Baudin's Cockatoo (Vulnerable) *Calyptorhynchus baudinii* Forest Red-tailed Black Cockatoo (Vulnerable) *Calyptorhynchus banksii naso"* (DotEE 2017), particularly in relation to assessment of foraging habitat.

Table 4.3: State and Commonwealth legislation, policy and guidelines of most relevance to this study.

Legislation, Guideline or Policy	Application to this Study	Regulating Authority
Commonwealth		
Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act).	The Australian Government's central piece of environmental legislation.	The Department of the Environment and Energy
Significant Impact Guidelines 1.1 - Matters of National Environmental Significance (DotE 2013).	Details the species falling within the MNES category and what constitutes a significant impact.	The Department of the Environment and Energy
EPBC Act referral guideline for three threatened black cockatoo species: Carnaby's Cockatoo (*Calyptorhynchus latirostris*), Baudin's Cockatoo (*Calyptorhynchus baudinii*) and the Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) (DSEWPaC 2012)	Details distribution, ecology and recommended survey methodology.	The Department of the Environment and Energy

Legislation, Guideline or Policy	Application to this Study	Regulating Authority
Western Australia		
Biodiversity Conservation Act 2016 (BC Act) and Biodiversity Conservation Regulations 2018	Western Australia's central environmental legislation. Came into effect 1 January 2019 and replaces the *Wildlife Conservation Act 1950*.	Department of Biodiversity, Conservation and Attractions
Wildlife Conservation Act 1950 (WC Act)	Now defunct and replaced by the BC Act, however the most recently published Wildlife Conservation (Specially Protected Fauna) Notice 2018 under this act is current at time of writing.	Department of Biodiversity, Conservation and Attractions
Environmental Factor Guideline: Terrestrial Fauna (EPA 2016a).	Overall aim of the study is to provide adequate information to assess the proposal against the objective of the environmental factor Terrestrial Fauna; stated to be "To protect terrestrial fauna so that biological diversity and ecological integrity are maintained".	Environmental Protection Authority

4.5 Nomenclature

Consistent with the EPA (2016b) technical guidelines for terrestrial vertebrate fauna survey, the avifauna nomenclature is in accordance with Christidis and Boles (2008).

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5.0 Results

5.1 Desktop Review: Presence in the Local Area

NatureMap records indicate that all three species have distributions that include the study area; Albany represents the southeastern extent of the distribution of the Forest Red-tailed Black-cockatoo and is well within the distribution of both Carnaby's Black-cockatoo and Baudin's Black-cockatoo.

The two white-tailed black-cockatoo species appear to be most commonly recorded in the Albany area. For example, the Great Cocky Count assessed 22 potential roost sites in the Albany area in 2018 and recorded 557 white-tailed cockatoos (Peck et al. 2018), while no Forest Red-tailed Black-cockatoo individuals were recorded from roost sites. The study area occurs within 12 km of two roost sites assessed during the Great Cocky Count, identified by the suburb names 'Kalgan' (approximately 12 km northeast of the study area), at which 219 white-tailed black-cockatoos were recorded in the 2018 counts; and 'McKail' (within 2 km of the study area), where 49 white-tail black-cockatoos were recorded. An additional known roost site is known from Lake Seppings, 4.8 km from the study area, however, no cockatoos were recorded there during the 2018 count.

A resident population of Carnaby's Black-cockatoo is known to occur within the Stirling Range National Park (Everard and Bamford 2016) and the species has been recorded from the Porongurup National Park.

5.2 Suitable Diameter at Breast Height (DBH) Trees

A total of 516 'suitable DBH trees' (> 50 cm DBH) were recorded in the study area during the survey (Table 5.1). Tuart (historically planted), Marri and Jarrah accounted for the largest proportion of breeding habitat trees at 42%, 31% and 22% respectively. Only Jarrah and Marri trees were found to support hollows, and in some cases a single tree supported up to three hollows.

Table 5.1 Number of breeding habitat trees and hollows.

Tree Species	Breeding Habitat Trees	Number of Hollows
Corymbia calophylla (Marri)	162	20
Eucalyptus diversicolor (Karri)	9	0
Eucalyptus gomphocephala (Tuart)	216	0
Eucalyptus marginata (Jarrah)	112	28
Eucalyptus megacarpa (Bullich)	17	0
Total	516	48

5.3 Hollow Assessment

A total of 48 'hollows' with an entrance diameter greater than or equal to 10 cm were recorded in Jarrah and Marri. Overall, the large majority of hollows (86%) were marginal in entrance size suitability (between 10 and 15 cm), with only six hollows with entrance dimensions greater than 15 cm and the largest being 30 cm across. Hollow bearing trees had an average DBH of 71.1 ± 2.6 cm; on average, hollows were located 5.7 ± 0.47 m above the ground and were 13.2 ± 0.8 cm in diameter.

Based on the conservative criteria employed during the ground-assessment, 37 of the 48 hollows were considered to warrant further investigation using the RPA. Results from the follow-up survey indicated that none of the hollows were suitable for black-cockatoo nesting, primarily because the depth of the chambers was not adequate (Plate 5.1 - Plate 5.10). While not possible to

ascertain from the ground-assessment, images obtained from the RPA revealed that many of the 'hollows' were actually not hollow or lacked sufficient space for a black-cockatoo to turn around inside (see Plate 5.11 and Plate 5.12). One hollow was occupied by a Common Brushtail Possum and another by feral bees.

The Tuart (*Eucalyptus gomphocephala*) occurring within the study area are not native and have been planted quite a few decades ago as indicated by their DBH but none were found to support hollows. However, Tuarts do have the potential to form hollows and are recognised as important breeding trees on the Swan Coastal Plain (Johnstone et al. 2010).

Plate 5.1: Pic 1_0002. Drone tree ARR_01; spout trunk, 14 cm diameter, depth inadequate.

Plate 5.2: Pic 2_0007.

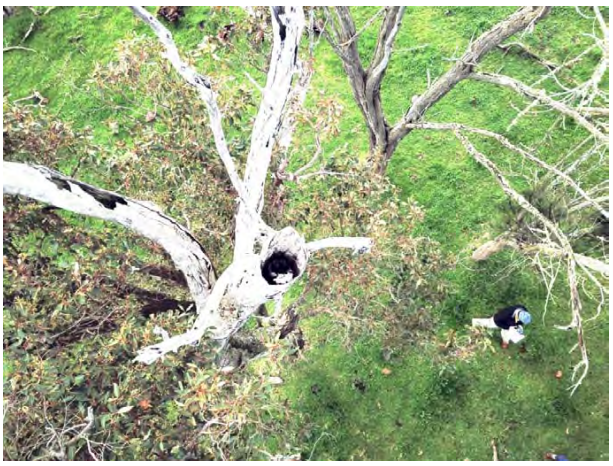

Plate 5.3: Pic 3_0013.

Plate 5.4: Pic 4_0025.

Plate 5.5: Pic 6_0030.

Plate 5.6: Pic 10_0044.

Plate 5.7: Pic 12_059.

Plate 5.8: Pic 19_0069.

Plate 5.9: Pic 20_0083.

Plate 5.10: Pic 22_0094.

Plate 5.11: Tree ARR_21; drone image before contrast manipulation.

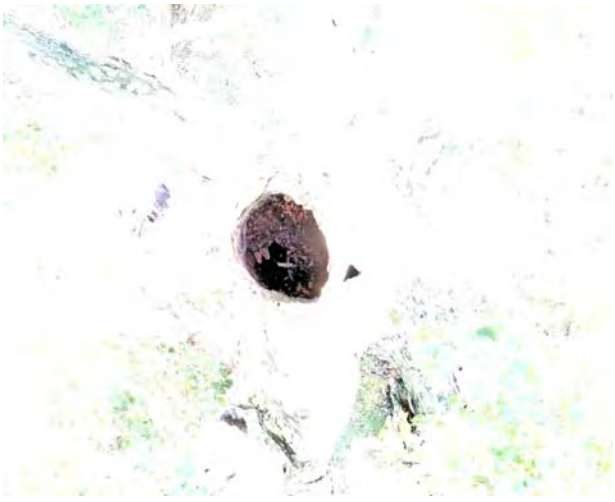

Plate 5.12: Tree ARR_21; drone image after contrast manipulation.

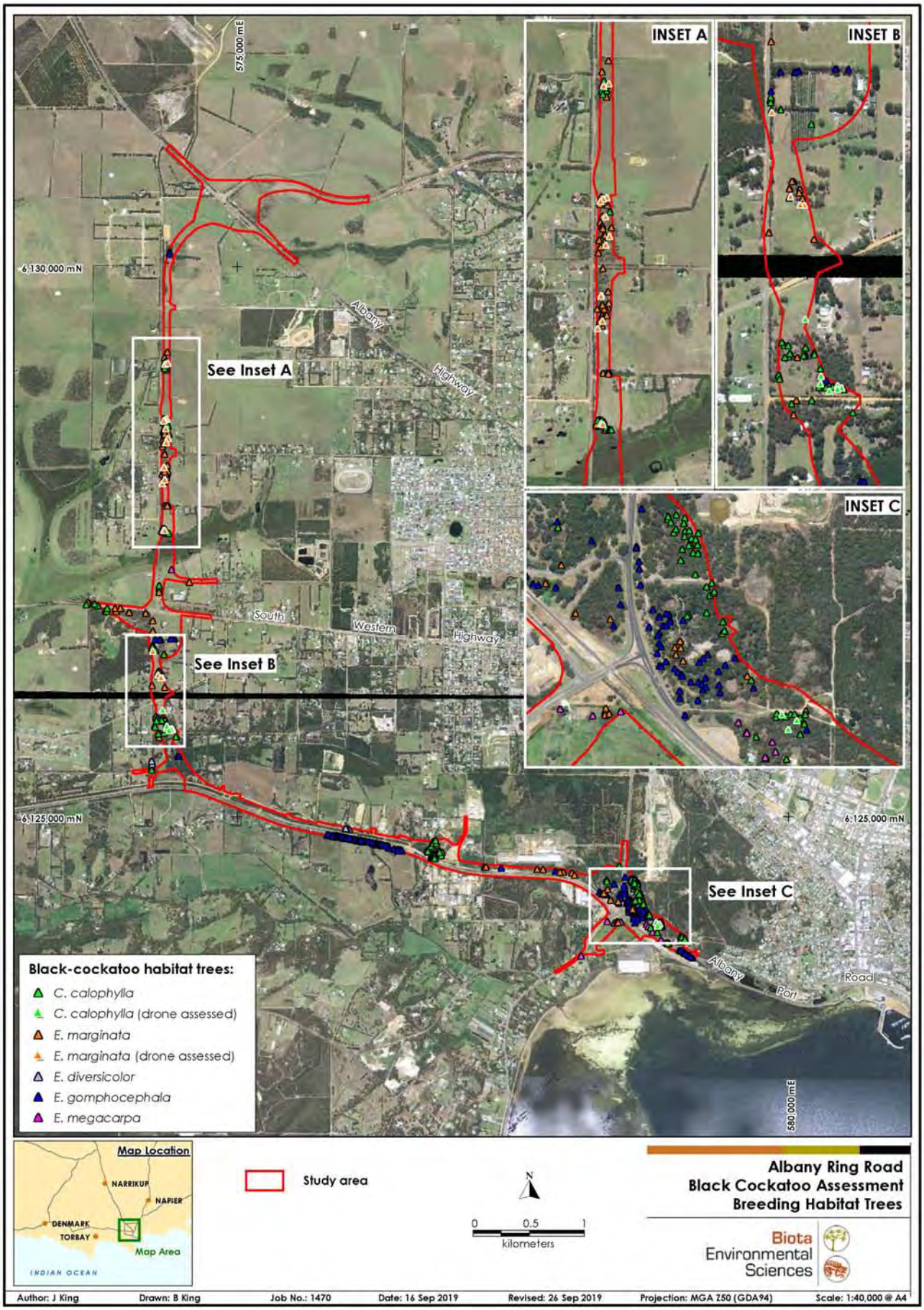

Figure 5.1: Black-cockatoo habitat trees recorded within the study area.

5.4 Foraging Habitat Assessment

The 185.0 ha study area includes 111.8 ha of cleared land, which is devoid of black-cockatoo foraging, breeding or roosting habitat. Using the detailed vegetation mapping of the study area prepared by Rathbone and Gilfillan (2018) as a guide, four vegetation units totalling 17.4 ha of native vegetation are likely to represent black-cockatoo foraging habitat. The foraging habitat quality score for each of these four vegetation units is shown in Table 5.2, while the scoring details are provided in Appendix 3. The distribution of this foraging habitat over the study area is shown in Figure 5.2. Table 5.3 includes descriptions of those vegetation units that are largely devoid of black-cockatoo foraging plants, however, in some areas of revegetation Jarrah and Marri have been planted which represent foraging plants.

Foraging habitat within the study area was largely represented by areas of Marri and Jarrah woodland, and evidence of all three species of black-cockatoo species utilising this habitat type has been previously described from characteristic chew marks on Marri nuts (Rathbone and Gilfillan 2018). The following vegetation units as described by Rathbone and Gilfillan (2018) were considered to represent the primary foraging habitat within the study area.

- Jarrah/Marri/Sheoak Laterite Forest with additional foraging plants including *Banksia grandis*, *Persoonia longifolia* and *Hakea amplexicaulis*;
- Marri/Jarrah Forest/Peppermint Woodland;
- Hakea spp. Shrubland/Woodland Complex with additional foraging plants including *E. marginata* and *Allocasuarina fraseriana;* and,
- Jarrah/Sheoak/*E. staeri* Sandy Woodland with additional foraging plants include *Banksia grandis* and *Hakea ruscifolia.*

In addition to these vegetation units, planted *Pinus radiata*, Jarrah and Marri occurred throughout the study area and also represent potential foraging habitat.

The Foraging Habitat Scoring Tool (DotEE 2017) has been applied to each vegetation type to assist with planning and offsetting (Table 5.2). It is important to note that the study area includes a buffer on the actual project disturbance footprint. Taking the entire study area into account, a starting score of High Quality is appropriate in many cases, as more than individual plants or small stands are included within this boundary, however, this is not necessarily the case for the smaller disturbance footprint, which should be scored separately.

Areas of Jarrah/Marri woodland returned foraging habitat scores indicative of very high quality for all three species of black-cockatoo. Areas largely devoid of Marri received lower scores for Baudin's Black-Cockatoo and Carnaby's Black-Cockatoo (ranging from Low Quality to Quality). The scattered *Pinus radiata* throughout the study area were considered to represent singular/small groups of foraging plants for Baudin's Black-Cockatoo and Carnaby's Black-Cockatoo, and as such qualified for a score indicating quality foraging habitat.

The Foraging Habitat Scoring Tool does include criteria that adjust the quality score downward, such as greater distances from known breeding areas and roosting sites. The study area occurs within the known breeding ranges of all three species as mapped in DotEE (2017), so no negative adjustments were applied on this basis. With regards to roosting sites, the Great Cocky Count includes at least two sites within 12 km of the study area, with white-tailed black-cockatoos recorded at both in 2018. In general, numbers of Forest Red-tailed Black-Cockatoos roosting in the vicinity of Albany are lower: no birds were recorded at roosts within 12 km of the study area in 2018, while in 2017 only 22 birds were recorded across the two roosts.

Table 5.2: Application of the Foraging Habitat Scoring Tool (DotEE 2017).
Low quality – 1-3; quality 4 – 5; high quality 6-7; very high quality 8-10.

Vegetation Unit	Area (ha)	Score		
		Baudin's	Carnaby's	Forest Red-tailed
Jarrah/Marri/Sheoak Laterite Forest	5.9	10	9	10
Marri/Jarrah Forest/Peppermint Woodland	5.7	10	9	10
Hakea spp. Shrubland/Woodland Complex	4.4	2	5	3
Jarrah/Sheoak/*E. staeri* Sandy Woodland	1.4	4	3	10
Planted *Pinus radiata*	-	4	0	-
Planted Jarrah and Marri	-	6	3	1

Table 5.3: Vegetation units (Rathbone and Gilfillan 2018) largely devoid of black-cockatoo foraging plants.

Vegetation Units	Area (ha)
Cleared	111.8
Revegetation or Plantation[1]	33.2
Taxandria juniperina Closed Forest	5.9
>75% Invasive Weeds	5.6
Homalospermum firmum/*Callistemon glaucus* Peat Thicket[2]	4.8
Peppermint Low Forest	1.1
Mosaic *T. marginata*/*Gastrolobium bilobum* Granite Shrubland/Yate Woodland	1.0
Evandra aristata Sedgeland	0.5
Taxandria marginata Granite Shrubland	0.3
Melaleuca preissiana Low Woodland	0.1
Total	164.3

1. includes some individual *Pinus radiata* trees.
2. *Callistemon* may be a foraging plant for Carnaby's Black-Cockatoo.

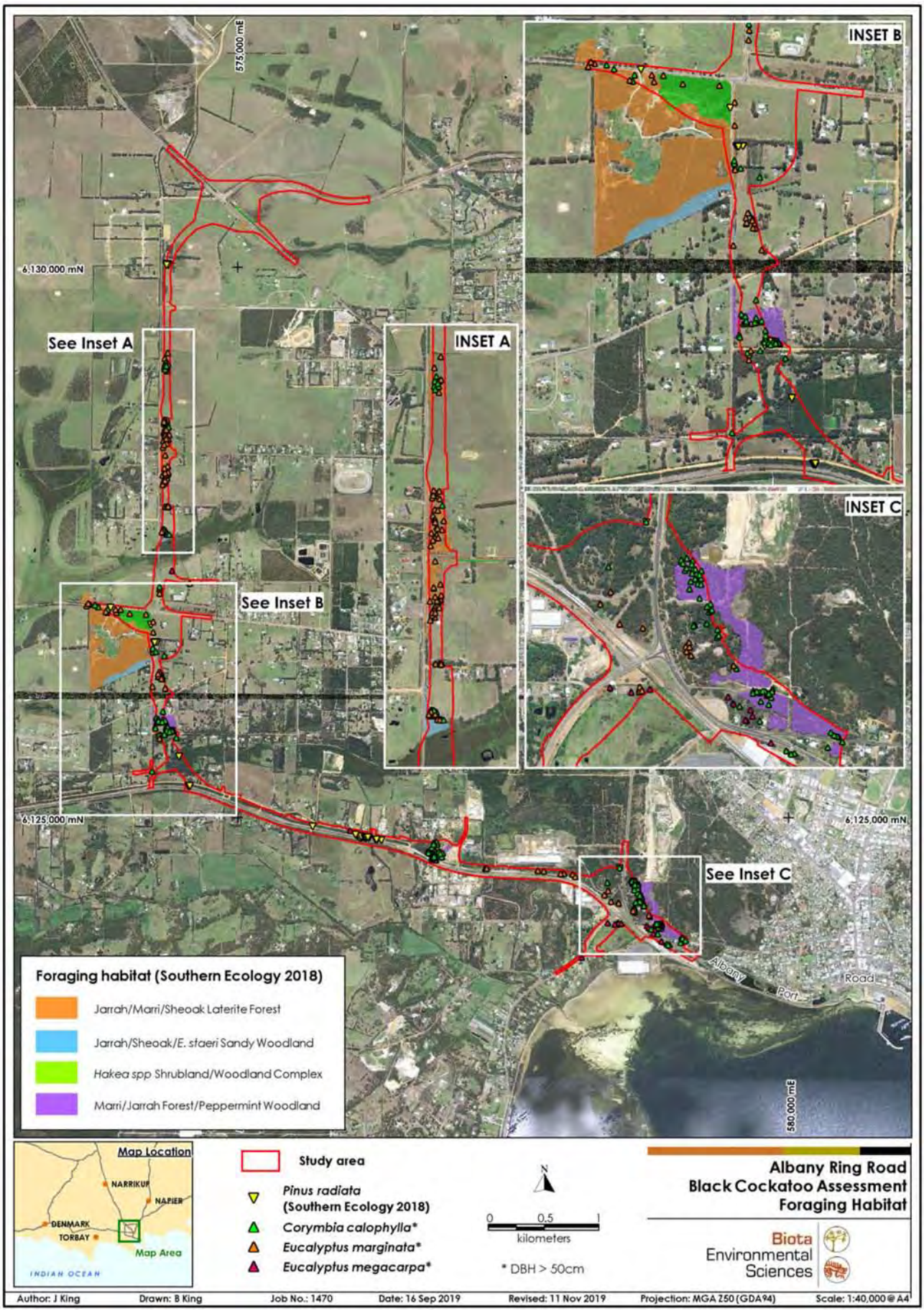

Figure 5.2: Potential black-cockatoo foraging habitat within the study area.

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6.0 Discussion

Within the Ultimate Footprint study area, up to 516 'suitable DBH trees' and 48 hollows were identified and marked. None of the 37 hollows followed up during the RPA assessment were found to be suitable for nesting. For the most part, the dimensions of the hollow entrances were marginal and caverns inside were far too small to support nesting.

The black-cockatoo foraging habitat within the study area has been considered in the context of wider availability using the meso-scale mapping of concordant vegetation units from the Albany Regional Vegetation Survey (Sandiford and Barrett 2010), out to a radius of 12 km around the study area (see Figure 6.1). This radius was chosen as it represents the typical maximum distance that black-cockatoos will fly from roosting locations to forage, under the hypothetical premise that cockatoos were roosting within the study area. The areas of each vegetation unit within the study area and in a 12 km radius are detailed in Table 6.1, while their occurrence is illustrated in Figure 6.1. In the immediate vicinity of the study area, the same foraging vegetation units occur within the Albany Mounts and in the crown reserve south-west of the intersection of South Coast Highway and George Street. Larger swathes of these same vegetation units are found within the Stirling Range National Park, Down Road Nature Reserve and Bakers Junction Nature Reserve.

Table 6.1: Foraging habitat within the study area and ARVS equivalent within 12 km.

Study Area	ARVS Code	Complex Definition	Within Study Area (ha)	Within 12 km (ha)
Afra/Emar/Ccal/Athe	12a	Jarrah/Marri/Sheoak Laterite Forest	5.9	5,077.5
Ccal/Afle	10	Marri/Jarrah Forest/Peppermint Woodland	5.7	475.8
Hspp/Complex	31	Hakea spp. Shrubland/Woodland Complex	4.4	1,101.8
Emar/Afra/Esta	13	Jarrah/Sheoak/*E. staeri* Sandy Woodland	1.4	2,101.7
		Total	17.4	8,756.8