

Main Roads WA
Mitchell Freeway Extension Hester Avenue to Romeo Road
Biological Survey

June 2019

Executive summary

Main Roads Western Australia (Main Roads) is currently developing the Mitchell Freeway Extension from Hester Avenue to Romeo Road, which includes an upgrade to Wanneroo Road from Dunstan Road to Trian Road.

GHD Pty Ltd (GHD) was commissioned by Main Roads to undertake a biological assessment, including a targeted Black Cockatoo habitat assessment of the proposed project area. The purpose of the survey is to delineate key flora, vegetation, fauna, soil, groundwater and surface water values (wetlands) and potential sensitivity to impact to Black Cockatoo foraging and breeding habitat. The outcome of the survey and information supplied in the biological survey and targeted fauna assessment will be used to inform the environmental assessment and approvals process.

The following definitions are referred to throughout this report:

- Survey area: Includes the proposed road corridors for Mitchell Freeway extension and Wanneroo Road upgrade plus a 50 metre (m) buffer. Covers a total area of 399.97 hectares (ha)
- Extended survey area: An approximate 500 m extension from the survey area where vegetation is present. Covers approximately 646.49 ha
- Study area: 5 kilometre (km) biological desktop search of the survey area.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.6 and the assumptions and qualifications contained throughout this report.

Key findings for survey area

Vegetation

Fourteen vegetation types were identified and described for the survey area, not including open water (lakes) or cleared and/or highly degraded areas. Approximately 43 % (170.90 ha) of the survey area is mapped as cleared/highly disturbed. Remnant vegetation remaining within the survey area is largely dominated by *Banksia* woodlands, mixed *Eucalyptus* woodlands and mixed heathlands. These vegetation types are generally associated with the landforms upon which they lie, with tall woodlands occurring in lower-lying areas with deep sandy soils, heathlands and shrublands on shallow soils on undulating dune systems, hilltops and ridges associated with limestone outcropping and *Banksia* woodlands in intermediate landforms associated with deep sandy soils.

The condition of the vegetation within the survey area ranged from Excellent to Completely Degraded. A large proportion of the survey area is in Degraded to Completely Degraded condition (243.85 ha, 61%). Remnant vegetation ranged in condition from Excellent to Degraded (scattered native trees/shrubs over weeds).

Five conservation significant ecological communities were identified within the survey area. The conservation significant ecological communities are:

- *Banksia* Woodlands of the Swan Coastal Plain Threatened Ecological Community (TEC) listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) - 85.98 ha
- *Banksia* dominated woodlands of the Swan Coastal Plain IBRA region Priority 3 Priority Ecological Community (PEC) listed by Department of Biodiversity, Conservation and Attractions (DBCA) - 102.13 ha

- *Melaleuca huegelii* - *Melaleuca systema* shrublands on limestone ridges (Floristic Community Type (FCT) 26a) TEC listed under the *Biodiversity Conservation Act 2016* (BC Act) - 3.87 ha
- Northern Spearwood shrublands and woodlands (FCT24) Priority 3 PEC listed by DBCA - 44.08 ha
- Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain Priority 3 PEC listed by DBCA - 11.88 ha.

Flora

Two hundred and ninety three flora taxa (including subspecies and varieties) representing 68 families and 177 genera were recorded from the survey area during the field survey. This total comprised 213 native taxa and 80 introduced flora taxa. Of the 80 introduced taxa, eight are listed as Declared Pests under the *Biosecurity and Management Act 2007*. Four of these taxa are also listed as Weeds of National Significance.

No EPBC Act or BC Act listed flora were recorded within the survey area. Six DBCA Priority (P) listed flora species were recorded within the survey area during the field survey:

- *Baeckea* sp. Limestone (N. Gibson & M.N. Lyons 1425) – P1
- *Acacia benthamii* – P2
- *Leucopogon* sp. Yanchep (M. Hislop 1986) – P3
- *Hibbertia spicata* subsp. *leptotheca* – P3
- *Pimelea calcicola* – P3
- *Stylidium maritimum* – P3.

Fauna

The survey area consists of nine broad fauna habitat types: Mixed heathland on limestone outcrops or heavy loams, Banksia woodland on grey/brown sand, Tuart (*Eucalyptus gomphocephala*) Forest in deep dark brown sand, Jarrah (*E. marginata*) woodland on grey/brown sand, Acacia Shrublands on dunes and deep sands, Parabolic dunes, Plantations, Rehabilitation areas and Scattered natives over weeds, Cleared/highly disturbed. Habitat values ranged from high to low value, with the low value site areas that are degraded or modified.

Within the survey area 124 vertebrate fauna species were recorded, including 17 mammals, 74 birds, 32 reptiles and one frog. Five conservation significant fauna species were identified as present and a further two likely to be present in the survey area based on a combination of observations and habitat assessment. The five conservation significant fauna species recorded within the survey area included:

- Carnaby's Cockatoo (*Calyptorhynchus latirostris*) – listed as Endangered under the BC Act and Endangered under the EPBC Act
- Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*) – listed as Vulnerable under the BC Act and Vulnerable under the EPBC Act
- Peregrine Falcon (*Falco peregrinus*) – listed as Other specially protected fauna under the BC Act
- Southern Brown Bandicoot (*Isodon fusciventer*) – listed as P4 by DBCA
- Western Brush Wallaby (*Notamacropus Irma*) – listed as P4 by DBCA.

Species likely to be present in the survey area:

- Black-striped Snake (*Neelaps calonotos*) – listed as P3 by DBCA
- Jewelled southwest Ctenotus (Swan Coastal Plain population) (*Ctenotus gemmula*) – listed as P3 by DBCA.

Targeted Black Cockatoo Assessment

Two species of Black Cockatoo, Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo, were recorded in the survey. Of the 570 identified potential breeding trees 20 were identified to have medium to/or large hollows present suitable for Black Cockatoo breeding or demonstrating signs of historical use. These trees had from 1 to 4 hollows present and were assessed via visual inspection and/or via a pole cam (if within 12 m from ground) in August 2018, November 2018, and January/February 2019. No Black Cockatoo were recorded utilising the identified hollows over the assessment period.

Feeding evidence was recorded in the survey area on *Banksia sessilis*, *B. attenuata*, *B. grandis* and Jarrah. Approximately 217.06 ha of suitable foraging habitat is mapped within the survey area.

Key findings for extended survey area

Twelve of the vegetation types identified in the survey area, not including Cleared/highly disturbed, also occurred in the extended survey area. The extended survey area did not contain *Eucalyptus decipiens* tall woodland or Pine plantation, but did contain Typha tall rushland and *Eucalyptus/Melaleuca* tall isolated clumps of trees, in addition to open water (Lake Nowergup). The condition of the vegetation within the extended survey area ranged from Excellent to Completely Degraded, however the overall condition was better than the survey area, with significantly less Completely Degraded vegetation present.

The five conservation significant ecological communities identified within the survey area were also mapped in the extended survey area. With the exception of the Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain PEC, all communities had a larger extent within the extended survey area compared to the survey area.

The six Priority flora species recorded within the survey area were also recorded in the extended survey area. In addition to the Priority species, one BC Act listed taxon, *Melaleuca* sp. Wanneroo (G.J. Keighery 16705) (Endangered) was recorded within an isolated patch in the extended survey area.

Eight of the nine fauna habitat types identified in the survey area also occurred in the extended survey area. Pine plantation was not represented, whereas Open water with riparian vegetation and weeds is an additional fauna habitat present in the extended survey area, in association with Lake Nowergup. Within the extended survey area 96 species were recorded and included 15 mammals, 57 birds, 22 reptiles and 2 frogs. Many of the species recorded in the survey and extended survey areas were the same, which is not unexpected given the similarity in habitats and proximity. The five conservation significant fauna species identified as present in the survey area were also identified in the extended survey area. There are an additional eight conservation significant species likely to be present in the extended survey area, which includes the two species considered likely to occur in the survey area. The larger number of species considered likely to occur is associated with the extended survey area incorporating Nowergup Lake, which provides habitat not found in the survey area.

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1. Introduction

1.1 Project background

Main Roads Western Australia (Main Roads) is currently developing Mitchell Freeway Extension Hester Avenue to Romeo Road which includes the upgrade to Wanneroo Road from Dunstan Road to Trian Road.

The proposed works are located within the City of Wanneroo approximately 30 kilometres (km) north of Perth central business district and 12 km south of the coastal suburb of Yanchep.

The Mitchell Freeway provides the primary road access route from the Perth north-west corridor towards the City of Perth. The freeway currently terminates at Hester Avenue. The freeway has been constructed in several stages since the 1960s, with further extension from Hester Avenue to Romeo Road being investigated. Duplication of Wanneroo Road to dual carriageway in both directions, extending from Dunstan Road to Trian Road Straight Line Kilometre (SLK) 34.50-40.40, is also being investigated.

Freeway extension and road duplication works will require installation of signs and lights, upgrade of services and access roads. The project is at a concept stage with no preliminary design.

Flora, vegetation, fauna, heritage and dieback assessment have been previously undertaken for some sections of the above projects. WA Metropolitan Region Scheme Amendment 992/33 was approved under Ministerial Statement 629 in 2003 and is applicable to portions of both projects.

1.2 Purpose of this report

GHD Pty Ltd (GHD) was commissioned by Main Roads to undertake a biological assessment, including a targeted Black Cockatoo habitat assessment of the proposed Mitchell Freeway extension and Wanneroo Road upgrade project areas as well as a designated extended survey area. The purpose of the survey is to delineate key flora, vegetation, fauna, soil, groundwater and surface water values (wetlands) and potential sensitivity to impact to Black Cockatoo foraging and breeding habitat.

The outcome of the survey and information supplied in the biological survey and targeted fauna assessment will be used to inform the environmental assessment and approvals process. The results of the biological survey may also assist in the preparation of a Clearing Impact Assessment and Vegetation Management Plan and may be used in State or Commonwealth approval documentation.

1.3 Survey areas

1.3.1 Survey area

The survey area for the project includes the proposed road corridors for Mitchell Freeway extension and Wanneroo Road upgrade plus a 50 metre (m) buffer, located approximately 35 km north of Perth in the City of Wanneroo. The freeway extension works are located between Hester Avenue, Clarkson and Romeo Road, Alkimos. The Wanneroo Road upgrade works are located from Dunstan Road to train Road Straight Line Kilometre (SLK) 35.50-40.40. The survey area (including a 50 m buffer) covers a total area of 399.97 hectares (ha). A single season detailed and targeted vegetation and flora assessment and Level 2 fauna survey, including a targeted Black Cockatoo assessment, was undertaken in the survey area.

The survey area boundary is shown on Figure 1, Appendix A.

1.3.2 Extended survey area

The extended survey area covers a larger area and extends between the two road alignments within the Neerabup National Park, between Hester Avenue and Karaborup Road and includes a part of the Neerabup Nature Reserve, east of Wanneroo Road and a larger area around Romeo Road in the north. The extended survey area covers approximately 646.49 ha. The biological survey conducted in the extended survey area included a reconnaissance survey to provide a local context of environmental constraints identified in the survey area, as per the Environmental Protection Authority (EPA) *Technical Guidance Flora and Vegetation Surveys for Environmental Impact Assessment* (2016a) for linear corridor surveys.

The extended survey area boundary is also shown on Figure 1, Appendix A.

1.3.3 Study area

A study area¹ was defined for the biological desktop based searches and includes a 5 km buffer of the survey area (Figure 1, Appendix A).

1.4 Scope of works

The scope of works was to undertake a desktop assessment and biological survey of the survey area and extended survey area. The following actions were completed to fulfil the scope:

- A desktop assessment of the study area prior to the field survey to identify biological features and constraints, which may be in, or near the survey area
- A review of relevant environmental reports
- A field survey to verify/ground truth the desktop assessment findings through a combination of detailed, targeted and reconnaissance survey
- Identification and mapping of vegetation types to a scale appropriate for the bioregion and described according to the National Vegetation Information System (NVIS) structure and floristics
- Identification and mapping of Threatened and/or Priority Ecological Communities (TECs or PECs) inferred through the use of quadrats and relevés
- Assess the survey areas flora species diversity, density, composition, structure and weed cover, recording the percentage of each in nominated quadrats
- Mapping of Black Cockatoo habitat and potential or known breeding trees in accordance with the Commonwealth guidelines
- Monitor identified potential Black Cockatoo hollows over the 2018\19 breeding season, via three assessments - August, November and January\February
- Delineation and mapping of fauna habitat types
- A flora and fauna likelihood of occurrence assessment based on the vegetation units and fauna habitat present within the survey area
- Mapping using Geographic Information Systems (GIS) mapping software
- A concise report (this document) on the findings of the biological survey
- Raw survey data at project completion in electronic form.

¹ The 5 km radius boundary of the study area has been defined by the Main Roads brief for the project.

1.5 Relevant legislation, conservation codes and background information

In WA some ecological communities, flora and fauna are protected under both Federal and State Government legislation. In addition, regulatory authorities also provide a range of guidance and information on expected standards and protocols for environmental surveys.

An overview of key legislation and guidelines, conservation codes and background information relevant to this biological survey is provided in Appendix B.

1.6 Report limitations and assumptions

This report has been prepared by GHD for Main Roads and may only be used and relied on by Main Roads for the purpose agreed between GHD and the Main Roads as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Main Roads arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report (including species listings). GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Main Roads and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of access tracks, operational works, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of the field survey. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This report has assessed the flora and fauna within the survey area and extended survey area (Figure 1, Appendix A). Should the survey area or extended survey area change or be refined, further assessment may be required.

2. Methodology

2.1 Desktop Assessment

Prior to the commencement of the field survey, a desktop assessment was undertaken to identify relevant environmental information pertaining to the study area and to assist in survey design. This included a review of:

- The Department of the Environment and Energy (DotEE) Protected Matters Search Tool (PMST) to identify communities and species listed under the *Environment Protection and Biodiversity Act 1999* (EPBC Act) potentially occurring within the study area (DotEE 2018a) (Appendix C)
- The Department of Biodiversity, Conservation and Attractions (DBCA) TEC and PEC database to determine the potential for conservation significant communities to be present within the study area
- The DBCA *NatureMap* database for flora and fauna species previously recorded within the study area (DBCA 2018) (Appendix C)
- The DBCA Threatened (Declared Rare) and Priority Flora (TPFL) database and the WA Herbarium database (WAHERB) for Threatened flora listed under the *Biodiversity Conservation Act 2016* (BC Act) and listed as Priority by the DBCA, previously recorded within the study area
- Existing datasets including previous pre-European vegetation mapping of the survey area (Beard 1979; Heddle et al. 1980 and Webb et al. 2016), aerial photography, hydrology information to provide background information on the variability of the environment, likely vegetation units and fauna habitats and to identify areas that potentially contain TECs and PECs
- Existing reports and/or data:
 - *Level 2 Flora and Level 1 Fauna Assessment for Mitchell Freeway extension: Burns Beach Road to Romeo Road* (GHD 2014a)
 - *Level 2 Fauna Survey for Neerabup Road Extension* (GHD (2014b)
 - *Black Cockatoo Assessment for the Mitchell Freeway Extension* (GHD 2013a)
 - *Black Cockatoo Assessment – Update* (GHD 2013b)
 - *Preliminary Environmental Impact Assessment (PEIA) and Gap Analysis for the Mitchell Freeway Extension (Hester Avenue to Romeo Road) and Wanneroo Road Upgrade (Dunstan Road to train Road)* (GHD 2018)
 - *Trapping results for Neerabup National Park, Central Section in vicinity of Hester Ave, Raw data provided* (DPaW 2013)
 - *Fauna studies in Water Supply reserve 34537, Adjacent to Neerabup National Park. Prepared for Water Authority of Western Australia by Conservation and Land Management* (CALM 1993)
 - Raw data for Level 1 Herpetofauna assessments on Pipidiny Road from 1996 to 2004 (Maryan, B. Pers comm)
 - *Fauna clearance trapping program for the Wanneroo Road Extension Burns Beach to Neerabup Roads 2017 to 2018* (MRIA 2018).

2.2 Field survey

2.2.1 Flora and vegetation

GHD botanists Angela Benkovic (flora licence no. SL012366) and Erin Lynch (flora licence no. SL012374) completed a single season detailed and targeted vegetation and flora assessment of the survey area and a reconnaissance survey of the extended survey area. Targeted surveys for conservation significant flora based on desktop assessments and habitat availability were undertaken across the survey area and extended survey area. Parts of the survey area were located within DBCA managed lands (Figure 3, Appendix A), therefore a Regulation 4 Authority was issued to Angela Benkovic and Erin Lynch (CE005785) authorising them to survey in these areas.

The detailed, reconnaissance and targeted surveys were undertaken over multiple visits between early spring and late spring (September – November 2018) with an additional targeted flora survey undertaken in early summer (December 2018). The timing and survey effort undertaken for the survey area and extended survey area are shown in Table 2-1. A total of 28 survey days were undertaken across the survey area and extended survey area.

Table 2-1 Survey timing and effort

Date	Botanist	Survey type	Area	Total survey effort
17-19 September 2018	Angela Benkovic and Erin Lynch	Detailed and targeted flora survey	Survey area	6 days
25-26 September 2018	Angela Benkovic and Erin Lynch	Detailed and targeted flora survey	Survey area	4 days
15-17 October 2018	Angela Benkovic and Erin Lynch	Detailed and targeted flora survey	Survey area and extended survey area	6 days
5-7 November 2018	Angela Benkovic and Erin Lynch	Detailed, targeted flora and reconnaissance survey	Survey area and extended survey area	6 days
10-12 December 2018	Angela Benkovic and Erin Lynch	Targeted flora survey	Survey area and extended survey area	6 days

The field survey was undertaken to identify and describe the dominant vegetation units, assess vegetation condition, and identify and record vascular flora taxa present at the time of survey. Searches for conservation significant or other significant ecological communities and flora taxa were also undertaken during the field survey.

The survey methodology employed by GHD was undertaken with reference to the Environmental Protection Authority (EPA) *Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment* (EPA 2016a).

Data collection

Field survey methods involved a combination of sampling quadrats, relevés, photographic reference points located in identified vegetation units and walking transects.

Forty-four non-permanent quadrats and seven relevés were described throughout the survey area and extended survey area. The location of the quadrats and relevés were concentrated within the survey area. Additional representative quadrats and relevés were undertaken within the extended survey area to represent vegetation types not present or of limited size within the

survey area. Quadrat and relevé locations are shown on Figure 5, Appendix A and the data is provided in Appendix D.

Quadrats (measuring 10 m x 10 m – area of 100 m²) were located within each identified vegetation unit. A minimum of three quadrats were located within each identified vegetation unit, where possible. Quadrats were not established in vegetation units that had been significantly altered by clearing and weeds. Relevés (unmarked area) were performed to supplement quadrat data and in areas where the vegetation was highly modified or size of the vegetation type was restricted. Field data at each quadrat was recorded on a pro-forma data sheet and included the parameters detailed in Table 2-2.

Table 2-2 Data collected during the field survey

Aspect	Measurement
Collection attributes	Site code, personnel/recorder; date, quadrat dimensions, photograph of the quadrat.
Physical features	Aspect, slope, landform, soil attributes, ground surface cover, leaf and wood litter.
Location	Coordinates recorded in GDA94 datum using a hand-held GPS tool to accuracy approximately ± 5 m.
Vegetation condition	Vegetation condition was assessed using the condition rating scale adapted by EPA (2016a) for the South West Botanical Province.
Disturbance	Level and nature of disturbances (e.g. weed presence, fire and time since last fire, impacts from grazing, exploration activities).
Flora	List of dominant flora from each structural layer. List of all species within the quadrat including average height and cover (using NVIS)

A flora inventory was compiled from taxa listed in described quadrats and relevés and from opportunistic floristic records throughout the survey area.

Vegetation units

Vegetation units were identified and boundaries delineated using a combination of aerial photography, topographical features and field data/observations.

Vegetation units were described based on structure, dominant taxa and cover characteristics as defined by quadrat and relevé data and field observations. Vegetation unit descriptions follow NVIS and are consistent with NVIS Level V (Association). At Level V up to three taxa per stratum are used to describe the association (NVIS Technical Working Group 2017).

Statistical analysis

PRIMER v6 (Clarke and Gorley 2006) was used to examine the similarity between sites using collected data. A presence/absence matrix was created of all taxa (including perennials and annuals) present in the quadrats recorded within the survey area. The dissimilarity between quadrats was determined using the Bray-Curtis measure and the Resemblance function in PRIMER. A Cluster analysis (using Agglomerative Hierarchical Clustering technique) based on group average was undertaken using the Bray-Curtis similarity matrix and results presented as a dendrogram. In addition, a nonmetric multi-dimensional scaling analysis (MDS) was undertaken using the Bray-Curtis similarity matrix and results presented as a two dimensional scatter plot. The analysis was repeated removing all weed and singleton taxa. The outputs of the PRIMER analysis were used to inform decisions on vegetation units.

Comparison of vegetation units with regional datasets

Statistical analysis

The Swan Coastal Plain bioregion (abbreviated as SWA) dataset (accessed through *NatureMap*) is derived from a database compiled and maintained over many years, combining the results of a number of floristic studies (conducted between 1990 and 1996) on plant communities of the SWA, south of Moore River. The SWA dataset includes sampling site details, the flora collected at these sampling sites and the floristic community type (FCT) assigned to these sampling sites. The taxonomy of the flora in the SWA dataset used is current as of December 2018 (updated by GHD).

PRIMER v6 (Clarke and Gorley 2006) was used to compare the GHD quadrats to existing data (where available) for FCTs described on the SWA. SWA site locations within a 5 km buffer of the survey area were located and the FCTs represented by these sites were identified. All site locations for these FCTs from the SWA dataset were extracted, along with those identified in the desktop searches (e.g. TEC and PEC searches). Representative quadrats from each FCT selected for the analysis are shown in Table 2-3.

The GHD quadrat data and SWA quadrat data was combined, reconciled to align nomenclature and a presence/absence matrix created of all taxa (including perennials and annuals). Singleton taxa (those occurring in only one quadrat) were removed from the matrix as well as taxa that were only identified to family or genus level. The dissimilarity between quadrats was determined using the Bray-Curtis measure and the Resemblance function in PRIMER. A Cluster analysis (using Agglomerative Hierarchical Clustering technique) based on group average was undertaken using the Bray-Curtis similarity matrix and results presented as a dendrogram. In addition, a nonmetric MDS was undertaken using the Bray-Curtis similarity matrix and results presented as a two dimensional scatter plot. A factor was added to the output to define sample groups by FCT. The outputs of the PRIMER analysis were used to inform decisions on vegetation units.

It is noted that PRIMER can be limited in use for this purpose as analysis is based on all species recorded in quadrats and does not take into account dominance of species. Further interpretation of statistical results, coupled with multiple field surveys and desktop information is needed to determine whether the vegetation units are representative of a certain FCT.

The Aquatic Root Mat Community Number 1 of Caves of the Swan Coastal Plain (Caves SCP01) TEC and *Spinifex longifolius* grasslands and low shrublands (FCTS14) was removed from the analysis as there were no established caves or *Spinifex* within the survey area or extended survey area. The Aquatic Root Mat Community in Caves of the Swan Coastal Plain TEC is an assemblage of aquatic invertebrates living in mats of fine tree rootlets and their associated microflora in caves containing previously permanent streams and pools in Yanchep National Park. The closest extent of the survey areas is approximately 4 km south south-east of a 1000 m buffer area of the cave entrances, where this TEC is known to occur.

Table 2-3 List of SWA sites used in the PRIMER analysis

Floristic Community Type Name and ID	Status	Quadrats
Woodlands over sedgeland in Holocene dune swales (FCT19b)	TEC [^]	19bcool 09, 19bcool14, 19bcool15, 19bxyan10
Northern Spearwood shrublands and woodlands (FCT24)	PEC [*]	24bold07, 24bold09, 24BOLD-1, 24bold12, 24bold13, 24bold14, 24BOLD-2, 24bold23, 24BOLD-3, 24BOLD-4, 24buck01, 24CHIDPT-1, 24cool 02, 24cool 03, 24cool 08, 24Hepb03, 24KERO-1, 24KERO-2, 24MI23, 24MTB-1,

Floristic Community Type Name and ID	Status	Quadrats
		24MTB-2, 24MTB-3, 24MTB-4, 24NAVB-3, 24NAVB-4, 24NEER-1, 24NEER-10, 24NEER-11, 24NEER-7, 24NEER-9, 24PTWALT-1, 24star01, 24star02, 24THOM-2, 24TRIG-5, 24TRIG-6, 24xbeer01
<i>Melaleuca huegelii</i> – <i>Melaleuca systema</i> shrublands on Limestone ridges (FCT26a)	TEC	26aCLIFT02, 26aCLIFT03, 26aSHE-4, 26aSHE-5, 26aSVH-1, 26aWABL-1, 26aYAN-12, 26aYAN-13, 26aYAN-15, 26aYAN-2, 26aYAN-24, 26azYAN4, 26azYAN5
Species poor mallees and shrublands on Limestone (FCT27)		27bold18, 27bold22, 27BU03, 27PAR1, 27SVH-2, 27WHILL-3, 27WHILL-4, 27wilb05, 27YALG-3, 27YALG-4, 27YALG-5, 27YALG-8
Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> – <i>Eucalyptus</i> woodlands (FCT28)	*	284M03, 28beel01, 28BULL-1, 28BULL-10, 28BULL-11, 28BULL-4, 28BULL-9, 28DEPOT-1, 28HARRY-1, 28HARRY-2, 28Hepb01, 28KING-1, 28KING-2, 28leda02, 28MILT-4, 28moore01, 28moore02, 28moore03, 28much01, 28much03, 28NEER-2, 28NEER-20, 28NEER-21, 28NEER-22, 28NEER-23, 28NEER-3, 28NEER-4, 28NEER-5, 28NEER-6, 28NEER-8, 28Pinn01, 28Pinn03, 28quinn02, 28sams01, 28sand01, 28SEAB-6, 28SHE-2, 28SHENT-1, 28star03, 28tokyu03, 28TRIG-3, 28TRIG-4, 28WABL-4, 28WARI-1, 28WARI-2, 28WATERRD1, 28wilb06, 28wilb07, 28wire01, 28wire02, 28WOODV-1, 28WOODV-2, 28YAN-25, 28YAN-3, 28YAN-4, 28YAN-6, 28YAN-8, 28YAN-9, 28yela01, 28yuri02
Coastal shrublands on shallow soils (FCT29a)	PEC	29aBMaid02, 29aBU01, 29aBU02, 29aBU04, 29aBURN-1, 29aBURN-2, 29aGARD02, 29aMI21, 29aNAVB-2, 29aNMAid01, 29aNMAid03, 29aPinn02, 29aPRES-1, 29arich02, 29arott02, 29aSEAB-4, 29aSEAB-5, 29aSEAB-8, 29aTRIG-2, 29awilb11
Acacia shrublands on taller dunes (FCT29b)	PEC	29bbold08, 29bbold10, 29bbold11, 29bGuild02, 29bGuild06, 29bMI01, 29bMI02, 29bMI03, 29bMI06, 29bMI07, 29bMI09, 29bMI18, 29bNPRES-1, 29bNWIL-1, 29bNWIL-3, 29bPB-2, 29bPB-3, 29bPB-4, 29bPB-5, 29bSEAB-2, 29bSEAB-3, 29bSEAB-7, 29bSW06, 29bSW07, 29bSW11, 29btokyu04, 29btokyu06, 29btokyu07, 29bTRIG-1, 29bWHILL-1, 29bWHILL-2, 29bwilb01, 29bwilb03, 29bwilb08, 29bwilb09, 29bwilb10, 29bwilb12
Quindalup <i>Eucalyptus gomphocephala</i> and/or <i>Agonis flexuosa</i> woodlands (FCT30b)	PEC**	30bLESCH-1, 30bLESCH-2, 30bLESCH-3, 30bLESCH-4, 30bLESCH-5, 30bNMAid04, 30bPEPB-1, 30bpip01, 30bPossum3, 30bPossum4
Northern <i>Acacia rostellifera</i> – <i>Melaleuca systema</i> shrublands (FCTS11)		S11bold05, S11m4601, S11m4602, S11MI04, S11MI05, S11MI08, S11rott01, S11SW05, S11SW08, S11SW09, S11SW10, S11TR06, S11TR07, S11TR08
Northern <i>Olearia axillaris</i> – <i>Scaevola crassifolia</i> shrublands (FCTS13)		S13MI11, S13MI12, S13MI17, S13MI19, S13MI22, S13SW02, S13SW03, S13SW04, S13TR03, S13TR04, S13TR05, S13wilb02

^ A sub-community of the Critically Endangered Sedgeland in Holocene dune swales of the southern Swan Coastal Plain EPBC listed TEC.

* A component of the Endangered *Banksia* Woodlands of the Swan Coastal Plain EPBC listed TEC.

** Can be a component of the Endangered *Banksia* Woodlands of the Swan Coastal Plain EPBC listed TEC.

Single site insertion analysis

A single site insertion (SSI) analysis was conducted on GHD quadrats that were considered to align with FCT26a. The SSI analysis involved analysing GHD quadrats Q9, Q14, Q23, Q26,

Q27 and Q37 individually against the SWA dataset. This type of analyses is considered a more powerful method of grouping each quadrat with the SWA data and therefore enables a more robust result.

Vegetation condition

The vegetation condition was assessed and mapped in accordance with the vegetation condition rating scale for the South West and Interzone Botanical Provinces of Western Australia (IBRA) (devised by Keighery (1994) and adapted by EPA (2016a)). The scale recognises the intactness of vegetation and consists of six rating levels. The vegetation condition rating scale is located in Appendix B.

Surveys for conservation significant flora

Prior to the field survey, information obtained from the desktop assessments (e.g. previous surveys, aerial photography, geology, soils and topography data, EPBC Act PMST (DotEE 2018), TPFL, *NatureMap* (DBCA 2018) and the WAHERB databases search results) were reviewed to determine conservation significant flora taxa potentially present within the study area. Additionally, ecological information (e.g. habitat, associated flora taxa and phenology) was sourced from *FloraBase* (WA Herbarium 1998–) to provide further details.

Potential habitats and locations of previous records were searched by walking transects spaced approximately 100 metres (m) apart across the study area and extended study area. Locations within the survey area with differing hydrology, fire or disturbance history to the surrounding areas were also searched where identified. Where individuals were identified, the location and number of plants present were recorded using handheld GPS units. When conservation significant flora were recorded, fine scale transects and meandering was performed.

Flora identification and nomenclature

Species well known to the survey botanist were identified in the field; all other species were collected and assigned a unique collection number to facilitate tracking. All specimens collected during the field assessment were dried and processed in accordance with the requirements of the WA Herbarium. Species were identified by the use of taxonomic literature, electronic keys and online electronic databases.

The conservation status of all recorded flora was compared against the current lists available on *FloraBase* (WA Herbarium 1998–) and the EPBC Act Threatened species database provided by DotEE (2018b). Nomenclature used in this report follows that used by the WA Herbarium as reported on *FloraBase* (WA Herbarium 1998–).

2.2.2 Fauna

Survey details and timing

Four field surveys were undertaken between August 2018 and February 2019. Field surveys consisted of three to 12 days and are demonstrated below in Table 2-4.

Table 2-4 Details of Surveys Undertaken

Field Trip	Dates	Task	Duration	Zoologist/Ecologist
1	28 August - 6 September 2018	Potential Black Cockatoo breeding trees, identification and mapping and monitor selected large hollows	8 days	Glen Gaikhorst Madi Roberts
2	29 October - 7 November 2018	Level 2 fauna trapping within the survey area and assessments within the extended survey area	10 days	Glen Gaikhorst Madi Roberts Brad Maryan Tim Moulds Robert Browne-Cooper
3	8 - 9 November 2018	Monitoring of identified potential Black Cockatoo breeding hollows	2 days	Glen Gaikhorst Madi Roberts Brad Maryan
4	15 - 17 January and 1 February 2019	Monitoring of identified potential Black Cockatoo breeding hollows	4 days	Madi Roberts Robert Browne-Cooper

Permits and ethics

A Regulation 17 licence to Take Fauna for Scientific Purposes was obtained from the DBCA prior to undertaking the fauna survey (Licence Number: 08-002838-1). The fauna survey (specifically trapping and animal handling) was undertaken in accordance with Standard Operating Procedures (SOPs) which were required to be followed under the conditions of GHD's fauna trapping permit. At the time of survey, compliance with these SOPs was accepted by DBCA as evidence of ethical treatment of animals.

Guiding documents

The fauna habitat and species survey was undertaken with reference to the EPA *Technical Guidance – Sampling methods for terrestrial vertebrate fauna* (EPA 2016b) and *Technical Guidance – Terrestrial Fauna Surveys* (EPA 2016c). The black cockatoo species habitat assessment was conducted in accordance with the EPBC Act referral guidelines 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*, (Department of Sustainability, Environment, Water, Populations, and Communities (DSEWPaC 2012).

Habitat assessment

A field data checklist was used to document the type, condition and extent of habitats within the survey area. The following information was collected:

- Habitat structure (e.g. vegetation type, presence/absence of structural layers such as ground cover and mid storey)
- Presence/absence of refuge including: density of ground covers, fallen timber, hollow-bearing trees and stags and rocks/boulder piles, and the type and extent of each refuge
- Presence/absence of waterways including type, extent and habitat quality within waterways
- Location of the habitat within the survey area in comparison to the habitat within the surrounding landscape

- Habitat connectivity and identification of wildlife corridors within and immediately adjacent to the survey area
- Current land use and disturbance history
- Identification and evaluation of key habitat features and types identified during the desktop assessment relevant to fauna of conservation significance
- Evaluation of the Likelihood of Occurrence of conservation significant fauna within the habitat (based on presence if suitable habitat and observations)
- A representative photograph of each habitat type.

Trapping program

Trapping for terrestrial fauna was undertaken using a series of standardised systematic trapping quadrat sites comprising pit-fall traps, Elliott box traps, cage traps and funnel traps within the survey area. Details of each trap type used are provided below. A total of nine quadrats were used throughout the survey area and each quadrat was systematically surveyed (trapped) for 9 to 11 nights. Trapping locations are depicted in Figure 9, Appendix A.

Pit-trap with drift fence

Seven pit-traps were established at each quadrat within the survey area. Pit-traps comprised of 20 litre plastic buckets (30 centimetre (cm) diameter, 40 cm deep) at each quadrat. A 50 metre (m) long flywire drift fence (30 cm high) bisected the pits; directing fauna into them. Pits were spaced at seven meter intervals along the fence. Soil and an egg carton were placed within each pit to provide shade and protection for captured animals.

Funnel traps

Ten funnel traps were used along each drift fence. Traps were placed such that animals were directed into them from the drift fence in between the pit traps. Funnel traps were covered with insulating materials to minimise heat or cold exposure to animals.

Elliott box traps

Ten Elliott box traps were used at each quadrat site. Traps were placed approximately ten metres apart and baited with universal bait (a mixture of peanut butter, rolled oats and sardines). Elliott traps were located within shady areas or covered with vegetation to minimise heat exposure to captured animals. A single line of 10 Elliott traps was used per site, positioned 50 m on one side of (and parallel to) the drift fence.

Cage traps

Two cage traps were located at each quadrat site. These traps were placed at each end of the line of Elliott traps. Cage traps were baited with universal bait. Additionally two extra quadrats of only cage traps were placed down the eastern and western flank of the road alignments adjoining Neerabup National Park. Each line had 10 cages that were placed at 200 m intervals.

Avifauna

Avifauna surveys were undertaken at each of the quadrat sites. Each survey comprised of a 20 minute census of birds within an unbounded 2 ha area, which is the standard method used by Birds Australia for the Bird Atlas project. Birds detected visually (using binoculars) and/or aurally over a 20 minute period were recorded. Numbers of each species observed were also recorded.

All systematic bird surveys were undertaken within four hours of dawn or two hours of dusk, as these are the times of day when birds are most active. In addition to systematic surveys, observations of birds were also made opportunistically.

Camera traps

Eighteen motion sensor cameras (Reconyx-Hyperfire) were deployed for a period of at least 29 to 32 nights within the survey area (6) and extended survey areas (12). Cameras were positioned in areas where potentially significant species might be recorded i.e. hollow logs or utilising species access tracks. Cameras were baited with sardines and or universal animal bait to attract fauna species within the survey area. For each camera location the time and date deployed and recovered, and the GPS coordinates were recorded (Table 2-5). Camera locations are depicted in Figure 9, Appendix A. Data from the cameras were downloaded to a computer and analysed for the presence of animals following the field survey.

Table 2-5 Camera trap locations

Camera number	Survey Location	Habitat type	Location		Nights deployed
			Easting	Northing	
Camera g	Survey area	<i>Banksia</i> Woodland	377609.82	6500724.49	32
Camera ghd1	Extended	<i>Banksia</i> Woodland	377074.54	6501227.22	31
Camera sg6	Extended	Tuart Woodland	379153.37	6499675.77	31
Camera sg7	Extended	Tuart Woodland	379470.44	6499310.65	31
Camera 3	Extended	Tuart Woodland	379674.28	6498822.93	31
Camera sg5	Extended	Tuart Woodland	378143.34	6500692.55	31
Camera sg10	Survey area	Jarraah Woodland	377778.52	6502123.85	31
Camera ghd13	Survey area	Jarraah Woodland	377950.03	6500424.86	31
Camera ghdc	Extended	<i>Banksia</i> Woodland	378067.7	6500170.64	31
Camera r14	Extended	Jarraah Woodland	378646.59	6499205.03	31
Camera ghd4	Extended	<i>Banksia</i> Woodland	378280.43	6499043.31	31
Camera sg4	Survey area	<i>B. sessilis</i> shrubland	378618.85	6498051.55	31
Camera 11	Extended	<i>Banksia</i> Woodland	379031.95	6497731.45	29
Camera 18	Extended	<i>Banksia</i> Woodland	379457.26	6497963.12	29
Camera r5	Extended	<i>Banksia</i> Woodland	379992.08	6496216.59	29
Camera 0	Survey area	<i>Banksia</i> Woodland	378662.32	6497741.35	29
Camera 6	Survey area	<i>B. sessilis</i> shrubland	380010.39	6497456.45	29
Camera sg1	Extended	Tuart Woodland	380307.84	6496396.70	29
Total					547

Bat Surveys

Bat Detectors (SM2 and SM4 Songmeters) were deployed at 14 survey location for either one or two nights. Survey locations were in both the survey area (10) and extended survey area (4). Bat detectors were positioned in areas where bat species might be recorded i.e. utilising water bodies, fly ways or tracks. Bat detectors were set to record from 25 minutes pre-dusk to 25 minutes post-dawn. For each detector the time and date deployed and recovered, and the GPS coordinates were recorded (Table 2-6). Bat detector locations are shown in Figure 9, Appendix A.

Data from the bat detectors were downloaded to a computer and analysed for the presence of animals following the field survey. Data from the detectors was assessed by Glen Gaikhorst for the presence of bat species.

Table 2-6 Bat Detector locations

Bat detector sites	Survey Location	Habitat type	Location		Nights deployed
			Easting	Northing	
Site 1	Survey area	<i>Banksia</i> Woodland	377698.60	6500541.92	2
Site 2	Survey area	Tuart Woodland	376925.67	6500879.96	2
Site 3	Survey area	Mixed shrubland	376008.51	6501090.86	2
Site 4	Survey area	<i>Banksia</i> Woodland	377686.15	6500159.61	2
Site 5	Survey area	Jarraah Woodland	378020.15	6499012.11	2
Site 6	Survey area	Mixed shrubland	378202.07	6498581.61	2
Site 7	Survey area	<i>Banksia</i> Woodland	379974.29	6495476.75	2
Site 8	Survey area	Tuart Woodland	379477.00	6498464.71	2
Site 9	Survey area	<i>Banksia</i> Woodland	378605.75	6499807.78	2
Nth Wanneroo Rd	Survey area	Jarraah Woodland	377785.74	6502093.89	2
Lake 1	Extended	Tuart Woodland	379273.83	6499443.02	2
Lake 2	Extended	Tuart Woodland	379560.46	6499250.73	1
South Track Neerabup	Extended	<i>Banksia</i> Woodland	380211.31	6495792.11	1
Central track Neerabup	Extended	<i>Banksia</i> Woodland	378444.66	6499214.09	1
Total					25

Other Searches

Rare and threatened species may have a patchy, disparate distribution through landscapes. To provide the best opportunity to determine the presence and relative prevalence of these species, this survey employed a variety of sampling methods. The systematic sampling was applied throughout the trapping program with additional sampling methods also applied at these sites. Furthermore, other areas that were not assessed through the systematic trapping effort were also surveyed using non-systematic techniques.

Diurnal searching

Each trapping site and supplementary areas was surveyed within the survey area (14 sites). Additional survey effort was undertaken within the extended survey area of 12 sites. Surveys comprised of searching the ground layer (overturning logs, rocks and leaf litter) and low vegetation (under bark and in tree stumps) and recording all individuals of amphibians, reptiles, and mammals. Species presence was also determined via secondary evidence, in the form of scats, tracks, feathers, burrows and remains. A minimum of one hour was spent at each site including the general area around it.

Nocturnal searching

Spot lighting was undertaken to locate nocturnal species that may otherwise remain undetected using other survey techniques. Hand held or head mounted spotlights were used for a minimum of one hour at each trapping line and within the general area.

Opportunistic observations

Opportunistic observations involve the recording of fauna taxa (physical presence and/or signs of presence) spatially throughout the Project Area. Opportunistic observations include physical observations (sighting or hearing fauna), and indirect evidence (scats, tracks, diggings, nests, feathers, bones, pellets) which indicate the current or recent activity of a species. Wherever possible, numbers of individuals, microhabitat use and other relevant information was recorded.

Opportunistic observations were recorded outside of the diurnal, nocturnal or general trap site surveys (for example when driving, walking to a site, checking camera traps and bat detectors).

Targeted Black Cockatoo habitat assessment

A Black Cockatoo habitat assessment (for Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo) was undertaken for the survey area to assess the presence, quality and extent of habitat. The assessment involved visual and aural assessment of the survey area, identifying breeding habitat (presence/absence of actual and potential breeding trees), foraging habitat, roosting areas, current activity and any other signs of use by Black Cockatoos. For the purpose of this assessment, the DSEWPaC (2012) Black Cockatoo referral guidelines were used to define breeding, foraging and night roosting habitat.

The Black Cockatoo habitat assessment method followed with the survey area and extended survey area varied:

- Survey area - Breeding habitat was identified within the survey area by identifying, recording and marking each potentially suitable cockatoo breeding tree (based on Diameter Breast Height (DBH) suitability) with a differential GPS. For each breeding tree, details of the tree species, size and number of hollows observed, evidence of use and any other significant observations were recorded. Where trees were recorded to have a suitable large hollow that could be used or had signs of being used, these trees were selected for continued monitoring in August 2018, November 2018 and January/February 2019. The monitoring involved visiting each tree with suitable hollows and visually inspecting for observations for presence, use and hollow persistence. Additionally each hollow up to 12 meters high was inspected for nesting Black Cockatoos with a Pole View Camera (Nestview Pole Camera NV4 – Faunatech).
- Extended survey area - Additionally within the extended survey area 29 plots of 0.25 ha (50 x 50 m) survey tree plots were undertaken, recording all potential Black Cockatoo trees within the bound area. Breeding habitat can then be extrapolated using averaged results from these plot surveys throughout the broader Neerabup National Park. Within each plot all potential Black Cockatoo breeding habitat was recorded according to the presence of suitable breeding trees (including the presence and size of hollow entrances).

Information collected during the field survey included:

- Foraging habitat - the location and extent of suitable Black Cockatoo species foraging habitat was identified and mapped for the survey area and extended survey area, based on the vegetation associations and presence/absence of known foraging species. During the field surveys any direct or indirect evidence of foraging by Black Cockatoos was recorded via GPS.
- Breeding habitat - suitable breeding habitat for Black Cockatoos is defined by DSEWPaC (2012) as trees of species known to support breeding within the range of the species which either have a suitable nest hollow or are of a suitable Diameter at Breast Height (DBH) to develop a nest hollow. For most tree species, suitable DBH is 500 mm. For Salmon Gum (*Eucalyptus salmonophloia*) and Wandoo (*Eucalyptus wandoo*), suitable DBH is 300 mm (DSEWPaC 2012). On average, Carnaby's Black Cockatoos are known to nest in hollows with an entrance diameter greater than 20 - 30 cm (Johnstone and Storr 1998; Groom 2011). While the Forrest Red-tailed Black Cockatoo is known to nest in hollows with an entrance of greater than 12 cm (Johnstone and Storr 1998). Therefore, during the field survey hollows were graded into small (up to 6 cm) Medium (6 to 10 cm) and Large (10+ cm).

- Night roosting habitat - suitable roosting habitat is defined by DSEWPaC (2012). Suitable roosting habitat was identified based on the presence of suitable tall trees, evidence of roosting (feathers, twig clips etc.) and proximity of known roosting sites in the survey area and extended survey area.
- Opportunistic observations - both visual and aural observations of Black Cockatoos within the survey area and surrounding region were noted during the survey. This information was used to calculate the amount of foraging habitat, potential breeding habitat and night roosting habitat within the survey area. Any area containing known foraging species or potential nesting trees was considered as habitat for Black Cockatoos.

This information was used to calculate the amount of foraging habitat, potential breeding habitat and night roosting habitat within the survey area and a guide to the habitats available within the extended survey area.

Species Identification and nomenclature

Identification of fauna species was made in the field using available field guides and electronic guides (Table 2-7). Where identification was not possible, photographs of specimens were collected to be later identified.

Table 2-7 Fauna references

Fauna group	Field guide
Mammals	Menkhorst and Knight (2004), Van Dyck and Strahan (2008)
Bats	Churchill (2008), Menkhorst and Knight (2010)
Birds	Morcombe (2004), Storr (1991)
Reptiles	Wilson and Swan (2017), Storr et al. (1999), Storr et. al. (2002)
Amphibians	Tyler and Doughty (2009)

Nomenclature used in this report follows that used by the WA Museum as reported on *NatureMap*. This nomenclature is deemed the most up-to-date species information for WA fauna, with the exception of birds, which follows Christidis and Boles (2008).

Survey effort

Survey effort is described as the amount and type of survey that is undertaken during an assessment. Each of the nine trapping sites was sampled for 9 to 11 consecutive trap-nights including bucket, cage, funnel and Elliott traps. Two additional cage trap sites ran for five nights. Bat acoustic recorders were set for 18 nights, 60 to 120 minutes of night search, 60 to 300 minutes of active search and 60 to 80 minutes of bird assessments undertaken at each site.

The total trapping effort consisted of 2690 trap-nights (total trap effort), 640 minutes of bird assessments, 1500 minutes of active searches, 730 minutes of night searches, 25 nights of Bat detection and 547 camera nights. Table 2-8 shows the survey effort undertaken for this assessment.

Table 2-8 Survey Effort Undertaken

Fauna Tapping			Location	Nights	Elliot traps		Pit Traps		Cage Traps		Funnel traps		Bat Detector	Birds search	Active search	Night search
Sites	Easting	Northing	(area)	Open	(total)		(total)		(total)		(total)		(nights)	(minutes)	(minutes)	(minutes)
Trap line 1	377626.33	6500532.27	Survey	10	10	100	7	70	2	20	10	100	2	60	120	90
Trap line 2	377129.98	6500620.91	Survey	10	10	100	7	70	2	20	10	100	2	80	150	90
Trap line 3	376084.69	6501116.74	Survey	11	10	110	7	77	2	22	10	110	2	60	150	120
Trap line 4	377715.28	6500100.71	Survey	11	10	110	7	77	2	22	10	110	2	60	180	90
Trap line 5	378010.15	6499032.11	Survey	10	10	100	7	70	2	20	10	100	2	80	300	80
Trap line 6	378263.17	6498523.50	Survey	10	10	100	7	70	2	20	10	100	2	80	300	80
Trap line 7	379935.98	6495502.07	Survey	9	10	90	7	63	2	18	10	90	2	60	120	60
Trap line 8	379497.47	6498501.08	Survey	9	10	90	7	63	2	18	10	90	2	80	120	60
Trap line 9	378609.49	6499832.51	Survey	10	10	100	7	70	2	20	10	100	2	80	180	60
Cages 1	379253.31	6499065.05	Survey	5					8	40						
Cages 2	377945.56	6499108.53	Survey	5					8	40						
Search 1	377810.64	6501931.22	Survey												120	
Search 2	378364.84	6499101.05	Survey												60	
Search 3	378632.50	6497759.23	Survey												120	
Search 4	377810.59	6501933.16	Survey										2		120	
Search 5	379381.50	6499484.78	Extended												120	
Search 6	377699.81	6499546.77	Extended												120	
Search 7	377660.42	6500395.10	Extended												120	
Search 8	378137.06	6500176.74	Extended												120	
Search 9	379408.86	6499710.76	Extended										2		60	
Search 10	379499.59	6499424.01	Extended										1		60	
Search 11	380044.65	6495611.11	Survey										1		120	
Search 12	380221.43	6495769.97	Extended										1		60	
Search 13	379319.19	6498089.71	Extended												60	
Search 14	376881.75	6501456.16	Extended												60	
Search 15	376716.89	6501347.29	Extended												60	
Search 16	376076.43	6501489.69	Extended												60	
Search 17	375829.81	6500689.56	Extended												60	
				TOTAL		900		630		260		900	25	640	1500	730

Comparison of species recorded to other surveys

GHD has undertaken Level 1 and Level 2 surveys of the Neerabup National Park in 2013 focusing on the alignment of the now operational Neerabup Road (GHD 2013a, 2014a). The Department of Parks and Wildlife (DPaW) (now DBCA) undertook a fauna survey in conjunction with this survey but focused on areas around Hester Ave (DPaW 2013). Conservation and Land Management (CALM) (now DBCA) in 1993 undertook a Level 2 survey of the Water reserve in the southern section of the Neerabup National Park (CALM 1993). Brad Maryan undertook herpetofauna assessments of Pipidiny Road from 1996 to 2004 for research on burrowing snake research (Maryan, B. Pers comm). The Metropolitan Road Infrastructure Alliance (MRIA 2018) undertook fauna clearance trapping along Wanneroo Road over approximately a 12 month period during 2017/2018. These reports and data have been reviewed and included in the report.

Fauna data analysis

Species accumulation

The number and type of species trapped each day was recorded and a species accumulation curve was created for the survey area using PRIMER v6 (Clarke and Gorley 2006). The species accumulation curve represent the successfulness of the trapping program for its duration. Typically, the longer the trapping program the more complete the representation of species sampled per trapping location or habitat type. Accumulation curves should show “levelling” of the groups species counts prior to the completion of the survey. Many limitations can influence the results of a curve and should be considered when interpreting the curve shape, and should be used as a guide to the effectiveness of systematic trapping methods. One curve was created for this survey within the survey area.

The data was run through Primer v6 against 8 existing models, these models are:

- Sobs - Curve of observed species counts
- Chao 1 - Chao's estimator based on number of rare species
- Chao 2 - Chao's estimator using just presence-absence data
- Jackknife 1 - Jackknife estimator based on species that only occur in one sample
- Jackknife 2 - Second order jackknife estimator
- Bootstrap - Bootstrap estimator based on proportion of quadrats containing each species
- MM (Michaelis-Menton) - Curve fitted to observed Sobs curve
- UGE - Calculated species accumulation curve based on (Ugland, Gray and Ellingsen 2003).

The best fit model was selected and discussed.

Scatter Plots

PRIMER v6 (Clarke and Gorley 2006) was used to examine the similarity between trapping sites using collected data. A matrix was created of all species (based on abundance) recorded at each trap site. The dissimilarity between sites was determined using the Bray-Curtis measure and the Resemblance function in PRIMER. A Cluster analysis (using Agglomerative Hierarchical Clustering technique) based on group average was undertaken using the Bray-Curtis similarity matrix and results presented as a dendrogram. In addition, a nonmetric MDS was undertaken using the Bray-Curtis similarity matrix and results presented as a two dimensional scatter plot. A factor was added to the output to define trap sites by habitat type.

2.3 Limitations

2.3.1 Desktop limitations

The EPBC Act PMST is based on bioclimatic modelling for the potential presence of species. As such, this does not represent actual records of the species within the area. The records from the DBCA searches of Threatened fauna provide more accurate information for the general area and local occurrence. However, some collection, sighting or trapping records cannot be dated and often misrepresent the current range of Threatened species.

2.3.2 Field survey limitations

The EPA (2016a, b) states that flora and fauna survey reports for environmental impact assessment in WA should contain a section describing the limitations of the survey methods used. The limitations and constraints associated with this field survey are discussed in Table 2-9.

Table 2-9 Survey Limitations

Aspect	Constraint	Comment
Sources of information and availability of contextual information.	Nil	Adequate information is available for the survey area, this includes: <ul style="list-style-type: none"> • Broad scale (1:250,000) mapping by Beard (1979) and digitised by Shepherd <i>et al.</i> (2002) • Vegetation mapping by Heddle <i>et al.</i> 1980 and Webb (DBCA) (2016) • Regional biogeography (Mitchell <i>et al.</i> 2002).
Scope (what life forms were sampled etc.)	Nil	Vascular flora and terrestrial vertebrate fauna were sampled during the survey. Non-vascular flora, invertebrate and aquatic fauna were not surveyed.
Proportion of flora collected and identified (based on sampling, timing and intensity) Proportion of fauna identified, recorded and/or collected	Nil	The vegetation survey was a single season survey and was undertaken over multiple visits between September and November 2018 (Spring). An additional targeted survey was undertaken in December (summer) targeting conservation significant flora. Spring is considered the most optimal time to undertake vegetation surveys in the Swan Coastal Plain bioregion. The vegetation survey was a broad scale and targeted assessment, undertaken to identify and describe the dominant vegetation units and map conservation significant flora. The fauna survey (Level 2) was undertaken in October/November 2018 and Black Cockatoo assessments undertaken in August 2018, November 2018 and January/February 2019. The Level 2 survey was undertaken within the survey area with additional effort (of active searches, cameras and bat detectors) within the extended survey area. Moderate to high numbers of fauna were identified during the survey period and the Black Cockatoo assessments were undertaken throughout the breeding season.
Flora determination	Minor	Flora determination was undertaken by GHD ecologists in the field and at the WA Herbarium. Three taxa could only be identified to family level only, fifteen taxa could be identified to genus level only, and four taxon could be tentatively identified to species level, due to lack of flowering and/or fruiting material required for identification. None of these species were considered to be potential conservation significant flora. The taxonomy and conservation status of the WA flora is dynamic. This report was prepared with reliance on taxonomy and conservation status current at the time of report development, but it should be noted this may change in response to ongoing research and review of the International Union for Conservation Nature criteria.
Completeness and further work which might be needed (e.g. was the relevant area fully surveyed)	Minor	The majority of the survey area was accessible and was accessed by foot or by vehicle. Some sections of the survey area were not accessible as they were fenced off and/or occurred on private property. The Public Transport Authority (PTA) rail corridor is completely fenced off and access prohibited, therefore observations were made at the fenced boundary. For the remainder of the survey area access tracks created as a result of infrastructure development (road, water and electrical services) and fire breaks, allowed access to the majority of the survey area.
Mapping reliability	Nil	The vegetation was mapped using high-resolution ESRI aerial imagery obtained from Landgate, topographical features, previous broad scale mapping (Beard 1979) and field data.

Aspect	Constraint	Comment
		Data was recorded in the field using hand-held GPS tools (e.g. Nomad Juno and Garmin GPS). Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. The Garmin GPS units used for this survey are accurate to within ± 5 metres on average. Therefore the data points consisting of coordinates recorded from the GPS may contain inaccuracies.
Timing/weather/season/cycle	Minor	<p>The field surveys were conducted in August, October/November and January 2019. In the three months prior to the flora survey (June to August), Perth weather station (Bureau of Meteorology (BoM) 2019) recorded a total of 411 mm of rainfall. This rainfall total is slightly lower than the long term average for the same period (June-August; 430.6 mm) (BoM 2019).</p> <p>The weather conditions recorded during the survey are within the observed climatic conditions previously recorded for the months of August, October/November and January 2019 (years 1899 to 2019) at the Perth weather station (BoM 2019). The weather conditions recorded during the survey were considered unlikely to have impacted the survey results.</p> <p>The survey timings were considered appropriate for the flora and fauna field surveys.</p>
Disturbances (e.g. fire, flood, accidental human intervention)	Minor	<p>Much of the survey area has been subjected to historical disturbance events (e.g. clearing, rubbish dumping); however, these disturbances did not impact the survey.</p> <p>For the fauna surveys nocturnal surveys were difficult due to increased undesirable activity. During one night a suspected stolen car continually drove past while trying to survey for fauna. Due to the inherit risk the night survey was cut short. The vehicle traversed the site and was found burnt out in the morning. Illegal activity (rubbish dumping) and public disturbance occurred almost daily.</p>
Resources	Nil	Adequate resources were employed during the field survey. Seven staff and 97 person days were spent undertaking the survey using dedicated botanists and zoologists.
Access restrictions	Nil	No access problems were encountered during the survey. The majority of the survey area was accessed on foot during the survey. Access to the fenced off rail corridor and private properties was prohibited.
Experience levels	Nil	The ecologists who executed the survey were practitioners suitably qualified in their respective fields. Angela Benkovic and Erin Lynch are Ecologists (botanist) with over 10 years' experience in undertaking ecological surveys in Western Australia. Glen Gaikhorst (Zoologist) is an Ecologist with over 24 years' experience in undertaking ecological surveys in Western Australia. Glen was supported by Brad Maryan, Robert Browne Cooper, Tim Moulds and Madi Roberts.

3. Desktop assessment

3.1 Regional biogeography

The study area is situated in the South West Botanical Province of Western Australia (Beard 1990) within the Swan Coastal Plain bioregion and Perth sub-region described by the Interim Biogeographic Regionalisation of Australia (IBRA) (DotEE 2018c).

The Swan Coastal Plain bioregion is a low lying coastal plain, mainly covered with woodlands. The Perth sub-region is characterised by colluvial and aeolian sands, alluvial river flats and coastal limestone. Heath and/or Tuart woodlands occur on limestone, Banksia and Jarrah-Banksia woodlands on Quaternary marine dunes of various ages, and Marri on Colluvial and alluvials. The region also includes a complex series of seasonal wetlands (Mitchell et al. 2002).

3.2 Hydrology

3.2.1 Groundwater

The Department of Water and Environmental Regulation Perth Groundwater Map indicates the study area is located in the Perth Groundwater Area under the *Rights in Water and Irrigation Act 1914* and the Perth Coastal and Gwelup Underground Pollution Control Area public drinking water source area (Priority 3 Protection Zone) proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* (Figure 4, Appendix A). Priority 3 areas are declared over land where water supply sources need to coexist with other land uses such as residential, commercial and light industrial developments.

3.2.2 Surface water

There are no wetlands, watercourses or drainage lines located within the survey area. The Geomorphic Wetlands Swan Coastal Plain dataset (Hill et al. 1996) identified 13 wetlands within the study area, none of these are located within or intersect the survey area (Table 3-1 and Figure 4, Appendix A). One geomorphic wetland, Lake Nowergup, is located approximately 200 m east of the Wanneroo Road upgrade survey area, within the extended survey area.

No wetlands of national or international importance (Ramsar) are present within the study area (DotEE 2018a).

Table 3-1 Geomorphic wetlands mapped within the study area

Name	Unique feature identifier	Category	Location relative to survey area
Neerabup Lake	8019	Resource Enhancement	600 m east of the southern end of the Wanneroo Road upgrade survey area
unknown	8018	Multiple Use	330 m east of the southern end of the Wanneroo Road upgrade survey area
unknown	8017	Resource Enhancement	580 m east of the southern end of the Wanneroo Road upgrade survey area
Camel Swamp	7938	Resource Enhancement	3.5 km east of the survey area
Nowergup Lake	8021	Conservation	200 m west of the Wanneroo Road upgrade survey area within the extended survey area

Name	Unique feature identifier	Category	Location relative to survey area
unknown	8020	Resource Enhancement	620 m east of the Wanneroo Road upgrade survey area
Carabooda Lake	8009	Resource Enhancement	200 m east of the northern end of the Wanneroo Road upgrade survey area
Beonaddy Swamp	8016	Resource Enhancement	2.9 km north of the survey area
Coogee Swamp	8015	Resource Enhancement	2.2 km north of the survey area
Pippidinny Swamp	8012	Conservation	3.8 km north of the survey area
unknown	8014	Multiple Use	2.5 km north of the survey area
Mindarie Lake	8013	Multiple Use	2.9 km north of the survey area
Wilgarup Lake	8022	Conservation	4.2 km north of the survey area

3.3 Landforms and soils

The SWA is comprised of five major geomorphological units, which lie more or less parallel to the coast. These geomorphological units are the Quindalup, Spearwood and Bassendean Dunes, the Pinjarra Plain and the Ridge Hill Shelf (McArthur and Bettenay 1960, Churchwood and McArthur 1980). The majority of the survey areas lie within the Spearwood Dunes, with the western end of Romeo Road occurring within the Quindalup Dunes. These land systems are broadly described as follows:

- Spearwood Dunes: Pleistocene and aeolian sands overlying Tamala limestone. Low dunes and swales of shallow pale grey sands over yellow sands are characteristic of the Spearwood system. Wetlands are associated with peats and carbonate sands, occasionally with clay overlaying sands
- Quindalup Dunes: Aeolian origin and are the youngest of the dune systems on the SCP. This system is characterised by large parabolic dunes north of the Swan River with broad to narrow swales and sand sheets between the dunes.

Churchwood and McArthur (1980) identified the soils within the survey areas as consisting of the following soil units:

- Cottesloe: Low hilly landscape with shallow brown sands over limestone, much exposed limestone
- Herdsman: Peaty swamps associated with Bassendean and Karrakatta units.

The Department of Primary Industries and Regional Development (previously Department of Agriculture and Food Western Australia (DAFWA)) soil mapping indicates there are five different soil subsystems within the survey area (DAFWA 2007). A description of the soil types present is provided in Table 3-2.

The soil types listed in Table 3-2 are also mapped to occur in the extended survey area, with the addition of 211SpW_SWAMP (Spearwood wet, swamp phase) and 211Qu_Qp (Quindalup South deep sand flat phase) (DAFWA 2007).

Table 3-2 Soil descriptions occurring within the survey area (DAFWA 2007)

Soil ID	Name	Description
211Sp_Kls	Karrakatta shallow soils Phase	Low hills and ridges. Bare limestone or shallow siliceous or calcareous sand over limestone. Dense low shrub dominated by <i>Dryandra sessilis</i> , <i>Melaleuca huegelii</i> and species of <i>Grevillea</i> .
211Sp_Ky	Karrakatta sand yellow phase	Low hilly to gently undulating terrain. Yellow sand over limestone at 1-2 m. <i>Banksia</i> spp. woodland with scattered emergent <i>E. gomphocephala</i> and <i>E. marginata</i> and a dense shrub layer
211Sp_Sp	Spearwood sand phase	Irregular banks of karst depressions. Some limestone outcrop. Shallow brown sands. <i>Banksia</i> spp. woodland with emergent <i>E. gomphocephala</i> and <i>E. marginata</i> ; dense shrub layer
211Qu_Q2	Quindalup South second dune phase	The second phase. A complex pattern of dunes with moderate relief. Calcareous sands have organic staining to about 20 centimetres (cm), passing into pale brown sand; some cementation below 1 m.
211Qu_Qp	Quindalup South deep sand flat phase	Undulating landscapes with deep calcareous sands overlying limestone. Soils have dark grey-brown sand to about 50 cm and then pale brown sand. Remnants of hummocks are often present.

3.4 Land use

3.4.1 Conservation reserves and estates

There are four conservation reserves located within the study area (Figure 3, Appendix A). Of these, two of the reserves are located within the boundaries of the survey areas. Neerabup National Park (Class A Reserve, R 27575) is located along the entire eastern boundary of the proposed Mitchell Freeway extension and extends east to the proposed Wanneroo Road upgrade survey area. The proposed Wanneroo Road upgrade survey area intersects Neerabup Nature Reserve (Class A Nature Reserve, R 24581), which is situated on the eastern side of Wanneroo Road.

There are 11 Bush Forever Sites located within the study area. Of these, the following two Bush Forever sites occur within the survey areas (Government of Western Australia 2000) (Figure 3, Appendix A).

- Bush Forever Site 383 – Neerabup National Park, Lake Nowergup Nature Reserve and adjacent bushland (361.42 ha occurs within the survey area)
- Bush Forever Site 130 – Link between Yanchep and Neerabup National Parks (2.66 ha occurs within the survey area).

3.4.2 Environmentally Sensitive Areas

The majority of the survey areas are classified as an Environmentally Sensitive Area (ESA) (Figure 3, Appendix A). The ESAs mapped over the survey areas are likely to be associated with the Bush Forever Sites, National Park and TECs.

3.4.3 Regional Ecological linkages

Two Regional Ecological Linkages transect the survey areas (Figure 3, Appendix A). Greenways linkage I.D number 6 and I.D number 8 (Tingay, Alan and Associates 1998) are part of a regionally significant contiguous bushland/wetland linkage (GoWA 2000). Greenways linkage I.D number 6 links Neerabup National Park (Bush Forever Site 383) to Lake Joondalup (Bush Forever Site 299) in the south and Yanchep and Neerabup National Parks (Bush Forever Site 130) in the north. Greenways linkage I.D number 8 provides an eastern linkage between Neerabup National Park (Bush Forever Site 383) and Hopkins Road Bushland, Nowergup (Bush Forever Site 190). Linkage I.D number 8 already has a significant barrier in the form of Wanneroo Road that affects the continuity of this corridor. Linkage I.D number 6 is interrupted by Hester Avenue and Neerabup Road to the south, however fauna underpasses have been constructed to reduce potential impacts to fauna and provide ecological continuity.

3.5 Vegetation and Flora

3.5.1 Broad vegetation mapping and extents

Vegetation associations

Broad scale (1:250,000) pre-European vegetation mapping of the study area has been completed by Beard (1979) at an association level. The mapping indicates the survey areas intersects three vegetation associations:

- Low woodland; *Banksia* (association 949) (majority of the Mitchell Freeway extension section of the survey area)
- Medium woodland; Tuart (association 998) (majority of the Wanneroo Road upgrade section of the survey area)
- Mosaic: shrublands; *Acacia lasiocarpa* and *Melaleuca systena* heath/ shrublands; *A. rostellifera* and *A. cyclops* thicket (association 1007) (north-western section of the survey area, along Romeo Road)

The extended survey area also intersects association 51: Sedgeland; reed swamps, occasionally with heath.

The pre-European mapping has been adapted and digitised by Shepherd *et al.* (2002). The extent of the vegetation associations have been determined by the state-wide vegetation remaining extent calculations maintained by the DBCA (current as of March 2019 –Government of Australia (GoWA) 2018b). As shown in Table 3-3, the current extents of all vegetation associations that intersect the survey area are above 30 % of their pre-European extents at the State, IBRA bioregion, IBRA subregion and Local Government Authority (LGA) levels.

Vegetation complexes

Regional vegetation complex mapping has been completed by Heddle *et al.* (1980) with updates from Webb *et al.* (2016) based on major landform boundaries within the SWA and forested region of south-west Western Australia. The mapping indicates two vegetation complexes are present within the survey area:

- Cottesloe Complex - Central and South: Consists of a mosaic of woodland of *Eucalyptus gomphocephala* (Tuart) and open forest of *E. gomphocephala* – *E. marginata* (Jarrah) – *Corymbia calophylla* (Marri); closed heath on the limestone outcrops (majority of survey area)
- Quindalup Complex: is restricted to the coastal dunes and can be subdivided mainly into two alliances. The strand and fore dune alliance contain *Angianthus cunninghamii*,

Trachyandra divaricatum, *Arctotheca populifolia*, *Atriplex isatidea*, *Cakile maritima*, *Leucophyta brownii*, *Carpobrotus virescens*, *Pelargonium capitatum*, *Senecio lautus*, *Actites megalocarpus*, *Spinifex longifolius*, *Tetragonia implexicoma*, *T. decumbens*. The mobile and stable dune alliance contains *Acacia cyclops*, *Anthocercis littorea*, *Lepidosperma gladiatum*, *Myoporum insulare*, *Nitraria billardiarei*, *Olearia axillaris*, *Scaevola crassifolia*, *S. nitida*, *Spyridium globulosum*, *Westringia rigida* and *Wilsonia backhousei*. The vegetation differs in its physiognomy and species composition from one place to another because of the variations in the dune environment caused by edaphic and topographical factors and the degree of shelter from salt-laden winds (McArthur 1957; Smith 1957). The low closed-forest of *Melaleuca lanceolata*, *Callitris preissii* is restricted to small localised pockets (Table 3.5). This formation was once more widespread along the coast (Baird 1958, Seddon 1972). Other local variations include remnant occurrences of *E. foecunda*, *Pittosporum ligustrifolium*, *Santalum acuminatum*, *Exocarpos sparteus* and *Acacia rostellifera* (Seddon 1972). Within Geographe Bay a low closed Peppermint forest extends directly to the fore dune and is characterised by an understory of *Spyridium globulosum*, *Hibbertia cuneiformis*, *Acacia littorea*, *Pimelea argentea* and *Lepidosperma gladiatum*

One additional vegetation complex is mapped from the eastern extent of the extended survey area: Herdsman Complex: described as sedgelands and fringing woodland of *E. rudis*-*Melaleuca* spp.

GoWA (2018c) has assessed the vegetation complexes mapped by Heddlé *et al.* (1980) and Webb *et al.* (2016) against presumed pre-European extents within the SWA IBRA bioregion (Table 3-4) and LGA levels (

Table 3-5). These tables show the current extent of all the vegetation complexes within the survey area are above 30 % of their pre-European extents remaining within the SWA IBRA bioregion and the City of Wanneroo.

Swan Coastal Plain Floristic Studies

Floristic studies on the SWA include those completed by Gibson *et al.* (1994) and other unpublished data collected as part of the System 6 and Part System 1 Update program and from various sources (e.g. Weston *et al.* 1993, Griffin 1994, DEP 1996 and Keighery 1996). This data has been compiled into a dataset, referred to in this report as the SWA dataset. A search of the SWA dataset identified 10 FCTs that are known to occur within a 5 km buffer of the survey area (Table 3-6).

3.5.2 Conservation significant ecological communities

The EPBC Act PMST identified three EPBC Act-listed TECs potentially occurring within the study area. These TECs were also identified in a search of the DBCA TEC/PEC database along with one additional TEC and six PECs. Details of these communities are provided in Table 3-7. The extents of TEC and PEC buffers, where available, are presented in Figure 2, Appendix A.

Table 3-3 Extents of vegetation associations mapped within the survey area (GoWA 2018b)

Vegetation association	Scale	Pre-European extent (ha)	Current extent (ha)	Remaining (%)	Remaining within DBCA managed lands (%)	Hectares (ha) within the survey area	% of current extent within the survey area
949	State: WA	218,193.94	123,104.02	56.42	55.86	249.71	0.20
	IBRA bioregion: Swan Coastal Plain	209,983.26	120,287.93	57.28	56.40	249.71	0.21
	Sub-region: Perth	184,475.82	104,128.96	56.45	58.99	249.71	0.24
	LGA: City of Wanneroo	37,138.40	17,196.34	46.30	70.10	249.71	1.45
998	State: WA	51,015.33	18,492.63	36.25	48.68	142.43	0.77
	IBRA bioregion: Swan Coastal Plain	50,867.50	18,492.32	36.35	48.68	142.43	0.77
	Sub-region: Perth	50,867.50	18,492.32	36.35	48.68	142.43	0.77
	LGA: City of Wanneroo	4,635.30	2,787.40	60.13	52.75	142.43	5.11
1007	State: WA	30,407.75	20,691.11	68.05	14.75	7.83	0.04
	IBRA bioregion: Swan Coastal Plain	30,109.89	20,679.62	68.68	14.75	7.83	0.04
	Sub-region: Perth	30,109.89	20,679.62	68.68	14.75	7.83	0.04
	LGA: City of Wanneroo	8,058.91	4,830.52	59.94	1.94	7.83	0.16

Table 3-4 Extent of vegetation complexes on the SWA mapped within the survey area (GoWA 2018c)

Vegetation complex	Pre-European extent (ha)	Current extent (ha)	Remaining (%)	Remaining within DBCA managed lands (%)	Hectares (ha) within the survey area	% of current extent within the survey area
Cottesloe Complex – Central and South	45,299.61	14,567.87	32.16	14.58	385.02	2.64
Quindalup Complex	54,573.87	33,011.4	60.49	10.98	14.64	0.04

Table 3-5 Extent of vegetation complexes within the City of Wanneroo for the survey area (GoWA 2018c)

Vegetation complex	Pre-European extent (ha)	Current extent (ha)	Remaining (%)	Proportion of the vegetation complex within the the LGA (%)
Cottesloe Complex – Central and South	13,313.58	5,545.39	41.65	29.39
Quindalup Complex	8,818.26	5,352.77	60.70	16.16

Table 3-6 SWA dataset FCTs within the study area

FCT	Description
Seasonal wetlands	
19b	Woodlands over sedgeland in Holocene dune swales
Uplands centred on Spearwood Dunes	
24	Northern Spearwood shrublands and woodlands
26a	<i>Melaleuca huegelii</i> – <i>Melaleuca systema</i> shrublands on Limestone ridges
27	Species poor mallees and shrublands on Limestone
28	Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> – <i>Eucalyptus</i> woodlands
Uplands centred on Quindalup Dunes	
29a	Coastal shrublands on shallow soils
29b	<i>Acacia</i> shrublands on taller dunes
30b	Quindalup <i>Eucalyptus gomphocephala</i> and/or <i>Agonis flexuosa</i> woodlands
S11	Northern <i>Acacia rostellifera</i> – <i>Melaleuca systema</i> shrublands
S13	Northern <i>Olearia axillaris</i> – <i>Scaevola crassifolia</i> shrublands

Table 3-7 Threatened and Priority Ecological Communities identified within the study area

Community type	EPBC Act	BC Act/ DBCA	Description	Location from the survey area
Aquatic Root Mat Community in Caves of the Swan Coastal Plain	Endangered	Critically Endangered	The Aquatic Root Mat Community in Caves of the Swan Coastal Plain ecological community occurs in caves of the Swan Coastal Plain in southwest Western Australia. Known occurrences are in seven caves in Yanchep National Park. The habitat for the aquatic root mat community is within the seven individual caves, where there are cave streams, and the roots of tuart trees that extend into each of the caves and streams, plus the catchments for the streams that flow through the caves. This includes areas of the Gnangara mound catchment between the caves and the top of the mound, and the superficial water table that supplies the water to the cave-streams. Caves containing the aquatic root mat community occur where sandy soils underlie superficial limestone and where the waters of the Gnangara Mound seep through the	The northern extent of the survey area intersects the 5 km buffer of these cave systems.

Community type	EPBC Act	BC Act/ DBCA	Description	Location from the survey area
			sand to form a system of subterranean pools and streams, a few of which have been permanent in historical times (DotEE 2017).	
Woodlands over sedgeland in Holocene dune swales of the southern Swan Coastal Plain (SCP19b)	Endangered	Critically Endangered	The community occurs in linear damplands and occasionally sumplands, between Holocene dunes. Typical and common native species are the shrubs <i>Acacia rostellifera</i> , <i>A. saligna</i> , <i>Xanthorrhoea preissii</i> , the sedges <i>Baumea juncea</i> , <i>Ficinia nodosa</i> , <i>Lepidosperma gladiatum</i> , and the grass <i>Poa porphyroclados</i> . Several exotic weeds are found in this community but generally at low cover values. Two sub-groups of SCP19 have been identified as follows: <ul style="list-style-type: none"> Community type 19a is termed 'sedgeland in Holocene dune swales' and generally occurs in the younger swales. Community type 19b is termed 'woodlands over sedgeland in Holocene dune swales' and tends to occur in older swales. This subgroup has an overstorey of woodlands including <i>Eucalyptus gomphocephala</i>, <i>Melaleuca raphiophylla</i> and <i>Banksia littoralis</i>. 	Closest occurrence is 2.9 km north of the survey area.
Northern Spearwood shrublands and woodlands – (SCP24)*	Endangered TEC (part)	Priority 3	Heaths with scattered <i>Eucalyptus gomphocephala</i> occurring on deeper soils north from Woodman Point. Most sites occur on the Cottesloe unit of the Spearwood system. The heathlands in this group typically include <i>Banksia sessilis</i> , <i>Calothamnus quadrifidus</i> , and <i>Schoenus grandiflorus</i> (DBCA 2019)	Multiple occurrences within and surrounding the survey area.
<i>Melaleuca huegelii</i> - <i>Melaleuca systema</i> shrublands on limestone ridges (SCP26a)		Endangered	Species rich thickets, heaths or scrubs dominated by <i>Melaleuca huegelii</i> , <i>M. systema</i> , <i>Banksia sessilis</i> over <i>Grevillea preissii</i> , <i>Acacia lasiocarpa</i> and <i>Spyridium globulosum</i> , occurring on skeletal soil on ridge slopes and ridge tops. Broadly occurs on Spearwood Sands (Tamala Limestone) on large limestone ridges (Threatened Species Scientific Committee (TSSC) 2005)	Multiple occurrences within and surrounding the survey area.
Coastal shrublands on shallow sands, southern Swan Coastal Plain (SCP29a)		Priority 3	Mostly heaths on shallow sands over limestone close to the coast. No single dominant but important species include <i>Spyridium globulosum</i> , <i>Rhagodia baccata</i> and <i>Olearia axillaris</i> .	Closest occurrence is 4.2 km south west of the survey area.

Community type	EPBC Act	BC Act/ DBCA	Description	Location from the survey area
<i>Acacia</i> shrublands on taller dunes, southern Swan Coastal Plain (SCP29b)		Priority 3	Community is dominated by <i>Acacia</i> shrublands or mixed heaths on the larger dunes. This community stretches from Seabird to south of Mandurah. No consistent dominant but species such as <i>Acacia rostellifera</i> , <i>Acacia lasiocarpa</i> , and <i>Melaleuca systema</i> were important	Closest occurrence is 3.3 km south west of the survey area.
Quindalup <i>Eucalyptus gomphocephala</i> and / or <i>Agonis flexuosa</i> woodlands (SCP30b)**		Priority 3	This community is dominated by either Tuart or <i>Agonis flexuosa</i> . The presence of <i>Hibbertia cuneiformis</i> , <i>Geranium retrorsum</i> and <i>Dichondra repens</i> differentiate this group from other Quindalup community types. The type is found from the Leschenault Peninsular south to Busselton	Closest occurrence is approximately 4 km north of the survey area.
<i>Banksia</i> woodlands of the Swan Coastal Plain (TEC) <i>Banksia</i> dominated woodlands of the Swan Coastal Plain IBRA region (PEC)	Endangered	Priority 3	The ecological community is a woodland associated with the Swan Coastal Plain. A key diagnostic feature is a prominent tree layer of <i>Banksia</i> , with scattered eucalypts and other tree species often present among or emerging above the <i>Banksia</i> canopy. The understorey is a species rich mix of sclerophyllous shrubs, graminoids and forbs. The ecological community is characterised by a high endemism and considerable localised variation in species composition across its range (TSSC 2016).	Closest occurrences range from 3 to 4 km north and east of the survey area
Tuart (<i>Eucalyptus gomphocephala</i>) woodlands of the Swan Coastal Plain (PEC)		Priority 3	Mostly confined to Quindalup Dunes and Spearwood Dunes from Jurien Bay to the Sabina River, with outliers along some rivers. Tuart is the key dominant canopy species however Tuart communities comprise a variety of flora and fauna assemblages. Flora commonly occurring with Tuart include <i>Agonis flexuosa</i> , <i>Banksia attenuata</i> , <i>B. grandis</i> , <i>Allocasuarina fraseriana</i> , <i>Xylomelum occidentale</i> , <i>Macrozamia riedlei</i> , <i>Xanthorrhoea preissii</i> , <i>Spyridium globulosum</i> , <i>Templetonia retusa</i> and <i>Diplolaena dampieri</i> (DBCA 2019)	Data not available

*A component of the Endangered *Banksia* woodlands of the Swan Coastal Plain EPBC listed TEC

**Can form a component of the Endangered *Banksia* Woodlands of the Swan Coastal Plain EPBC listed TEC

3.5.3 Flora diversity

The *NatureMap* database identified 337 flora taxa, representing 67 families and 189 genera previously recorded within the study area. This total comprised 272 native flora taxa and 65 naturalised (introduced) flora taxa. Dominant families recorded included Fabaceae (42 taxa), Asteraceae (30 taxa) and Proteaceae (22 taxa).

The *NatureMap* database search is provided in Appendix C.

3.5.4 Conservation significant flora

The EPBC Act PMST, *NatureMap* and DBCA Threatened and Priority Flora databases identified the presence/potential presence of 26 conservation significant flora taxa within the study area (Appendix C). The desktop searches recorded:

- 12 Threatened flora taxa listed under the EPBC Act and/or WC Act
- Two Priority 1 taxon
- Three Priority 2 taxa
- Seven Priority 3 taxa
- Two Priority 4 taxa

The locations of conservation significant flora registered on the DBCA databases are mapped on Figure 2, Appendix A.

3.6 Fauna

3.6.1 Fauna diversity

The *NatureMap* database identified 252 terrestrial vertebrate fauna species previously recorded within the study area. This total comprised of 163 birds, 54 reptiles, 30 mammals and 5 amphibians. Of the 252 fauna species previously recorded, 239 are native species and 13 are naturalised (introduced) species.

The *NatureMap* database search is provided in Appendix C.

3.6.2 Conservation significant fauna

The EPBC Act PMST and DBCA *NatureMap* database and GHD observations identified the presence/ potential presence of 25 conservation significance fauna taxa within the study area (Appendix C). This total does not include species identified by the PMST as marine and/or migratory marine. These species have been excluded from this assessment as no marine habitat was present within or immediately adjacent to the survey area.

The species listed included:

- 13 species listed as Threatened under the EPBC Act and/or as Threatened under the BC Act (six are also listed as Migratory under the EPBC Act)
- Five bird species listed as Migratory only (terrestrial and wetland) under the EPBC Act and/or as Migratory species under the BC Act
- One species listed as Other specially protected fauna under the BC Act
- Five species listed as Priority by DBCA

One additional species not identified in the desktop searches has been identified by GHD as potentially occurring within the study area:

- Jewelled Ctenotus (*Ctenotus gemmula*) – listed as Priority 3 by the DBCA.

For the purpose of assessing the species likely to be impacted by the proposed project, only those species identified or likely to occur within the survey area are discussed in the Likelihood of occurrence assessment in Section 4.2.10.

3.7 Previous survey results

3.7.1 Mitchell Freeway extension: Burns Beach Rd to Romeo Rd Level 2 Flora and Level 1 Fauna assessment (GHD 2014a)

The biological survey was completed during May to July and September to October in 2013 to identify the environmental values of the proposed Mitchell Freeway extension and associated works between Burns Beach Road and Romeo Road. The project was broken down into three stages and covered a total area of 438 ha.

- Stage 1 – Freeway extension from Burns Beach Road and Hester Avenue and the connecting roads (Neerabup Road and Hester Avenue)
- Stage 2 – Freeway extension from Hester Avenue to Romeo Road and connecting road (Romeo Road)
- Stage 3 – Wanneroo Road duplication from Joondalup Drive to Hall Road.

Vegetation and flora

Six vegetation types (and an additional mosaic vegetation type) were mapped across the study area: *Banksia* woodland (VT1), Jarrah–*Banksia* woodland (VT2), Tuart woodland (VT3), Mixed low heath on limestone (VT4), *Melaleuca huegelii*–*M. systema* shrubland on limestone (VT5), *Banksia sessilis* closed tall scrub (VT6) and mosaic of VT1 and VT4.

Vegetation types 3, 4 and 6 appeared to correspond with the Priority 3 PEC “Northern Spearwood Shrublands and Woodlands”. Vegetation type 5 appeared to correspond with the State listed Endangered TEC “*Melaleuca huegelii*–*M. acerosa* [now *M. systema*] shrublands on limestone ridges”.

The GHD survey identified a total of 392 flora species from 79 families and 234 genera within the study area. This number included 246 native species and 146 introduced/planted species. No Threatened flora were identified within the study area during the survey. Five Priority flora taxa listed by DBCA were recorded within the study area: *Acacia benthamii* (Priority 2), *Eucalyptus caesia* (Priority 4) (roadside plantings), *Jacksonia sericea* (Priority 4), *Pimelea calcicola* (Priority 3) and *Stylidium maritimum* (Priority 3).

Fauna

Six broad fauna habitat types were identified in the study area, including planted/highly degraded/cleared areas. The fauna habitat types within the study area consisted predominantly of a combination of mixed eucalypt woodlands and *Banksia* woodlands dominated by an overstorey of *E. gomphocephala* (Tuart), *E. marginata* (Jarrah), *Corymbia calophylla* (Marri), *Banksia attenuata* and *B. menziesii* and were generally associated with grey sandy soils on plains or low undulating dune systems. The eucalypt and *Banksia* woodlands ranged from Degraded to Excellent condition and provided particularly high habitat value for fauna species due to the variety of microhabitats and various resource niches available (i.e. fallen logs, hollows, leaf litter, sandy soil).

A total of 61 fauna species, consisting of 47 birds, seven reptiles and seven mammals were recorded within the study area during the field surveys. Of these, nine were introduced (feral) species. Two conservation significant fauna species were recorded during the survey:

- Carnaby's Cockatoo (*Calyptorhynchus latirostris*) listed as Endangered under the EPBC Act and Threatened under the former WC Act (now BC Act)
- Carpet Python (*Morelia spilota imbricata*) listed as Schedule 4 under the former WC Act.

The Carpet Python is no longer listed under the current BC Act. The survey also identified from potential diggings the likely presence of the DBCA Priority 5 species, Quenda/Southern Brown Bandicoot (*Isoodon obesulus fusciventer*).

Ten bird species recorded during the survey were considered to be significant birds of the Swan Coastal Plain portion of the Perth Metropolitan Region, including the Brown Goshawk, Carnaby's Black Cockatoo, Emu, Splendid Fairy-wren, New Holland Honeyeater, White-cheeked Honeyeater, Grey Shrike-thrush, Golden Whistler and Scarlet Robin. These species are either habitat specialists with a reduced distribution on the Swan Coastal Plain or are wide-ranging species with reduced populations on the Swan Coastal Plain. Additionally the Carpet Python and Echidna were also considered to be locally significant fauna as even though they have large distributions they have declined on the Swan Coastal Plain. The study area is also considered to contain suitable habitat for a number of other fauna species identified as locally significant, including the Honey Possum, White-striped Bat, Speckled Granite Gecko (Swan Coastal Plain population) and Little Eagle.

3.7.2 Neerabup Road Extension: Level 2 Fauna Survey (GHD 2014b)

A Level 2 fauna study for the proposed Neerabup Road extension was completed in November and December 2013. Methods employed for the survey were developed in conjunction with regional science staff of the former Department of Parks and Wildlife (now DBCA). Three types of woodland habitat were present in the study area which was considered to be generally in Good to Excellent condition. The survey resulted in 114 vertebrate fauna species being recorded comprising 1485 individuals. This included 70 birds, 29 reptiles, one amphibian, eight native mammals (including bats) and six introduced mammals.

Five species of conservation significance were recorded, including Carnaby's Black Cockatoo, Rainbow Bee-eater, Carpet Python, Southern Brown Bandicoot and the Western Brush Wallaby. A further six conservation significant species were considered likely or possible to occur in the study area.

3.7.3 Mitchell Freeway Extension Black Cockatoo Assessment (GHD 2013a and 2013b)

A targeted black cockatoo assessment of the proposed Mitchell Freeway extension and associated works between Burns Beach Road and Romeo Road (total survey area of 437.3 ha) was undertaken in May and July 2013 (GHD 2013a). The assessment followed the EPBC Act referral guidelines for three Threatened Black Cockatoo species: Carnaby's Cockatoo (*Calyptorhynchus latirostris*), Baudin's Black Cockatoo (*Calyptorhynchus baudinii*) and Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii* subsp. *naso*) (DSEWPaC 2012). The key results of the field assessment included:

- 207.01 ha of suitable feeding habitat was mapped
- Evidence (in the form of direct observation of the birds, chewed Marri nuts and chewed-off branches and nuts from *Banksia* species) that Carnaby's Cockatoo forages extensively across the study area
- The assessment identified a total of 836 trees with a diameter at breast height (DBH) of >500 mm within the study area. A total of 198 trees contained at least one hollow which may provide suitable breeding habitat now, or in the future for black cockatoos. This total includes 153 trees that contain hollows that were not of a suitable size and were not

currently considered suitable for black cockatoo nesting, but may provide suitable breeding habitat in the future. The remaining 45 trees contained hollows that were currently considered to provide suitable nesting habitat (>20 cm entrance size)

- A follow-up survey was undertaken in September 2013 (GHD 2013b) to re-visit the 198 previously identified trees within the study area during the breeding season for Black Cockatoos. All three species of Black Cockatoo were recorded during the survey period and were regularly seen in the area. No evidence of Black Cockatoos breeding within the study area were identified at the time of the survey. Breeding records and use of hollows in the study area by other species (including European honey bees, Corellas and Galahs) demonstrated that there is competition for hollows in the area.

4. Survey results

4.1 Vegetation and flora

4.1.1 Vegetation types and condition within the survey area

Fourteen vegetation types were identified and described for the survey area, not including Cleared/highly disturbed areas (Table 4-1 and Figure 5, Appendix A).

Remnant vegetation within the survey area is dominated by VT01 *Banksia* woodlands (24%, 96.82 ha) and VT08 Mixed low heathland (7%, 27.89 ha). These vegetation types are generally associated with the landforms upon which they lie, with tall woodlands occurring in lower-lying areas with deep sandy soils, heathlands and shrublands on shallow soils on undulating dune systems, hilltops and ridges associated with limestone outcropping and *Banksia* woodlands in intermediate landforms associated with deep sandy soils. The vegetation types were often distributed in a mosaic like pattern within the survey area as the soil landscapes and dune landforms changed. Areas which have been completely cleared of native vegetation such as roads, tracks, railway, planted non-natives and building structures have been mapped as cleared.

The condition of the vegetation within the survey area ranged from Excellent to Completely Degraded. The survey area is predominantly located along existing transport corridors (Wanneroo Road, Joondalup line railway and Romeo Road) as well as established residential areas. Therefore a large proportion of the survey area has been highly disturbed and/or cleared. Areas containing scattered remnant natives over an understorey dominated by weed species have been assigned conditions of Degraded to Completely Degraded. Approximately 43 % (170.90 ha) of the survey area is mapped as Cleared/highly disturbed, with 61% in Degraded or worse condition (243.85 ha). The extents of the vegetation condition ratings mapped within the survey area are detailed in Table 4-2 and mapped in Figure 6, Appendix A.

Large amounts of rubbish dumping (including household goods, asbestos, car parts, boats, building materials, household rubbish and garden waste) was observed throughout the survey area, particularly along Romeo Road. It appears the tracks within the extension of Romeo Road are regularly used by the public for off-road bikes and four wheel drives. In general, the greater the distance from roads, tracks and built up areas, the better the condition of the native vegetation. The heathland vegetation types generally remained in Very Good condition due to the dense understorey restricting weed invasion.



4.1.2 Vegetation types and condition within extended survey area




Twelve of the 14 vegetation types identified in the survey area, not including Cleared/highly disturbed, also occurred in the extended survey area (Table 4-1 and Figure 5, Appendix A). The extended survey area did not contain VT05 *Eucalyptus decipiens* tall woodland or VT16 Pine plantation, but did contain VT13 Typha tall rushland and VT14 *Eucalyptus/Melaleuca* tall isolated clumps of trees. These additional vegetation types are associated with Lake Nowergup, east of Wanneroo Road.




When compared to the survey area, much less of the extended survey area in relative and absolute terms is mapped as Cleared/highly disturbed at 6 % (39.95 ha). Similar to the survey area, the extended survey area was dominated by VT01 *Banksia* woodlands (40%, 259.12 ha) and VT08 Mixed low heathland (13%, 85.66 ha). Vegetation types VT10 *Lomandra maritima* low forbland and VT11 *Acacia* closed shrubland are predominantly mapped within the extended survey area with only a very small areas occurring within the survey area.




The condition of the vegetation within the extended survey area ranged from Excellent to Completely Degraded. Illegal rubbish dumping was observed within the extended survey area, particularly along tracks within Neerabup National Park. The majority of the vegetation remaining within Neerabup National Park is in Excellent to Very Good condition, particularly in heathland vegetation and areas away from access tracks. The heathland vegetation types generally remained in Very Good condition due to the dense understorey restricting weed invasion. The majority of the vegetation within Neerabup Nature Reserve was in Degraded condition with the vegetation structure severely altered. The area around Lake Nowergup was mostly cleared with weedy grasses and herbs completely dominating the ground cover. The extents of the vegetation condition ratings mapped within the extended survey area are detailed in Table 4-2 and mapped in Figure 6, Appendix A.



Table 4-1 Vegetation types within the survey areas




Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
<i>Banksia</i> low woodland (VT01)	Low woodland of <i>Banksia attenuata</i> and <i>B. menziesii</i> with occasional <i>Allocasuarina fraseriana</i> and <i>Eucalyptus tottiana</i> over a mid to low shrubland of <i>Hibbertia hypericoides</i> , <i>Xanthorrhoea preissii</i> and <i>Acacia pulchella</i> var. <i>glaberrima</i> over open sedgeland and forbland of <i>Mesomelaena pseudostygia</i> , <i>Conostylis aculeata</i> and <i>Desmocladius flexuosus</i> .	Grey to brown sandy plains and gently undulating terrain.	Survey area – 96.82 ha Extended survey area – 259.12 ha	Q3, Q8, Q10, Q16, Q17, Q18, Q19, Q31, & Q32 FCT: Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> – <i>Eucalyptus</i> woodlands (FCT28)	
Tuart/Banksia open woodland (VT02)	Tall open woodland of <i>Eucalyptus gomphocephala</i> , <i>Banksia attenuata</i> and <i>Allocasuarina fraseriana</i> over a mid to low shrubland of <i>Hibbertia hypericoides</i> , <i>Xanthorrhoea preissii</i> and <i>Acacia pulchella</i> var. <i>glaberrima</i> over open sedgeland and weedy grassland of <i>Mesomelaena pseudostygia</i> , <i>*Bromus diandrus</i> and <i>*Briza maxima</i> .	Brown sandy soil on upper slopes.	Survey area – 5.39 ha Extended survey area – 6.78 ha	Q12, Q13 & Q35, FCT: Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> – <i>Eucalyptus</i> woodlands (FCT28)	



Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
Jarrah tall woodland (VT03)	Tall woodland of <i>Eucalyptus marginata</i> , <i>Banksia</i> spp. and <i>Allocasuarina fraseriana</i> over shrubland of <i>Hibbertia hypericoides</i> , <i>Xanthorrhoea preissii</i> and <i>Acacia pulchella</i> var. <i>glaberrima</i> over a forbland/ grassland of <i>Mesomelaena pseudostygia</i> , <i>Desmocladius flexuosus</i> and weedy grasses (<i>*Ehrharta longiflora</i> and <i>*Briza maxima</i>).	Plains with grey to brown sand.	Survey area – 12.83 ha Extended survey area – 20.41 ha	Q11, Q24 & Q25 FCT: refer to Table foot note *	
Tuart tall woodland (VT04)	Woodland of <i>Eucalyptus gomphocephala</i> over sparse shrubland of <i>Xanthorrhoea preissii</i> , <i>Acacia saligna</i> and <i>Rhagodia baccata</i> over a sparse forbland/grassland of weeds (<i>*Carpobrotus edulis</i> , <i>*Euphorbia terracina</i> and <i>*Ehrharta longiflora</i>).	Brown sand on upper slopes.	Survey area – 11.88 ha Extended survey area – 7.05 ha	Q21, Q22, Q34, R1 & R6	
<i>Eucalyptus decipiens</i> tall woodland (VT05)	Tall woodland of <i>Eucalyptus decipiens</i> , <i>Allocasuarina fraseriana</i> and <i>Banksia</i> spp. over low shrubland of <i>Xanthorrhoea preissii</i> , <i>Hibbertia hypericoides</i> and <i>Acacia pulchella</i> var. <i>glaberrima</i> over a dense understorey of <i>Mesomelaena pseudostygia</i> and weedy grasses and herbs (<i>*Lagurus ovatus</i> , <i>*Avena barbata</i> and <i>*Sonchus oleraceus</i>).	Brown sand in low-lying plains.	Survey area – 0.44 ha	Q40 FCT: refer to Table foot note *	

Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
Jarrah/Marri tall woodland (VT06)	Tall woodland of <i>Eucalyptus marginata</i> and <i>Corymbia calophylla</i> and <i>Allocasuarina fraseriana</i> with the occasional <i>Eucalyptus gomphocephala</i> over open shrubland of <i>Xanthorrhoea preissii</i> , <i>Acacia pulchella</i> var. <i>glaberrima</i> and <i>Hibbertia hypericoides</i> over open herbs and sedges of <i>Mesomelaena pseudostygia</i> , <i>Desmocladius flexuosus</i> and <i>Orthrosanthus laxus</i> var. <i>laxus</i> .	Brown sandy plains and mid to upper slopes.	Survey area – 3.13 ha Extended survey area – 70.32 ha	Q36, Q39 & R2 FCT: refer to Table foot note *	
<i>Banksia sessilis</i> tall closed shrubland (VT07)	Tall closed shrubland of <i>Banksia sessilis</i> , <i>Melaleuca systema</i> and <i>Calothamnus quadrifidus</i> subsp. <i>quadrifidus</i> over shrubland of <i>Xanthorrhoea preissii</i> , <i>Hibbertia hypericoides</i> and <i>Hakea trifurcata</i> over Forbland/Sedgeland of <i>Desmocladius flexuosus</i> , <i>Conostylis aculeata</i> and <i>Mesomelaena pseudostygia</i> .	Grey/brown shallow sand over limestone, some outcropping.	Survey area – 16.19 ha Extended survey area – 32.51 ha	Q1, Q2, Q20 & R7 FCT: Northern Spearwood shrublands and woodlands (FCT24)	
Mixed low heathland (VT08)	Low heath of mixed species dominated by <i>Melaleuca systema</i> , <i>Calothamnus quadrifidus</i> subsp. <i>quadrifidus</i> , <i>Acacia lasiocarpa</i> var. <i>lasiocarpa</i> over a mixed dense understorey (dominated by <i>Desmocladius flexuosus</i> , <i>Mesomelaena pseudostygia</i> and <i>Lomandra maritima</i>).	Shallow grey sand with limestone outcropping.	Survey area – 27.89 ha Extended survey area – 85.66 ha	Q4, Q5, Q6, Q7, Q15, Q28, Q29, Q30, Q33 & Q43 FCT: Northern Spearwood shrublands and woodlands (FCT24)	

Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
<i>Melaleuca huegelii</i> / <i>M. systema</i> mid shrubland (VT09)	Mid shrubland of <i>Melaleuca huegelii</i> , <i>M. systema</i> and <i>Grevillea preissii</i> subsp. <i>preissii</i> over an open understorey of <i>Desmocladus flexuosus</i> , <i>Banksia dallanneyi</i> and <i>Stylidium maritimum</i> P3. Small isolated occurrences within VT08.	Limestone ridges.	Survey area - 3.87 ha Extended survey area – 4.83 ha	Q9, Q14, Q23, Q26, Q27 & Q37 FCT: <i>Melaleuca huegelii</i> – <i>Melaleuca systema</i> shrublands on Limestone ridges (FCT26a)	
<i>Lomandra</i> low forbland (VT10)	Scattered low shrubs of <i>Melaleuca systema</i> over a low forbland of <i>Lomandra maritima</i> , <i>Acanthocarpus preissii</i> and <i>Conostylis candicans</i> subsp. <i>candicans</i> over a groundcover dominated by <i>Desmocladus flexuosus</i> and introduced grasses and herbs (<i>*Euphorbia terracina</i> , <i>*Avena barbata</i> and <i>*Lagurus ovatus</i>).	Upper slopes of coastal dunes.	Survey area – 0.49 ha Extended survey area – 5.47 ha	Q38, Q41 & Q42	
<i>Acacia</i> closed shrubland (VT11)	<i>Acacia rostelifera</i> , <i>Melaleuca systema</i> and <i>Spyridium globulosum</i> closed shrubland over <i>Hibbertia hypericoides</i> and <i>Acanthocarpus preissii</i> with an understorey dominated by introduced herbs (<i>*Euphorbia terracina</i> , <i>*Carpobrotus edulis</i> and <i>*Asparagus asparagoides</i>) and grasses (<i>*Vulpia myuros</i> forma <i>myuros</i> , <i>*Bromus diandrus</i> and <i>*Ehrharta calycina</i>).	Coastal dunes.	Survey area – 0.07 ha Extended survey area- 13.23 ha	Q44 FCT: Northern <i>Acacia rostelifera</i> – <i>Melaleuca systema</i> shrublands (FCTS11)	

Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
Scattered natives over weeds (VT12)	Areas that have been impacted by previous clearing or grazing and consist of scattered native trees and/or shrubs including <i>Eucalyptus marginata</i> , <i>E. gomphocephala</i> , <i>Corymbia calophylla</i> , <i>Banksia</i> spp., <i>Allocasuarina fraseriana</i> with a scattered mid and lower storey including <i>Acacia</i> spp., <i>Xanthorrhoea preissii</i> and <i>Hibbertia hypericoides</i> over a groundcover completely dominated by introduced grasses (<i>Avena barbata</i> , <i>Bromus diandrus</i> and <i>Ehrharta calycina</i>) and herbs (<i>Euphorbia terracina</i> , <i>Carpobrotus edulis</i> and <i>Pelargonium capitatum</i>).	Grey/brown sand, some limestone outcrops, gently undulating terrain.	Survey area – 36.06 ha Extended survey area – 65.67 ha	R4 & R5	
Typha tall rushland (VT13)	Tall rushland to isolated clumps of rushes of <i>Typha orientalis</i> along the lake edge over a grassland/ herbland of <i>Bromus diandrus</i> , <i>Ehrharta longiflora</i> and <i>Pelargonium capitatum</i> .	Open water	Extended survey area - 15.29 ha	n/a	

Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
<i>Eucalyptus/Melaleuca</i> tall isolated clumps of trees (VT14)	Tall isolated clumps of trees of <i>Eucalyptus rudis</i> and <i>Melaleuca raphiophylla</i> over a grassland/herbland of <i>*Bromus diandrus</i> <i>*Ehrharta longiflora</i> and <i>*Pelargonium capitatum</i> .	Deep grey sandy soils in low lying areas surrounding the lake.	Extended survey area – 11.61 ha	R3	
Natural regrowth (VT15)	Previously cleared areas where natural regrowth of some native plant species has occurred. Natural regrowth is scattered with an understorey dominated by introduced grasses and herbs. Evidence of revegetation of native trees and shrubs (revegetation plant bags) was also present in some areas.	Sandy plain and low undulating dunes.	Survey area – 13.58 ha Extended survey area – 3.53 ha	n/a	
Pine plantation (VT16)	Planted pine plantation.	Sandy plain	Survey area – 0.43 ha	n/a	

Vegetation Types	Vegetation association	Landform and substrate	Location (survey area/extended survey area) and extent (ha)	Sample locations (quadrat/releve) and FCT alignment	Representative photograph
Open water	Inland freshwater lake	Lake	Extended survey area - 5.07 ha	n/a	
Cleared/highly disturbed	Generally completely cleared of native vegetation and consists of roads, railway, tracks, planted non-native vegetation and building structures.	-	Survey area – 170.90 ha Extended survey area – 39.95 ha	n/a	

Note: * FCT alignment - These quadrats aligned closest to FCT28, however the canopies of these communities were dominated by *Eucalyptus* spp. with emerging *Banksia* spp. Therefore field observation determined that these communities were not representative of a Banksia Woodland

Table 4-2 Vegetation condition ratings within the survey areas

Vegetation Condition	Extent in the survey area (ha) (%)	Extent in the extended survey area (ha) (%)
Excellent	4.18 (1%)	51.21 (8%)
Excellent - Very Good	21.48 (5%)	161.89 (25%)
Very Good	59.51 (15%)	132.72 (21%)
Very Good - Good	18.01 (5%)	46.82 (7%)
Good	36.17 (9%)	40.71 (6%)
Good - Degraded	16.77 (4%)	24.37 (4%)
Degraded	36.23 (9%)	26.28 (4%)
Degraded – Completely Degraded	29.60 (7%)	117.14(18%)
Cleared	178.02 (45%)	40.28 (6%)
Not rated	0	5.07 (1%)
Total	399.97	646.49

4.1.3 Floristic analysis

The similarity between GHD quadrat data, from both the survey area (39 quadrats) and extended survey area (five quadrats), were examined using PRIMER analysis and run using three scenarios:

- All species (base quadrat data)
- Native species only (weed species removed from each quadrat)
- Species that occur only once (singles) removed from each quadrat.

All these scenario's produced a stress value of 0.19 indicating poor/ random representation. 'Species that occur only once' scenario has been selected to demonstrate the groupings. The cluster analysis and resulting dendrogram for the 'species that occur only once' scenario is shown in Appendix D. The two dimensional MDS scatter plot for this scenario is illustrated in Plate 4-1. The MDS scatter plot shows quadrats that loosely group together with their representative vegetation type. The vegetation types were mapped using a combination of statistical analysis, dominant species, landforms and field observations.

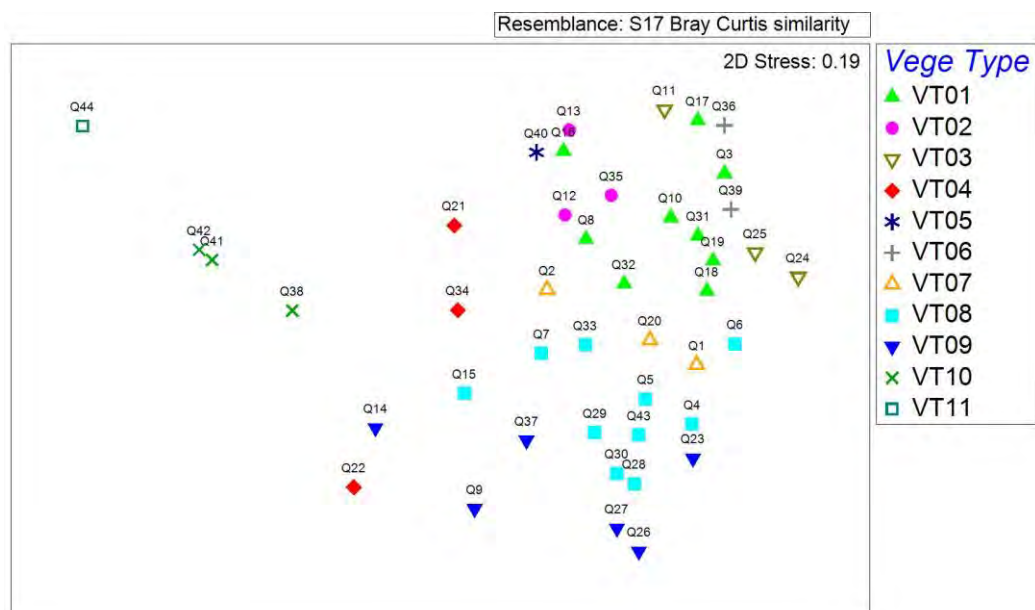


Plate 4-1 MDS showing broad clustering of quadrats

The GHD quadrats were compared to the SWA dataset for sites within a 5 km buffer of the survey area (see section 2.1) to assist in FCT assignment. Once again all scenarios produced a poor/ random representation with a stress value of 0.22. The 'species that occur only once' scenario was selected again to demonstrate the groupings. The cluster analysis and resulting dendrogram for the 'species that occur only once' scenario is shown in Appendix D. The two dimensional MDS scatter plot for this scenario is illustrated in Plate 4-2. Even though the two dimensional MDS scattered plot produced a high stress value, some similarities can be observed between GHD quadrats and the following FCTs:

- Northern Spearwood shrublands and woodlands FCT24 (PEC)
- *Melaleuca huegelii* – *Melaleuca systema* shrublands on Limestone ridges- FCT26a (TEC listed under the BC Act)
- Spearwood *Banksia attenuata* or *Banksia attenuata* – *Eucalyptus* woodlands- FCT28 (this is a component of the Endangered *Banksia* woodlands of the Swan Coastal Plain TEC listed under the EPBC Act).

Field observations inferred GHD VT09 may align with FCT26a, but the multiple site analysis showed a poor representation overall. Therefore, a SSI analysis using quadrats represented by VT09 (Q09, Q14, Q23, Q26, Q27 & Q37) was performed. Six two-dimensional MDS scatter plots were produced and are provided in Appendix D. All stress values were >0.2 for the SSI analysis. Quadrats Q26, Q27 and Q37 were most similar to FCT26a, however, each of the VT09 quadrats showed a similarity of > 32% with one or more quadrats of the SWA dataset. All quadrats for VT09 were established within the survey area. The similarity for each quadrat when compared to FCT26a was:

- Q09 – 16.0 < 34.7%
- Q14 - 16.4 < 32.8%
- Q23 – 16.0 < 32.9%
- Q26 – 21.2 < 45.6%
- Q27 - 20.7 < 33.8%
- Q37 – 27.5 < 50.5%

The statistical analysis has limitations in that results are produced based on taxa presence or absence. No consideration is given to dominant taxa or landforms. Therefore statistical output must be complemented by field based observation when determining FCT assignment. Based on the presence of key species, landforms, field observations and statistical outputs, VT09 is considered synonymous with FCT26a.

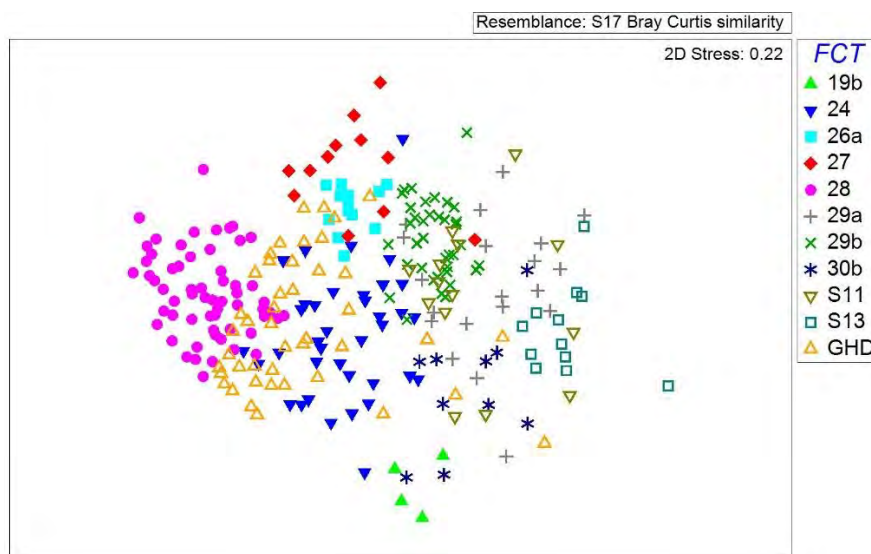


Plate 4-2 MDS showing GHD quadrats compared to the SWA dataset

4.1.4 Conservation significant ecological communities

Based on the results of the desktop searches, dominant species, landform features, field observations, and coupled with the statistical analyses, five conservation significant ecological communities were identified within the survey area and extended survey area. The conservation significant ecological communities are:

- *Banksia* Woodlands of the Swan Coastal Plain TEC (FCT28 is a component of this TEC) listed under the EPBC Act
- *Banksia* dominated woodlands of the Swan Coastal Plain IBRA region P3 PEC listed by DBCA
- *Melaleuca huegelii* - *Melaleuca systena* shrublands on limestone ridges (FCT26a) TEC under the BC Act
- Northern Spearwood shrublands and woodlands (FCT24) P3 PEC listed by DBCA
- Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain P3 PEC listed by DBCA.

Representative photographs of the TECs and PECs recorded within the survey area are provided in Appendix D.

Banksia Woodlands of the Swan Coastal Plain (TEC)

The *Banksia* Woodlands of the Swan Coastal Plain was listed in September 2016 as an Endangered TEC under the EPBC Act. The Commonwealth TEC encompasses a number of FCTs, some of which are also listed as State TECs/PECs. Spearwood *Banksia attenuata* or *Banksia attenuata* – *Eucalyptus* woodlands (FCT28), which was identified within the survey area and extended survey area is not listed under the BC Act as a TEC or by DBCA as a PEC. However FCT 28 is considered a component of the Commonwealth TEC due to key structural features as detailed by the Threatened Species Scientific Community (TSSC) (2016). The TSSC (2016) describes the key structural features of the community as:

- A prominent tree layer of *Banksia*, with scattered eucalypts and other tree species often present among, or emerging above, the canopy
- The understorey is a species rich mix of sclerophyllous shrubs, graminoides and forbs
- High endemism and considerable localised variation in species composition across its range.

The TSSC (2016) provides guidance for determining whether the TEC is present. These criteria are listed in Appendix B. During the field survey two vegetation types were assessed as meeting the key diagnostic characteristics for the *Banksia* Woodlands of the SCP TEC:

- VT01 - *Banksia* low woodland
- VT02 – Tuart/*Banksia* open woodland.

A breakdown of the mapped *Banksia* Woodlands of the SCP TEC patches (by vegetation type, condition and extent) is detailed in Table 4-3 with the TEC extent mapped in Figure 7, Appendix A. There is 85.97 ha of *Banksia* Woodland SCP TEC in the survey area and 263.65 ha within the extended survey area.

Table 4-3 Extent of Banksia Woodlands of the SCP TEC within the survey areas

Patch ID and Patch extent (ha)	Vegetation location and extent (ha)	Vegetation condition and extent			Comments
		Condition	VT01 (ha)	VT02 (ha)	
Patch 1 Total area 12.04	Survey area Total 4.86	VG G D	2.85 1.01 1.01		Area mapped as TEC is in Very Good condition and occurs within the survey area and extended survey area, dissecting this patch is a dirt road and a couple of dirt bike tracks. It is noted by TSSC (2016) that a patch may include small scale variation in structure and condition and/or gaps such as tracks and disturbances (<30 m wide from the edge of the tree canopy), as long as overall functionality of the community is not significantly altered.
	Extended survey area Total 7.18	VG G	6.41 0.77		
Patch 2 Total area 2.90	Survey area Total 2.03	VG D	1.01 1.02		Area mapped as TEC is predominately in Very Good condition. A dirt road dissects the centre of this patch.
	Extended survey area Total 0.87	VG D	0.86 0.01		
Patch 3 Total area 5.90	Survey area Total 5.90	VG	5.90		Patch 3 is solely within the survey area and is in Very Good condition with minor dirt tracks traversing the patch.
Patch 4 Total area 285.40	Survey area VT01 60.07 VT02 1.22 Total 61.29	Ex Ex-VG VG VG-G G G-D D DCD	4.18 13.80 19.94 2.07 10.43 6.68 2.44 0.53	1.01 0.21	Patch 4 is the largest patch within the survey/ extended survey area and is made up of two vegetation types VT01 and VT02. This patch has a number of minor dirt tracks traversing the patch as well as scattered patches of other vegetation types within it. Apart from these small scale variations it is predominately in Good or better condition.

Patch ID and Patch extent (ha)	Vegetation location and extent (ha)	Vegetation condition and extent			Comments
		Condition	VT01 (ha)	VT02 (ha)	
	Extended survey area Total 224.11	E E-VG VG VG-G G G-D D	46.03 95.42 69.92 5.27 5.14 2.32 0.01		
Patch 5 Total area 14.14	Extended survey area VT01 10.03 VT02 4.11 Total 14.14	VG-G G-D	10.03	0.77 3.34	Patch 5 occurs within the extended survey area (Neerabup National Park) and is made up of VT01 and VT02. It has a couple of minor dirt tracks dissecting it but is overall in Very Good to Good condition
Patch 6 Total area 0.07	Survey area Total 0.07	G	0.07		Within the survey area Patch 6 is below the minimum patch size threshold for Good condition Banksia Woodland (>2 ha). However TSSC (2016) states that consideration should be given to the surrounding environment when identifying a patch. Patch 6 makes up a very small component of Banksia Woodland within Neerabup Nation Park south of Hester Avenue.
Patch 7 Total area 1.71	Extended survey area Total 1.71	VG-G	1.71		An isolated patch with no tracks or variations, located at the south eastern extent of the extended survey area.
Patch 8 Total area 1.37	Survey area Total 1.37	VG-G G G-D	0.99 0.10 0.28		Patch 8 was dissected by a fire break and was located on the eastern side of Wanneroo Road. This patch is part of a larger <i>Banksia</i> woodland remnant that extends beyond the survey area. The overall condition of this larger remnant was considered Good.
Patch 9	Survey area Total 2.41	VG VG-G	1.14 1.27		Located within the survey area and extended survey area Patch 9 occurred on the eastern side of Wanneroo Road, it was dissected by a fire break from north to south

Patch ID and Patch extent (ha)	Vegetation location and extent (ha)	Vegetation condition and extent			Comments
		Condition	VT01 (ha)	VT02 (ha)	
Total area 10.47	Extended survey area Total 8.33	VG	8.33		
Patch 10 Total area 1.29	Extended survey area Total 1.29	E-VG	1.29		This patch was isolated within the extended survey area. It was surrounded on all sides by VT08 – mixed low heathland
Patch 11 Total area 4.43	Survey area Total 4.32 Extended survey area Total 0.10	G G	1.38	2.94 0.10	Consisting of VT01 and VT02 this patch occurred at the northern extent of Wanneroo Road, separated by a fire break
Patch 12 Total area 3.81	Survey area Total 1.23 Extended survey area Total 2.58	VG-G G G		0.98 0.25 2.58	Patch 12 occurred along the eastern side of Wanneroo Road within the boundary of Nowergup Lake. A small fire break dissected the patch
Patch 13 Total area 5.84	Survey area Total 2.48 Extended survey area Total 3.36	VG-G D VG-G	2.39 0.09 3.36		Patch 13 occurred at the southern extent of the survey area and extended survey area. A number of minor dirt tracks dissected this patch at various places.

Banksia dominated woodlands of the SCP IBRA region (PEC)

The field assessment also confirmed the presence of the *Banksia* dominated woodlands of the SCP IBRA region PEC, listed as Priority 3 by DBCA. Similar to the TEC, this PEC was associated with VT01 and VT02. This PEC differs from the TEC in that it has no minimum condition or patch size thresholds. There is 102.13 ha of the PEC present within the survey area and 265.90 ha present within the extended survey area. These totals include the *Banksia* Woodlands of the SCP TEC and should not be double counted. A breakdown of the PEC extent by condition is detailed in Table 4-4 with the PEC distribution mapped in Figure 7, Appendix A.

Table 4-4 Extent of the *Banksia* dominated woodlands of the SCP IBRA region PEC within the survey areas

Location and Condition	Vegetation Types		Total
	VT01	VT02	
Survey area			
Excellent	4.18	-	4.18
Excellent – Very Good	13.80	-	13.80
Very Good	29.70	-	29.70
Very Good - Good	6.73	0.98	7.71
Good	18.62	4.19	22.81
Good - Degraded	11.27	0.21	11.48
Degraded	11.53	-	11.53
Degraded – Completely Degraded	0.92	-	0.92
Survey area total	96.75	5.38	102.13
Extended survey area			
Excellent	46.03	-	46.03
Excellent – Very Good	96.71	-	96.71
Very Good	85.51	-	85.51
Very Good - Good	20.37	0.77	21.14
Good	6.55	2.67	9.22
Good - Degraded	2.91	3.34	6.25
Degraded	0.56	-	0.56
Degraded – Completely Degraded	0.42	-	0.42
Completely Degraded	0.06	-	0.06
Extended survey area total	259.12	6.78	265.90

Melaleuca huegelii - Melaleuca systema shrublands on limestone ridges (TEC)

The *Melaleuca huegelii-Melaleuca systema* shrublands of limestone ridges TEC occurs on skeletal soils on ridge slopes and ridge tops with limestone outcropping. The community is described as comprising of species rich thickets, heaths or scrubs dominated by *Melaleuca huegelii*, *M. systema*, *Banksia sessilis* over *Grevillea preissii*, *Acacia lasiocarpa* and *Spyridium globulosum* (community 26a as described by Gibson *et al.* 1994). The community is highly restricted and known from massive limestone ridges around Yanchep north of Perth, and south of Perth near Lake Clifton.

A multiple site analysis and SSI analysis showed some similarity between GHD VT09 and FCT26a - *Melaleuca huegelii-Melaleuca systema* shrublands of limestone ridges TEC. Field observations and landform features confirmed the similarities through the following key characteristics:

- Occurs on the SCP on the Cottesloe complex of the Spearwood system
- Recorded on limestone ridges and outcrops

- Vegetation type contained key species; *Melaleuca huegelii*, *M. systema*, *Banksia sessilis*, *Grevillea preissii*, *Acacia lasiocarpa* and *Spyridium globulosum*.

There is 3.87 ha of the *Melaleuca huegelii*-*Melaleuca systema* shrublands of limestone ridges TEC within the survey area and 4.83 ha within the extended survey area. The condition of this vegetation ranged from Excellent-Very Good to Good (Table 4-5). The location of the *Melaleuca huegelii*-*Melaleuca systema* shrublands of limestone ridges TEC within the survey areas is mapped in Figure 7, Appendix A.

Table 4-5 Extent of the *Melaleuca huegelii*-*Melaleuca systema* shrublands of limestone ridges TEC within the survey areas

Condition	Extent (ha)
Survey area	
Excellent – Very Good	0.44
Very Good	2.13
Very Good – Good	0.02
Good	1.28
Survey area total	3.87
Extended survey area	
Excellent – Very Good	1.17
Very Good	3.26
Very Good – Good	0.34
Good	0.06
Extended survey area total	4.83

Northern Spearwood shrublands and woodlands (PEC)

The Northern Spearwood shrublands and woodlands (FCT24) PEC occurs as heaths or heaths with scattered *Eucalyptus gomphocephala* occurring on deeper soils north from Woodman Point. *Banksias* found in this community include *Banksia attenuata* and *B. menziesii*. The heathlands in this group typically include *Dryandra sessilis* (now *Banksia sessilis*), *Calothamnus quadrifidus* and *Schoenus grandiflorus*, with other common species including *Hardenbergia comptoniana*, *Melaleuca acerosa* (now *Melaleuca systema*) and *Xanthorrhoea preissii*.

The GHD vegetation types that were statistically representative of the Northern Spearwood shrublands and woodlands PEC were VT07 and VT08. Field observations confirmed the similarities. The key characteristics of Northern Spearwood shrublands and woodlands PEC met by VT07 and VT08, were:

- Occurs on the western SCP on the Cottesloe units of the Spearwood system
- The vegetation types includes occurrences of *Banksia attenuata* and *B. menziesii*
- The heath community may consist of *Banksia sessilis*, *Calothamnus quadrifidus*, *Melaleuca systema*, *Xanthorrhoea preissii*, *Lepidosperma squamatum*, *Hardenbergia comptoniana*, *Phyllanthus calycinus*, *Conostylis aculeata*, *Dianella revoluta*, *Lomandra maritima*, *Schoenus grandiflorus*, *Desmocladius flexuosa* and *Austrostipa flavescens*.

Table 4-6 shows the condition and extent of the Northern Spearwood shrublands and woodlands PEC within the survey area and extended survey area through the GHD representative vegetation types (VT07 and VT08). Figure 7, Appendix A illustrates the location of the Northern Spearwood shrublands and woodlands PEC within the survey areas.

Table 4-6 Extent of the Northern Spearwood shrublands and woodlands PEC within the survey areas

Location and Condition	Vegetation Types		Total
	VT07	VT08	
Survey area			
Excellent – Very Good	3.37	2.06	5.43
Very Good	1.46	22.69	24.15
Very Good - Good	3.99	0.79	4.78
Good	2.06	1.60	3.66
Good - Degraded	2.02	-	2.02
Degraded	2.84	0.69	3.53
Degraded – Completely Degraded	0.44	-	0.44
Completely Degraded	-	0.06	0.06
Survey area total	16.19	27.89	44.08
Extended survey area			
Excellent	-	0.85	0.85
Excellent – Very Good	15.32	39.31	54.63
Very Good	1.73	34.99	36.72
Very Good - Good	7.32	7.00	14.32
Good	1.61	3.51	5.12
Good - Degraded	5.08	-	5.08
Degraded	1.07	-	1.07
Degraded – Completely Degraded	0.38	-	0.38
Extended survey area total	32.51	85.66	118.17

Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain (PEC)

Mostly confined to Quindalup Dunes and Spearwood Dunes from Jurien Bay to the Sabina River, with outliers along some rivers. Tuart is the key dominant canopy species however; Tuart communities comprise a variety of flora and fauna assemblages. Flora commonly occurring with Tuart include: *Agonis flexuosa*, *Banksia attenuata*, *Banksia grandis*, *Allocasuarina fraseriana*, *Xylomelum occidentale*, *Macrozamia riedlei*, *Xanthorrhoea preissii*, *Spyridium globulosum*, *Templetonia retusa* and *Diplolaena dampieri*.

During the field survey one vegetation type (VT04) was assessed as meeting the key diagnostic characteristics for the Tuart woodlands of the Swan Coastal Plain PEC, as outlined by DBCA (2019), specifically:

- The survey area occurs in the SCP IBRA bioregion
- Mostly confined to Quindalup Dunes and Spearwood Dunes from Jurien bay to the Sabina River
- Tuart is the key dominant canopy species however Tuart communities comprise a variety of flora and fauna assemblages
- Flora commonly occurring with Tuart include Peppermint (*Agonis flexuosa*), *Banksia attenuata*, *Banksia grandis*, *Allocasuarina fraseriana*, *Xylomelum occidentale*, *Macrozamia riedlei*, *Xanthorrhoea preissii*, *Spyridium globulosum*, *Templetonia retusa* and *Diplolaena dampieri*.

GHD vegetation type VT04 aligned with the Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain PEC. There was 11.88 ha within the survey area and 7.04 ha in the extended survey area. Table 4-7 presents the extent and condition of the Tuart (*Eucalyptus gomphocephala*)

woodlands of the Swan Coastal Plain PEC within the survey areas, with the distribution shown in Figure 7, Appendix A.

Table 4-7 Extent of the Tuart Woodlands of the Swan Coastal Plain PEC within the survey areas

Vegetation condition	Extent (ha) within the survey area
Survey area	
Very Good	0.55
Very Good – Good	0.45
Good	4.59
Good - Degraded	1.96
Degraded	0.97
Degraded – Completely Degraded	3.35
Survey area total	11.87
Extended survey area	
Good	0.28
Degraded	0.19
Degraded – Completely Degraded	6.57
Extended survey area total	7.04

4.1.5 Other significant vegetation

Vegetation that grows in association with wetlands or lakes is considered other significant vegetation (EPA 2016a). Although no vegetation that grows in association with wetlands or lakes was identified within the survey area, there was within the extended survey area.

VT14 and VT13 represented the Conservation Category Wetland (CCW) Nowergup Lake. This vegetation has a restricted distribution and has been historically impacted by extensive clearing throughout the local and broad areas. The vegetation of Nowergup Lake was in Degraded condition with isolated clumps of *Eucalyptus rudis* and *Melaleuca raphiophylla* surrounding the edge of the lake with a rushland of *Typha orientalis* within the shallow edges. The groundcover was dominated by a grassland/ herbland of **Bromus diandrus* **Ehrharta longiflora* and **Pelargonium capitatum*. There is approximately 26.90 ha of wetland/ lake vegetation within the extended survey area that grows in association with CCW Nowergup Lake.

4.1.6 Flora diversity

Two hundred and ninety three flora taxa (including subspecies and varieties) representing 68 families and 177 genera were recorded from the survey area during the field survey. This total comprised 213 native taxa and 80 introduced flora taxa.

Dominant families recorded from the survey area included:

- Fabaceae (37 taxa)
- Poaceae (24 taxa)
- Myrtaceae (21 taxa)
- Asteraceae and Proteaceae (19 taxa each).

A flora taxa list by quadrat and vegetation type is provided in Appendix D.

A species accumulation curve was generated using PRIMER to assess adequacy of sampling effort within the survey area (Plate 4-3). The species accumulation curve for the survey area, based on flora recorded within quadrats, is approaching an asymptote, which suggests that the

current survey effort is sufficient. The bootstrap estimate of species richness generated from this data indicates that 252 species could be expected from the survey area based on the diversity recorded within quadrats. The total species recorded within the quadrats was 222 however the total for the survey area including relevés and opportunistic species was 293 flora taxa. The survey area is considered representative of the floristic diversity in the area.

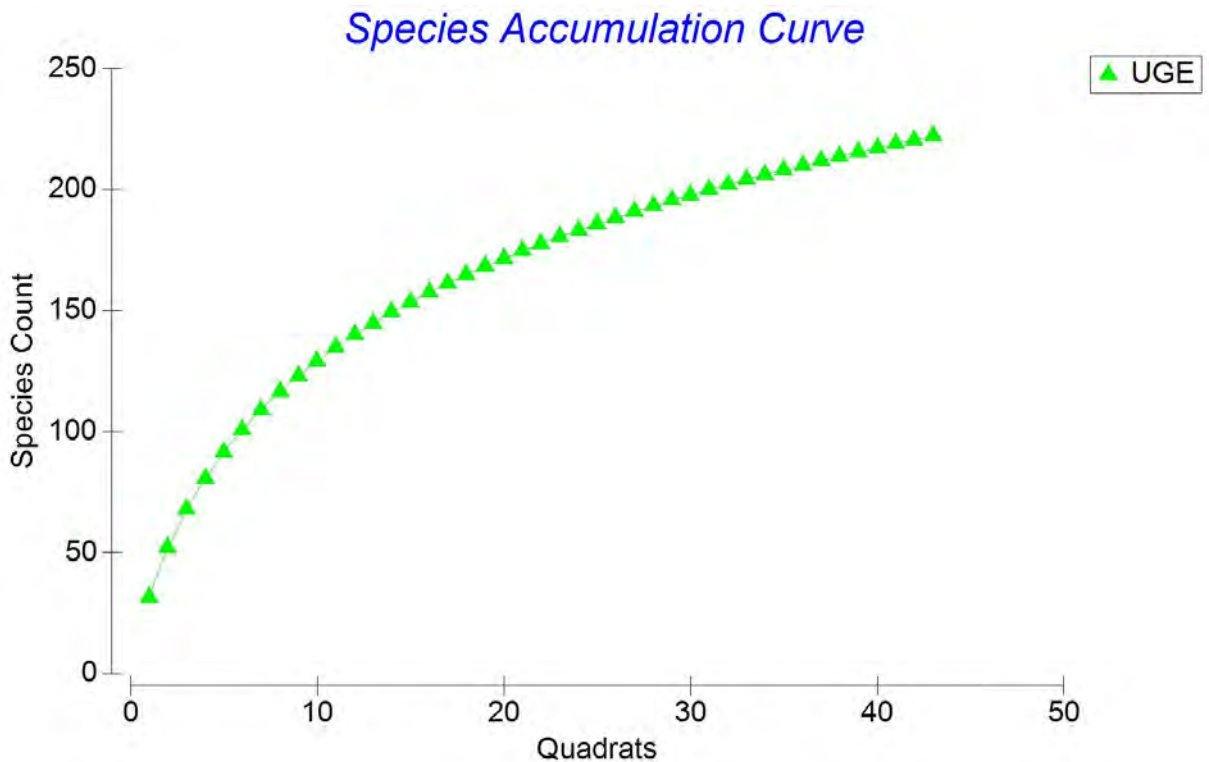


Plate 4-3 Species accumulation curve using quadrat data

4.1.7 Introduced flora

Of the 80 introduced taxa recorded within the survey area, eight are listed as Declared Pests under the *Biosecurity and Management Act 2007*. Four of these taxa are also listed as Weeds of National Significance (WoNS):

- **Moraea flaccida* (One-leaf Cape Tulip)– Declared Pest
- **Gomphocarpus fruticosus* (Narrowleaf Cottonbush) – Declared Pest
- **Echium plantagineum* (Paterson's Curse) – Declared Pest
- **Solanum linnaeanum* (Apple of Sodom)– Declared Pest
- **Opuntia stricta* (Common Prickly Pear)- Declared Pest and WoNS
- **Lantana camara* (Common Lantana)- Declared Pest and WoNS
- **Asparagus asparagoides* (Bridal Creeper) – Declared Pest and WoNS
- **Zantedeschia aethiopica* (Arum lily) – Declared Pest and WoNS

The remaining introduced taxa are considered environmental weeds and all have been previously recorded on the Swan Coastal plain. The locations of the Declared Pests and WoNS recorded within the survey area are shown in Figure 6, Appendix A and provided in Appendix D in tabular format.

4.1.8 Conservation significant flora

No EPBC Act or BC Act listed flora were recorded within the survey area. Six DBCA Priority listed flora species were identified within the survey area during the field survey (Herbarium Accession # 7839):

- *Melaleuca* sp. Wanneroo (G.J. Keighery 16705) listed Endangered (En) under the BC Act
- *Baeckea* sp. Limestone (N. Gibson & M.N. Lyons 1425) DBCA listed P1
- *Acacia benthamii* DBCA listed P2
- *Leucopogon* sp. Yanchep (M. Hislop 1986) DBCA listed P3
- *Hibbertia spicata* subsp. *leptotheca* DBCA listed P3
- *Pimelea calcicola* DBCA listed P3
- *Stylidium maritimum* DBCA listed P3.

Although no additional Priority listed flora taxa were identified in the extended survey area, one BC Act listed taxon, *Melaleuca* sp. Wanneroo (G.J. Keighery 16705) (Endangered) was recorded in an isolated patch.

Descriptions of the conservation significant flora recorded during the field survey are below. Table 4-8 summarises the location and count of the significant flora recorded during the field assessment.

Table 4-8 Conservation significant flora location and count

Taxa	Count	
	Survey area	Extended survey area
<i>Melaleuca</i> sp. Wanneroo (G.J. Keighery 16705) (En)	-	3
<i>Baeckea</i> sp. Limestone (N. Gibson & M.N. Lyons 1425) (P1)	354	83
<i>Acacia benthamii</i> (P2)	15	2
<i>Leucopogon</i> sp. Yanchep (M. Hislop 1986) (P3)	425	1341
<i>Hibbertia spicata</i> subsp. <i>leptotheca</i> (P3)	73	141
<i>Pimelea calcicola</i> (P3)	125	67
<i>Stylidium maritimum</i> (P3)	944	291

***Melaleuca* sp. Wanneroo (G.J. Keighery 16705) listed as Endangered under the BC Act**

Melaleuca sp. Wanneroo (G.J. Keighery 16705) (En) is described as an erect shrub, 1 - 2.5 m high x 2 m wide. Flowers are pale yellow and flower in November. This species is found on well drained grey sand with 30-70% limestone outcropping (WA Herbarium 1998–). Three plants were recorded within the extended survey area mapped as VT08. The occurrence of this taxon was restricted to an isolated patch of tall (3 m) heathland *Melaleuca systema* with *Banksia sessilis* on exposed limestone (60%). Other taxa represented by VT08 were recorded in this area but were not dominant. The survey area and extended survey area were extensively surveyed for similar VT08 variations however no further occurrences were recorded, it is unlikely that this taxon occurs elsewhere within the survey area or extended survey area due to its restricted preferred habitat. Plate 4-4 shows *Melaleuca* sp. Wanneroo (G.J. Keighery 16705) dried specimen, in situ and habit.



Dried specimen



In situ



Habit

Plate 4-4 *Melaleuca* sp. Wanneroo (G.J. Keighery 16705)

***Baeckea* sp. Limestone (N. Gibson & M.N. Lyons 1425) DBCA listed Priority 1**

Baeckea sp. Limestone (N. Gibson & M.N. Lyons 1425) (P1) is a compact shrub 1.2 (1.6) high x 1 m wide. Flowers are pale pink and flower in September to November. It is found on grey sand over limestone (WA Herbarium 1998–).

During the field survey 437 individuals were recorded: 354 were recorded within the survey area and 83 were recorded within the extended survey area. The taxon was recorded within VT08 and VT09. Plate 4-5 shows *Baeckea* sp. Limestone (N. Gibson & M.N. Lyons 1425) dried specimen, in situ and habit.



Dried specimen



Flower



Habit

Plate 4-5 *Baeckea* sp. Limestone (N. Gibson & M.N. Lyons 1425) (P1)

***Acacia benthamii* DBCA listed Priority 2**

Acacia benthamii (P2) is described as a shrub, approximately 1 m high. The flowers are yellow, from August to September. Typically found in sand on limestone breakaways (WA Herbarium 1998–).

Seventeen individuals were recorded during the field survey: 15 were recorded within the survey area and two were recorded within the extended survey area. The plants were individually protected by a fence made of chicken wire. The individuals were recorded in VT15 -Revegetation. Plate 4-6 shows *Acacia benthamii* dried specimen and habit.



Dried specimen



Habit

Plate 4-6 *Acacia benthamii* (P2)

***Leucopogon* sp. Yanchep (M. Hislop 1986) DBCA listed Priority 3**

Leucopogon sp. Yanchep (P3) is an erect shrub, 0.15-1 m high, to 0.6 m wide. Flowers are white/pink and flower between April to June or September. It is found on light grey-yellow sand, brown loam, limestone, laterite, granite, coastal plain, breakaways, valley slopes and low hills (WA Herbarium 1998–).

During the field survey 1766 individuals were recorded: 425 were recorded within the survey area and 1341 were recorded within the extended survey area. The taxon was recorded within VT08. Plate 4-7 shows *Leucopogon* sp. Yanchep (M. Hislop 1986) dried specimen and habit.



Dried specimen



Habit

Plate 4-7 *Leucopogon* sp. Yanchep (M. Hislop 1986) (P3)

***Hibbertia spicata* subsp. *leptotheca* DBCA listed Priority 3**

Hibbertia spicata subsp. *leptotheca* (P3) is described as an erect or spreading shrub, approximately 0.2-0.5 m high with yellow flowers in July to October. It grows near coastal limestone ridges, outcrops and cliffs (WA Herbarium 1998–).

During the field survey 214 individuals were recorded: 73 were recorded within the survey area and 141 were recorded within the extended survey area. The taxon was recorded within VT08 and VT09. Plate 4-8 shows *Hibbertia spicata* subsp. *leptotheca* dried specimen and in situ



Dried specimen

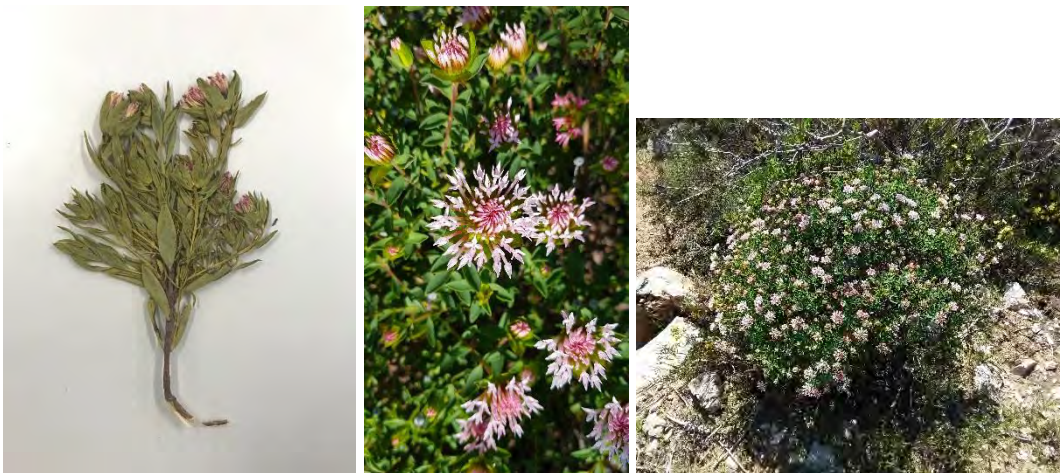
In situ

Plate 4-8 *Hibbertia spicata* subsp. *leptotheca* (P3)

***Pimelea calcicola* DBCA listed Priority 3**

Pimelea calcicola (P3) is described as an erect to spreading shrub, 0.2-1 m high. It has pink flowers from September to November and grows on sandy soils along coastal limestone ridges (WA Herbarium 1998–).

During the field survey 192 individuals were recorded: 125 were recorded within the survey area and 67 were recorded within the extended survey area. The taxon was recorded within VT08 and VT09. Plate 4-9 shows *Pimelea calcicola* dried specimen, in situ and habit.



Dried specimen

Flower

Habit

Plate 4-9 *Pimelea calcicola* (P3)

***Stylidium maritimum* DBCA listed Priority 3**

Stylidium maritimum (P3) is described as a caespitose perennial, herb, 0.3-0.7 m high, with white/purple flowers in September to November. It grows in sandy soils over limestone, dune slopes and flats in coastal heath, shrubland and open Banksia woodland (WA Herbarium 1998–).

During the field survey 1235 individuals were recorded: 944 were recorded within the survey area and 291 were recorded within the extended survey area. The taxon was recorded within VT08 and VT09. Plate 4-10 shows *Stylidium maritimum* dried specimen, in situ and habit.



Dried specimen

Flower

Habit

Plate 4-10 *Stylidium maritimum* (P3)

Likelihood of Occurrence assessment

A likelihood of occurrence assessment was conducted post-field survey for all conservation significant flora taxa identified in the desktop assessment (Appendix D). This assessment took into account previous records, habitat requirements, efficacy of the survey, intensity of the survey, flowering times and the cryptic nature of species. The assessment considered the survey area and extended survey area separately.

The likelihood of occurrence assessment for the survey area concluded that six taxa are known to occur, one taxa is likely to occur and five taxa may possibly occur (Table 4-9). The remaining taxa are unlikely or highly unlikely to occur within the survey area.

By comparison, the extended survey area likelihood of occurrence assessment concluded seven taxa are known to occur, one taxa is likely to occur and six taxa may possibly occur (Table 4-9). The additional taxa considered possible to occur in the extended survey area is *Eucalyptus argutifolia* (Vulnerable).

The taxa considered likely to occur in both survey areas, *Jacksonia sericea* (P4), has previously been recorded within the survey area, however was not identified during the current survey. Potential specimens of *J. sericea* identified within the survey area as well as specimens from previously recorded populations (GHD 2014a) were re-collected. All these specimens were informally identified by Michael Hislop (Identification Botanist, WA Herbarium) as *Jacksonia calcicola*. Michael Hislop commented that *Jacksonia sericea* and *J. calcicola* are closely related species that are known to intergrade in the northern Perth suburbs (M. Hislop pers comm. 9 Nov. 2018). *Jacksonia calcicola* was a common and dominant component of the understorey throughout the survey area and extended survey area, particularly in association with the *Banksia* woodlands and mixed heathlands. Given the complexity of distinguishing the two species it is considered *Jacksonia sericea* is likely to occur within the survey area and extended survey area however its occurrence may be isolated.

Table 4-9 Taxa likely to or possible to occur within the survey areas

Taxa	Known habitat (WA Herbarium 1998-)	Likelihood to occur and vegetation types that support known habitat	
		Survey area	Extended survey area
<i>Jacksonia sericea</i> (P4)	Calcareous and sandy soils.	Likely VT 01, 07, 08, 09 and disturbed areas	Likely VT 01, 07, 08, 09 and disturbed areas
<i>Conostylis bracteata</i> (P3)	Sand, limestone on consolidated sand dunes.	Possible VT 07, 08, 09, 10,	Possible VT 07, 08, 09, 10.
<i>Conostylis pauciflora</i> subsp. <i>euryrhipis</i> (P4)	White, grey or yellow sand on consolidated dunes.	Possible VT 07, 08, 09, 10,	Possible VT 07, 08, 09, 10,
<i>Eucalyptus argutifolia</i> (VU under EPBC Act and BC Act)	Shallow soils over limestone. Slopes or gullies of limestone ridges, outcrops.	Unlikely	Possible VT 07, 08, 09
<i>Fabronia hampeana</i> (P2)	Moss growing on the trunk of <i>Macrozamia</i>	Possible VT01, 02, 03, 04, 05, 06	Possible VT01, 02, 03, 04, 05, 06
<i>Leucopogon maritimus</i> (P1)	Pale yellow to white-grey sand, upper slopes of coastal dunes, limestone.	Possible VT 07, 08, 09, 10	Possible VT 07, 08, 09, 10
<i>Sarcozona bicarinata</i> (P3)	White sand.	Possible VT 10	Possible VT 10

4.2 Fauna

4.2.1 Fauna habitat within the survey area

Nine broad fauna habitat types were identified in the survey area and extended survey area based on the predominant landforms, soil and vegetation structure in the area. These following habitat types closely correspond to the vegetation types outlined in Table 4-1:

- Mixed heathland on limestone outcrops or heavy loams
- Banksia woodland on grey/brown sand
- Tuart (*Eucalyptus gomphocephala*) woodland in deep dark brown sand
- Jarrah (*E. marginata*) woodland on grey/brown sand
- Acacia shrublands on dunes and deep sands
- Parabolic dunes
- Pine Plantation (survey area only)
- Natural Regrowth
- Scattered natives over weeds, Cleared/highly disturbed

The fauna habitat of the survey area is described further in Table 4-10 and mapped in Figure 8, Appendix A.

The native vegetation within the survey consists predominantly of a combination of mixed eucalypt woodlands and Banksia woodlands. These habitat types consist of a dominant overstorey of

Eucalyptus gomphocephala (tuart), *E. marginata* (jarrah), *Corymbia calophylla* (marri), *Banksia attenuata*, *B. menziesii* and *B. sessilis* and were generally associated with grey sandy soils on plains, low undulating dune systems or limestone out cropping. The eucalypt and *Banksia* woodlands ranged from degraded to excellent condition and provided particularly high habitat value for fauna species due to the variety of microhabitats and various resource niches available (i.e. fallen logs, hollows, leaf litter, sandy soil and foraging plant species).


Portions of the survey area demonstrated large amounts of dumped rubbish including boats, cars, building materials, house hold rubbish and vegetation. The particularly affected areas were those just off Hester Ave and Romeo Road including the Romeo Road extension. In most cases the dumped rubbish kills/impacts on vegetation survival reducing habitat available for some species. Other species were recorded to utilise the rubbish such as the Marble Gecko, Mulga Snake and Bobtail that were recorded underneath sheet iron and super six fencing. Pollutants from the rubbish dumping was also evident including oils, car parts, paint and other liquid contaminants. Most fencing surrounding the private lands or remnant areas had been cut or flattened.


Some areas have been highly degraded by historical clearing (fire breaks, tracks, old farms) and provide very little to no habitat value for most fauna species as these areas are generally devoid of vegetation. Roadside vegetation may provide some shelter and opportunistic food for some bird species.


4.2.2 Fauna habitat within the extended survey area


Eight of the nine fauna habitat types identified in the survey area also occurred in the extended survey area. Pine plantation was not represented, whereas Open water with riparian vegetation and weeds is an additional fauna habitat present in the extended survey area, in association with Lake Nowergup. The fauna habitat of the survey area and extended survey area is described further in Table 4-10 and mapped in Figure 8, Appendix A.


Table 4-10 Fauna habitats in the survey areas


Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Banksia woodland</p> <p>Corresponding vegetation types: VT01, VT05</p> <p>Woodlands of <i>Banksia attenuata</i>/<i>B. menziesii</i> (with occasional <i>Eucalyptus</i>/<i>Corymbia</i> species, <i>B. grandis</i> and <i>Allocasuarina fraseriana</i>) over shrubland of <i>Hibbertia hypericoides</i>, <i>Xanthorrhoea preissii</i> and <i>Acacia pulchella</i> over dense understorey of <i>Mesomelaena pseudostygia</i>, weedy grasses and herbs and <i>Desmocladius flexuosus</i> on grey to brown sand.</p> <p>This habitat type dominates the survey area and extended survey areas and contains good structural diversity and a variety of micro-habitat types including patches of thick leaf litter, fallen logs and branches. Patches showed evidence of historical fire but was mostly long unburnt. Areas where public or trade workers can access often had dumped rubbish and worn tracks. Most tracks were on existing features however some areas showed driving over vegetation. Overall the vegetation is in excellent condition. There are no water ways in the habitat type.</p> <p>Conservation Significant Fauna</p> <p>Four conservation significant species were recorded utilising this habitat type including Forest Red-tailed Black Cockatoo, Carnaby's Black Cockatoo, Southern Brown Bandicoot and Western Brush Wallaby. The Forest Red-tailed Black Cockatoo and Carnaby's Cockatoo were recorded loafing and feeding in the habitat. Feeding was recorded in <i>Banksia attenuata</i> (cones), <i>B. grandis</i> (flowers), scattered Jarrah, Marri and <i>Allocasuarina</i> (nuts). This habitat would be a highly utilised resource (core foraging habitat) for these species. The Southern Brown Bandicoot and Western Brush Wallaby would utilise this habitat daily and be considered core habitat. The Peregrine Falcon would opportunistically utilise this habitat for foraging only. The Black Striped Snake and Jewelled South West Ctenotus are likely to utilise this habitat particularly in areas of deep sands would be considered core habitat.</p> <p>Habitat Significance- High</p>	<p>Survey area – 97.25 ha</p> <p>Extended survey area – 259.11 ha</p>	


Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Tuart Forest</p> <p>Corresponding vegetation types: VT02, VT04, VT14</p> <p>Forest/woodlands of <i>Eucalyptus gomphocephala</i> over sparse shrubland of <i>Xanthorrhoea preissii</i>, <i>Acacia saligna</i>, <i>Rhagodia baccata</i> and <i>Hakea lissocarpa</i> over sparse understorey of weedy grasses and herbs in deep dark brown sand.</p> <p>This habitat type contains good structural diversity and a mosaic of micro-habitat types which are closely associated with the fire history in the area. Mostly the habitat was long unburnt and good log and ground cover was present. Some logs showed hollows suitable for use by small mammals and reptiles. Free standing Tuarts often had hollows present and large ones would be considered suitable for Black Cockatoo although no breeding was recorded during the survey. Other breeding bird species were recorded and include Tree Martin, Galah, Australian Ringneck and Elegant Parrot. All hollows small and large demonstrated some use by bees, both free standing and on the ground. Litter was generally present on the ground however in areas of dense weed cover was overgrown litter was not visible. There were no waterways in this habitat type however the habitat surrounding Lake Nowergup (outside of the riparian zone) was Tuart Forest.</p> <p>Conservation Significant Fauna</p> <p>Three conservation significant species were recorded utilising this habitat type including Forest Red-tailed Black Cockatoo, Carnaby's Cockatoo and Southern Brown Bandicoot. The Forest Red-tailed Black Cockatoo and Carnaby's Cockatoo were recorded loafing in the habitat. This habitat would have hollows suitable for Black Cockatoo breeding and one suspected breeding tree was recorded within the extended survey, no breeding was recorded in the survey area. Roosting was recorded in this habitat type. The Southern Brown Bandicoot would utilise this habitat daily and be considered core habitat. The Peregrine Falcon would opportunistically utilise this habitat for foraging and may utilise large hollows or branch platforms from breeding.</p> <p>Habitat Significance- High</p>	<p>Survey area – 17.27 ha</p> <p>Extended survey area – 25.44 ha</p>	


Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Jarrah woodland</p> <p>Corresponding vegetation types: VT03, VT06</p> <p>Woodland of <i>Eucalyptus marginata</i> and <i>Banksia grandis</i> with scattered <i>Corymbia</i>, <i>B. attenuata</i>/<i>B. menziesii</i> over shrubland of <i>Hibbertia hypericoides</i>, <i>Xanthorrhoea preissii</i> and <i>Acacia pulchella</i> over dense understorey of <i>Mesomelaena pseudostygia</i>, weedy grasses and herbs and <i>Desmocladius flexuosus</i> on grey to brown sand.</p> <p>The habitat values of this habitat type varies according to the complex combination of fire (old and more recent – 5 to 10 years), disease (potential dieback), condition (structural and species diversity) of the vegetation and the proximity of the habitat to disturbed area. This habitat has logs present but few had hollows. Free standing Jarrah often had small hollows present but large ones were uncommon and scattered. Where large hollows were present these would be considered suitable for Black Cockatoo although no breeding was recorded during the survey. Other breeding bird species were recorded and include Galah and Elegant Parrot. All hollows small and large demonstrated some use by bees, both free standing and on the ground (in Jarrah stems). Litter and debris was common and would be utilised by ground dwelling species.</p> <p>Conservation Significant Fauna</p> <p>Four conservation significant species were recorded utilising this habitat type including Forest Red-tailed Black Cockatoo, Carnaby’s Black Cockatoo, Southern Brown Bandicoot and Western Brush Wallaby (on the edge). The Forest Red-tailed Black Cockatoo and Carnaby’s Cockatoo were recorded loafing and feeding in the habitat. Feeding was recorded in Jarrah, Marri, <i>B attenuata</i> (cones) and <i>B. grandis</i> (flowers). Where large hollows are present they May be utilised by Black Cockatoo, however no breeding was recorded during the field survey. Roosting was recorded in this habitat type. This habitat would be a highly utilised resource (core foraging habitat) for these species. The Southern Brown Bandicoot and Western Brush Wallaby would utilise this habitat daily and be considered core habitat. The Peregrine Falcon would opportunistically utilise this habitat for foraging and may utilise large hollows or branch platforms from breeding. The Black Striped</p>	<p>Survey area – 15.97 ha</p> <p>Extended survey area – 90.73 ha</p>	



Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Snake and Jewelled South West Ctenotus are likely to utilise this habitat particularly in areas of deep sands would be considered core habitat.</p> <p>Habitat Significance- High</p>		
<p>Mixed Heathland Corresponding vegetation types: VT07, VT08, VT09 The Mixed Heathlands is a mosaic habitat of low shrubs dominated by <i>Banksia sessilis</i>, <i>Melaleuca systena</i>, <i>M. Huegelii</i>, <i>Spyridium globulosum</i>, <i>Xanthorrhoea preissii</i> and <i>Calothamnus</i> sp. This habitat type occurs across the survey area and is associated with heathlands on limestone outcropping or limestone rocky soils. The majority of the heathland areas appear long unburnt (> 20 years) given the size and density of the habitat. The dense heathland provides good foraging and breeding opportunities for small native ground mammals, birds and reptiles. Small skinks, geckos and snakes were raked from sandy spoil heaps along the track during the survey. It is the only habitat that the Honey Possum was recorded. Fallen timber was not present however clumps of dead shrubs and <i>Xanthorrhoea</i> were scattered in this habitat type and provide good cover for ground dwelling species. Leaf-litter was scattered and densest under shrubs. Litter was absent from those areas where fauna had created runways or rest spots through the heathland.</p> <p>Conservation Significant Fauna Three conservation significant species were recorded utilising this habitat type including Carnaby's Black Cockatoo, Peregrine Falcon and Southern Brown Bandicoot. The Carnaby's Cockatoo were recorded feeding in this habitat particularly on <i>Banksia sessilis</i>. The Peregrine Falcon was recorded flying overhead in this habitat and would likely utilise this habitat for foraging/hunting. The Southern Brown Bandicoot was recorded in this habitat and be considered core habitat. The Western Brush Wallaby would opportunistically utilise this habitat. The</p>	<p>Survey area – 45.95 ha Extended survey area – 123.00 ha</p>	

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Black Striped Snake and Jewelled South West Ctenotus are likely to utilise this habitat particularly in areas of sands incursion.</p> <p>Habitat Significance- High</p>		
<p>Acacia shrubland Corresponding vegetation type: VT11 This habitat type is present in the extended survey area in the north western portion. The <i>Acacia</i> shrubland consists of <i>Acacia rostellifera</i>, <i>Melaleuca systema</i> and <i>Spyridium globulosum</i> closed shrubland over <i>Hibbertia hypericoides</i>, <i>Acanthocarpus preissii</i> and a sparse shrubland over an understorey dominated by introduced herbs (<i>*Euphorbia terracina</i>, <i>*Carpobrotus edulis</i>, <i>*Asparagus asparagoides</i>) and grasses (<i>*Vulpia myuros</i>, <i>*Bromus diandrus</i>, <i>*Ehrharta calycina</i>, <i>*Lagurus ovatus</i>).</p> <p>This habitat type was long unburnt and had a very thick layer of litter and wood debris under storey over deep sand. This habitat was also present on low dunes and within the swales. Traversing this habitat was difficult due to the thickness of some areas. Portions of this habitat had been impacted by off road vehicles and motorbikes with numerous tracks and degraded areas. Dumping of rubbish was also evident. Faunal presence was restricted but unique with it being the only location the Mulga Snakes were recorded. This habitat would also be utilised by a number of other coastal species such as skinks, burrowing reptiles, small birds, and mammal species. These areas also provides ideal habitat for the Black-striped Snake and other burrowing snakes.</p> <p>Conservation Significant Fauna No conservation significant species were recorded utilising this habitat type. The Southern Brown Bandicoot and Western Brush Wallaby are likely to utilise it due to it having very dense cover. The Peregrine Falcon would opportunistically utilise this habitat for foraging. The Black Striped Snake is likely to utilise this habitat due to the deep sands would be considered core habitat.</p>	<p>Survey area – 0.07 ha Extended survey area – 13.23 ha</p>	 <p>Parabolic dunes in the back ground</p>

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
Habitat Significance- Medium		
<p>Parabolic dunes Corresponding vegetation type: VT10 This habitat type is present in the extended survey area in the north western portion. The parabolic dunes comprise scattered low shrubs of <i>Melaleuca systema</i> over a low forbland of <i>Lomandra maritima</i>, <i>Acanthocarpus preissii</i> and <i>Conostylis candicans</i> over a groundcover dominated by <i>Desmocladius flexuosus</i> and introduced grasses and herbs (<i>*Euphorbia terracina</i>, <i>*Avena barbata</i> and <i>*Lagurus ovatus</i>).</p> <p>The dunes are low to approximately 8 meters and comprise deep white sands. Vegetation is sparse and low an artefact of a wind swept system, limiting the amount of ground cover and litter. Additionally the area has been impacted by off road vehicles and motorbikes with numerous tracks and degraded areas throughout the site. Dumping of rubbish was also evident. Faunal presence was restricted but unique with it being the only location <i>Lerista lineopunctata</i> and White-backed Swallows were recorded. This habitat would also be utilised by a number of other coastal species such as skinks, burrowing reptiles, small birds, and mammal species. These areas also provides ideal habitat for the Black-striped Snake and other burrowing snakes.</p> <p>Conservation Significant Fauna No conservation significant species were recorded utilising this habitat type. The Southern Brown Bandicoot and Western Brush Wallaby may utilise portions of it however use would be opportunistic and limited. The Peregrine Falcon would opportunistically utilise this habitat for foraging. The Black Striped Snake is likely to utilise this habitat due to the deep sands would be considered core habitat.</p> <p>Habitat Significance- Medium</p>	<p>Survey area – 0.49 ha Extended survey area – 5.47 ha</p>	

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Open water with riparian vegetation and weeds Corresponding vegetation types: VT13, VT17 This habitat type occurs across a small portion of the extended survey area and comprises an ephemeral lake (Lake Nowergup) that supports an exterior reed bed of <i>Typha</i> and scattered <i>Melaleuca</i>. The ground cover/understory is an assortment of introduced weeds which is densely matted. Scattered logs and branches were present but limited. This habitat appeared long unburnt (> 20 years) based on limited burn scaring. The lake appears seasonally inundated and provides the only open water body habitat within the survey or extended survey area. Numerous water birds were in this environment, including frogs (two species calling). The water bodies would also be utilised by most fauna species as a water source.</p> <p>Conservation Significant Fauna No conservation significant species were observed utilising this habitat. However the water body is likely to be used opportunistically by Black Cockatoo and other mobile species such as the Peregrine Falcon, Western Brush Wallaby and Southern Brown Bandicoot.</p> <p>Habitat Significance- High</p>	<p>Extended survey area – 20.36 ha</p>	

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Natural Regrowth Corresponding vegetation type: VT15 Areas comprise portions of the previous works associated with the construction of the rail corridor. The habitat comprises remnant natives, plantings and modified natural regrowth of <i>Banksia attenuata</i>, <i>Acacia</i>, Jarrah (small) and mixed shrubs. Natural regrowth was scattered and with an understorey dominated by introduced grasses and herbs. Logs and woody debris were scattered and litter was associated to <i>Banksia</i> and shrubs with areas of bare ground present in between vegetation.</p> <p>Conservation Significant Fauna No conservation significant species were observed utilising this habitat. However the habitat is likely to be used opportunistically by Black Cockatoo (foraging) and other mobile species such as the Peregrine Falcon, Western Brush Wallaby and in denser areas the Southern Brown Bandicoot. The Black Striped Snake is likely to utilise this habitat due to the deep sands but restricted to dense litter areas.</p> <p>Habitat Significance- Medium</p>	<p>Survey area – 13.58 ha Extended survey area – 3.53 ha</p>	

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>Pine plantation Corresponding vegetation type: VT16 A small pine plantation was present near to Wanneroo Road in the survey area. The plantation is managed and likely utilised as a harvested tree. The plantation may opportunistically be utilised by fauna species but would be an ongoing food supply for the Carnaby's Black Cockatoo.</p> <p>Conservation Significant Fauna No conservation significant species were recorded utilising this habitat type. The Peregrine Falcon would opportunistically utilise this habitat for foraging.</p> <p>Habitat Significance- Low but is a core feeding species for Carnaby's Black Cockatoo</p>	<p>Survey area – 0.43 ha</p>	
<p>Scattered natives over weeds, Cleared/highly disturbed Corresponding vegetation types: VT12, VT18 This habitat type occurs in the cleared areas (old farm) in the north west portion of the extended survey area plus areas along Wanneroo Road, Romero Road and publicly disturbed areas within the survey area. The soils are mostly sand with small areas of limestone incursion. Some impacted areas within the limestone incursion appeared to be due to the removal of <i>Xanthorrhoea preissii</i>. Dumped rubbish was also present in areas. This habitat is mostly disturbed however the isolated scattered shrubs and trees may provide habitat and linkage for birds and mobile mammals traversing the environment. Due to the nature of the habitat present both native and introduced grazers were recorded. Limited fallen branches, logs or hollows were present in this habitat type and were present only under the scattered trees.</p> <p>Conservation Significant Fauna</p>	<p>Survey area – 206.96 ha Extended survey area – 105.62 ha</p>	

Broad Fauna Habitat Types	Location (survey area/extended survey area) and extent (ha)	Representative photograph
<p>No conservation significant species were recorded utilising this habitat type. The Peregrine Falcon and Black Cockatoo would opportunistically utilise this habitat for foraging.</p> <p>Habitat Significance- Low but is a core feeding species for Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo</p>		

4.2.3 Habitat corridors and linkages

Habitat within the survey and extended survey area currently form part of the Neerabup National Park, Neerabup Nature Reserve and associated Bush Forever sites. These bushland areas form part of a vegetated corridor that runs north to south partially bound by railways, the existing Mitchell Freeway and portions of Wanneroo Road. The vegetation within the PTA rail boundary is currently fenced off with 2.5 m high chain mesh fencing which presents a barrier to movement of ground dwelling fauna between remnant vegetation to the east and west of the existing railway. The majority of the survey area and extended survey area west of the railway has been cleared or is currently being cleared for urban development, with only small patches of remnant vegetation remaining.

The areas of remnant vegetation in and immediately surrounding the survey and extended survey areas form part of a regionally significant contiguous bushland/wetland linkage (GoWA 2000). A large proportion of this vegetation is currently protected as national park, reserves and a series of Bush Forever sites (Government of Western Australia 2000). The vegetation within Neerabup National Park (Bush Forever site 383) is linked to vegetation to the north, south (Bush Forever site 299, across the road), east and west (Site 323, through bushland to Site 397); and is part of Greenways 35, 2, 5 (Tingay, Alan and Associates 1998). Neerabup National Park provides a north/south narrow corridor to allow movement of animals along the coastal plain and associated wetlands.

4.2.4 Habitat Scatter Plot

The similarity between sites based on the GHD trapping data was examined using PRIMER. The cluster analysis (Plate 4-11) and resulting dendrogram (Plate 4-12) showed that according to the species recorded the habitat surveyed, some demonstrate uniqueness in the species recorded and with habitats isolated or clustered. This is particularly the case for the woodlands where Sites 2, 8, 5 (both Tuart and Jarrah woodlands) are clustered with mixed heathland (Sites 3 and 6) together. The remaining sites, *Banksia* shrublands demonstrate overlap and similarities to all sites. Particularly site 1 which clumps with woodlands within the dendrogram. These results are not surprising due to the relatively small survey area and the amount of overlap and variation throughout the survey area.

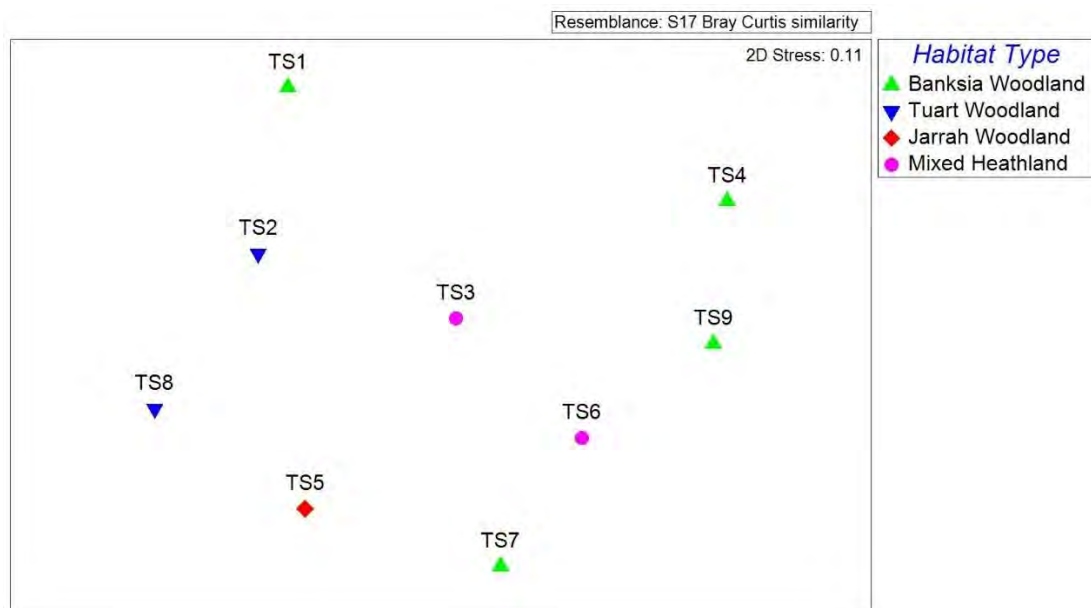


Plate 4-11 Cluster Analysis Habitats based on trapping data

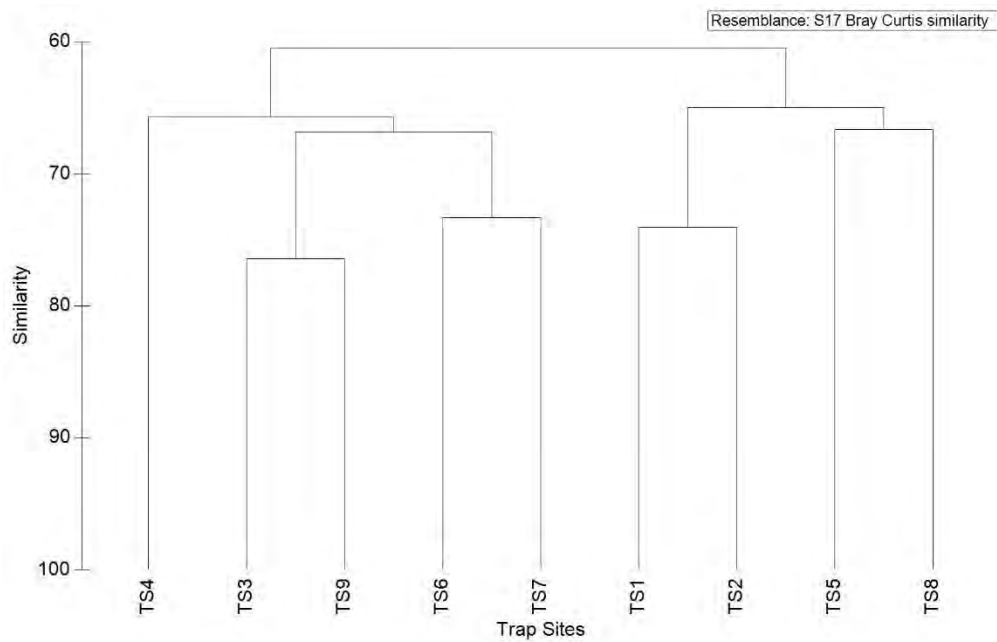


Plate 4-12 Dendrogram of Habitats based on trapping data

4.2.5 Fauna assemblages and abundance

The October/November (Level 2) 2018 fauna surveys recorded species within both the survey area and extended survey area. Within the survey area 124 vertebrate fauna species were recorded, including 17 mammals, 74 birds, 32 reptiles and one frog. Within the extended survey area 96 species were recorded and included 15 mammals, 57 birds, 22 reptiles and 2 frogs. Many of the species recorded in the survey and extended survey areas were the same, therefore when combined the trapping program recorded 140 vertebrate fauna species utilising the survey area, including 17 mammals, 85 birds, 35 reptiles and three amphibians. Of these 12 introduced species were identified and were all mammals and birds.

The compiled species list can be found in Appendix E. A breakdown of the fauna assemblages is provided below.

Although many of the species recorded in the survey and extended survey areas were the same, the extended survey area had a large wetland (Lake Nowgerup) present and therefore demonstrated additional species. These species will not be present within the survey area therefore the below breakdown of the fauna assemblages is for the survey area only.

Mammals

The surveys recorded 17 mammal species within the survey area, including six introduced and 11 native mammals. The composition of native species includes five bats, two macropod, Honey Possum, Possum, Bandicoot, Echidna and six introduced mammals. The most specious family was the microchiropteran Vespertilion bats (3 species), macropods (two species), Molossid bats (two species), Canids (two species), Murids (two species) with felid, Phalangerid, Leporid, Peramelid, Tarsipedid and Tachyglossid each having a single species.

One hundred and eleven individual mammals (excluding camera and bats data) were recorded over the trapping program between 9 species, with the most abundant being the Western Grey Kangaroo and Southern Brown Bandicoot. Thirty seven Western Grey Kangaroo sightings were recorded (33% of total native mammal recordings) with 30 Southern brown Bandicoot (27% of total native mammal recordings).

Bats were only recorded via echolocation, therefore only presence or absence information could be collected. Some species overlap in call identification and therefore may represent multiple species (such as in the *Nyctophilus* group). In any case, in this region there are no species of conservation significance. A breakdown of mammal families recorded during the surveys is provided in Table 4-11.

Table 4-11 Mammal families recorded during the field surveys

Mammal Family	No. of species
Canidae (Dog)	2
Felidae (Cat)	1
Leporidae (Rabbit)	1
Molossidae (Freetail Bats)	2
Muridae (Rodents)	2
Macropodidae (Kangaroos)	2
Peramelidae (Bandicoots)	1
Phalangeridae (Honey Possum)	1
Tachyglossidae (Echidna)	1
Tarsipedidae (Honey Possum)	1
Vespertilionidae (Bats)	3
Total	17

Birds

The bird surveys identified 74 bird species from 31 families. Of the 74 species five are introduced. The most specious families were the Meliphagidae (eight species), Acanthizidae (six species) and Accipitridae (six species). One thousand four hundred and thirty eight individual bird sightings were recorded over the trapping program. The most abundant species were the Brown Honeyeater with 164 records (11% of total bird recordings), New Holland Honeyeater with 149 records (10% of total bird recordings), Carnaby's Cockatoo with 82 records (6% of total bird records) and Galah with 69 records (5% of total bird recordings). A breakdown of bird families recorded during the survey is provided in Table 4-12.

Table 4-12 Bird families recorded during field surveys

Bird Family	No. of species
Accanthizidae (Weebill/Gerygone)	6
Accipitridae (Diurnal birds of prey)	6
Artamidae (Magpie group)	3
Cacatuidae (Cockatoo group)	5
Campephagidae (Cuckoo-shrikes)	2
Casuariidae (Emu)	1
Columbidae (Doves)	5
Corvidae (Crows)	1
Cuculidae (Cuckoos)	3
Falconidae (Falcons)	4
Halcyonidae (Kingfishers)	1
Hirundinidae (Swallows)	2
Maluridae (Wrens)	2
Meliphagidae (Honeyeaters)	8
Meropidae (Bee eater)	1
Monarchidae (Lark)	1
Motacillidae (Pipit)	1

Bird Family	No. of species
Nectariniidae (Mistletoebird)	1
Neosittidae (Sittella)	1
Pachycephalidae (Whistlers)	3
Pardalotidae (Pardalote)	1
Petroicidae (Robin)	2
Phasianidae (Quail)	1
Podargidae (Frogmouth)	1
Psittacidae (Parrots)	5
Rhipiduridae (Fantail)	2
Strigidae (Boobook)	1
Threskiornithidae (Ibis)	1
Tytonidae (Owl)	1
Timaliidae (Silvereye)	1
Turnicidae (Button Quail)	1
Total	74

Reptiles

A total of 32 reptile species were recorded during the field surveys from eight families. The most specious families were Scincidae (14 species), Elapidae (7 species) and Pygopodidae (5 species). Six hundred and seven reptile captures were recorded in the survey area over the trapping program. The most abundant species were Two-toed Earless Skink with 117 records (19% of total reptile recordings), West Coast Ctenotus with 91 records (15% of total reptile recordings) and Bobtail with 69 records (11% of total reptile recordings). A breakdown of reptile families recorded during the survey is provided in Table 4-13.

Table 4-13 Reptile families recorded during the field surveys

Reptile Family	No. of species
Agamidae (Dragons)	1
Diplodactylidae (Geckos)	1
Elapidae (Snakes)	7
Gekkonidae (Geckos)	1
Pygopodidae (Legless Lizards)	5
Scincidae (Skinks)	14
Typhlopidae (Blind Snakes)	1
Varanidae (Monitors)	2
Total	32

Amphibians

One amphibian species was recorded in the survey area. The species recorded was the Pobblebonk (*Lymnodynastes dorsalis*) a member of Myobatrachidae family. Two individuals were recorded during the survey.

4.2.6 Species Accumulation

As an indication of fauna trapping effectiveness, an accumulation curve was run for the data collected during the field survey within 8 models in Primer V6. The best fit model was UGE (Plate 4-13). The UGE curve reaches a curve asymptote (very few new species were recorded) after trap night 10. The curve asymptote (model levelling) is demonstrated by the end of the survey indicating that of the species active at the time of the survey a majority of them were sampled prior to the end of the trapping program. This is also comparable to the raw data of

which the known species in the region (of reptile, small mammal and frogs) approximately 52 could utilise the habitats present in the survey area (based on *NatureMap* records). This study recorded 35 species similar in numbers to the dendrogram.

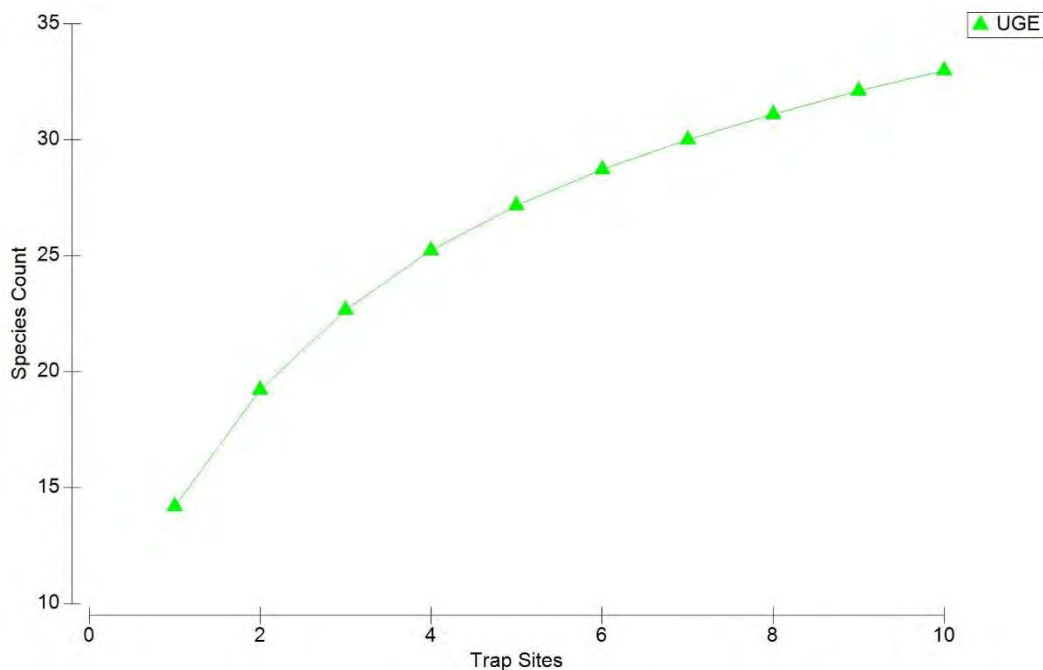


Plate 4-13 Species accumulation for the trapping program

4.2.7 Comparisons to other surveys in the area

The results in this assessment gave a higher species count than those undertaken in the Neerabup National Park and surrounds previously. This is likely due to the large survey area, diversity of habitats and effort undertaken during the survey period. Table 4-14 shows the numbers of birds, reptiles, mammals and amphibian per survey. The complete species list per survey is captured in Appendix E.

Table 4-14 Comparison of numbers of species per previous surveys

Projects	Level of Assessment	Birds	Reptiles	Mammals	Amphibia	Totals
This survey	Level 2	85	35	17	3	140
CALM 1993	Level 2	43	15	8	2	68
DPaW 2013	Level 2	20	18	10	0	48
GHD 2014b	Level 2	59	25	13	1	98
MRIA 2018	Level 2	52	21	9	1	83
GHD 2014a	Level 1	48	7	7	0	62
Maryan pers comm. 1996-2004	Level 1	0	34	0	3	37

4.2.8 Locally significant fauna

Locally significant fauna are also those which are not formally listed under State or Commonwealth legislation or listed as Priority fauna by the DBCA but are considered to have a

restricted distribution on the Swan Coastal Plain or have dramatically declined in numbers since European settlement (GoWA 2000).

Twenty six bird species recorded during the survey are considered to be significant birds of the Swan Coastal Plain portion of the Perth Metropolitan Region (GoWA 2000). This includes:

- Twelve birds listed as category 3: Inland Thornbill, Yellow-rumped Thornbill, Western Thornbill, Weebill, White-browed Scrubwren, Painted Button Quail, Common Bronzewing, Splendid Fairy-wren, Varied Sittella, Grey Shrike-thrush, Golden Whistler, and Scarlet Robin
- Fourteen birds listed under category 4: Collared Sparrowhawk, Brown Goshawk, Wedge-tailed Eagle, Whistling Kite, Little Eagle, Brown Falcon, Peregrine Falcon, Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Emu, New Holland Honeyeater, White-cheeked Honeyeater, Little Wattlebird and Black-faced Woodswallow.

These species are either habitat specialists with a reduced distribution on the Swan Coastal Plain or are wide-ranging species with reduced populations on the Swan Coastal Plain.

The Mulga Snake, Reticulated Whip Snake, Western Slender Blue-tongue, Western Blue-tongue, Javelin Legless Lizard, Gould's Hooded Snake, all the Bat species, Honey Possum, Common Brushtail Possum and Echidna would also be considered to be locally significant fauna, even though they have large distributions they have declined or have limited distribution on the Swan Coastal Plain. Additionally the Mulga Snake, Western Blue-tongue and Javelin Legless Lizard are species that are on the southern edge of a more north distribution.

4.2.9 Introduced species

Mammals and birds comprised the only groups in which introduced fauna were recorded. In total 11 species were observed and included:

- Dog (*Canis domesticus*)
- Red Fox (*Vulpes vulpes*)
- Cat (*Felis catus*)
- European Rabbit (*Oryctolagus cuniculus*)
- House Mouse (*Mus musculus*)
- Black Rat (*Rattus rattus*)
- Rainbow Lorikeet (*Trichoglossus haematodus*)
- Laughing Kookaburra (*Dacelo novaeguineae*)
- Spotted Dove (*Streptopelia chinensis*)
- Laughing Dove (*Streptopelia senegalensis*)
- Feral Pigeon (*Columbia livia*).

Of the species recorded the Dog evidence was likely roaming or walked animals by neighbouring properties, while the remaining species are considered feral fauna species to the region.

4.2.10 Conservation significant fauna

Five conservation significant fauna species were recorded within the survey area during the field survey. These included:

- Carnaby's Cockatoo (*Calyptorhynchus latirostris*) – listed as Endangered under the BC Act and Endangered under the EPBC Act
- Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*) – listed as Vulnerable under the BC Act and Vulnerable under the EPBC Act
- Peregrine Falcon (*Falco peregrinus*) – listed as Other specially protected fauna under the BC Act
- Southern Brown Bandicoot (*Isodon fusciventer*) – listed as P4 by DBCA
- Western Brush Wallaby (*Notamacropus Irma*) – listed as P4 by DBCA.

Black Cockatoo evidence is presented in Figure 10, Appendix A, with Peregrine Falcon, Southern Brown Bandicoot and Western Brush Wallaby shown in Figure 11, Appendix A.

Likelihood of Occurrence assessment

In addition to the field survey results, an assessment on the likelihood of conservation significant species occurring in the survey area and extended survey area was undertaken. This assessment is based on species' biology, habitat requirements, the quality and availability of suitable habitat as determined during the field survey, and records of the species in the survey area and locality. Species-specific searches of the DBCA *NatureMap* database with a buffer radius of 5 km were also conducted in order to gather information about the broader regional occurrence of species to further inform the likelihood of occurrence assessment. Some species identified in the PMST are not realistically considered to occur in the survey area or are not terrestrial vertebrate species and have been excluded from the assessment (i.e. marine species).

In total 25 species (2 mammals, 2 reptile and 21 birds) were recorded from desktop assessment as potentially occurring in the survey areas. Of these, five were recorded and two are likely to utilise the habitats present in the survey area. Table 4-15 summarises the species of conservation significance that are either known or considered likely to occur in the survey area.

There are six conservation significant species likely to be present in the extended survey area, in addition to the five known and two species considered likely to occur in the survey area. The larger number of species considered likely to occur is associated with the extended survey area incorporating Nowergup Lake, which provides habitat not found in the survey area. Table 4-15 summarises the species of conservation significance that are either known or considered likely to occur in the extended survey area.

The parameters of assessment for this likelihood of occurrence assessment and the full likelihood of occurrence assessment are provided in Appendix E.

Table 4-15 Summary of species known or likely to occur in the survey area

Species name	Status			Likelihood of occurrence	
	EPBC Act	BC Act	DBCA	Survey area	Extended survey area
<i>Calyptorhynchus latirostris</i> Carnaby's Black Cockatoo	EN	EN		Known – The species was recorded during the survey	Known – The species was recorded during the survey
<i>Calyptorhynchus banksii naso</i> Forest Red-tailed Black Cockatoo	VU	VU		Known – The species was recorded during the survey	Known – The species was recorded during the survey
<i>Falco peregrinus</i> Peregrine Falcon		OS		Known – The species was recorded during the survey	Known – The species was recorded during the survey
<i>Isoodon fusciventer</i> Southern Brown Bandicoot			P4	Known – The species was recorded during the survey	Known – The species was recorded during the survey
<i>Notamacropus irma</i> Western Brush Wallaby			P4	Known – The species was recorded during the survey	Known – The species was recorded during the survey
<i>Botaurus poiciloptilus</i> Australasian Bittern	EN	EN		Highly Unlikely - There is no suitable habitat for this species within the survey area.	Likely - There is suitable habitat for this species around Nowergup Lake.
<i>Rostratula australis</i> Australian Painted Snipe	EN, Mi	EN		Highly Unlikely - There is no suitable habitat for this species within the survey area.	Likely - There is suitable habitat for this species at Nowergup Lake.
<i>Neelaps calonotos</i> Black-striped Snake			P3	Likely - Suitable habitat for the Black-striped Snake is present within the survey area and there are a number of records within the study area.	Likely - Suitable habitat for the Black-striped Snake is present within the survey area and there are a number of records of this species within the study area
<i>Ctenotus gemmula</i> Jewelled southwest Ctenotus(Swan Coastal Plain population)			P3	Likely - There is suitable habitat present for this species within the survey area. The closest known record is approximately 13 km south east.	Likely - There is suitable habitat present for this species within the survey area. The closest known record is approximately 13 km south east.
<i>Oxyura australis</i> Blue-billed Duck			P4	Highly Unlikely - There is no suitable habitat for this	Likely - There is suitable habitat for

Species name	Status			Likelihood of occurrence	
	EPBC Act	BC Act	DBCA	Survey area	Extended survey area
				species within the survey area.	this species at Nowergup Lake.
<i>Actitis hypoleucos</i> Common Sandpiper	Mi	IA		Highly Unlikely - There is no suitable habitat for this species within the survey area.	Likely - There is suitable habitat for this species at Nowergup Lake.
<i>Calidris melanotos</i> Pectoral Sandpiper	Mi	IA		Highly Unlikely - There is no suitable habitat for this species within the survey area.	Likely - There is suitable habitat for this species at Nowergup Lake.
<i>Tringa nebularia</i> Common Greenshank	Mi	IA		Highly Unlikely - There is no suitable habitat for this species within the survey area.	Likely - There is suitable habitat for this species at Nowergup Lake.

Key – OS = Other Species Protection, Special Protection under BC Act. En= Endangered, Endangered under BC and EPBC Acts, VU= Vulnerable under BC and EPBC Acts, P3/4= Priority fauna listings under DBCA.

4.2.11 Targeted Black Cockatoo habitat assessment

Two species of Black Cockatoo, Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo were recorded during the survey.

Carnaby's Cockatoo is endemic to the south-west of Western Australia with a wide-spread distribution. Carnaby's Cockatoo nest in hollows of live or dead eucalypts, primarily smooth-barked Salmon Gum and Wandoo (Saunders 1979, 1982) though breeding has been reported in other wheatbelt tree species and some tree species on the Swan Coastal Plain and jarrah forest (Saunders 1979, 1982; Storr 1991; Johnstone and Storr 2004). Success in breeding is dependent on the quality and proximity of feeding habitat within 12 km of nesting sites (Saunders 1977, 1986; Saunders and Ingram 1987). Along with the trees that provide nest hollows, the protection, management and increase of this feeding habitat that supports the breeding of Carnaby's Cockatoo is a critical requirement for the conservation of the species.

The Forest Red-tailed Black Cockatoo is endemic to the south-west humid and sub-humid zones of Western Australia (Mawson and Johnstone 1997). It inhabits the dense Jarrah, Karri (*E. diversicolor*) and Marri forests receiving more than 600 mm of annual average rainfall. The current distribution is north of Perth and east to Mount Helena, Christmas Tree Well, North Banister, Mt Saddleback, Rocky Gully and the upper King River (Johnstone 1997). More recently the species has been utilising and persisting on the northern portions of the Swan Coastal Plain and is now considered a regular sighting (Johnstone et al 2017). Habitats in which the Forest Red-tailed Black Cockatoo occurs at Bungendore Park and Jarrahdale, have an understorey of Bull Banksia (*Banksia grandis*), Snottygobble (*Persoonia longifolia*), Sheoak (*Allocasuarina fraseriana*) and *Banksia* spp., with scattered Blackbutt (*E. patens*) and Wandoo (*E. wandoo*) (Johnstone and Kirkby 1999). The Forest Red-tailed Black Cockatoo roosts in Jarrah-Marri-Blackbutt habitat on road-sides, paddocks or forest blocks. While the Forest Red-tailed Black Cockatoo feeds on the seeds of other species, around 90 per cent of its diet is made up of the seeds from Marri and Jarrah fruits.

Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo were recorded in both the survey and extended survey areas. Foraging, roosting and breeding data was recorded for all areas. Potential breeding trees were recorded in the survey area while tree plots were undertaken throughout the extended area. The results of this assessment are presented and summarised in Table 4-16.

Potential breeding tree assessment within survey area

Five hundred and seventy potential Black Cockatoo breeding trees were identified within the survey area. These consisted of 413 –Tuart; 132 – Jarrah; 22 – Marri; 2 – Flooded Gum; and 1 - *Eucalyptus* sp.

Of the 570 identified potential breeding trees 20 were identified to have medium to/or large hollows present suitable for Black Cockatoo breeding or demonstrating signs of historical use. These trees were all tuarts, had from 1 to 4 hollows present, and are presented as 'monitoring sites' in Figure 10. Table 4-17 details the hollow entrance size, height, depth and angle for the 20 potential breeding trees with medium to/or large hollows present.

No Black Cockatoo were recorded utilising the identified hollows over the assessment period (August, November and January/February 2018/19). The complete list of potential breeding trees identified in the survey area and notes associated with the hollow assessment are included in Appendix E.

Potential breeding tree plots assessment within extended survey area

Twenty nine tree plots were located within the extended survey area to provide an estimate of potential breeding tree densities (Table 4-18). One hundred and fifty one potential breeding trees were recorded, which equates to an average of 5-6 potential breeding trees per 0.25 ha. From the mix of trees recorded, these numbers would approximately constitute 3 Tuart, 2 Jarrah and 1 Marri.

Of the 29 plots, three trees demonstrated evidence of chews with one of these highly likely to be utilised by Black Cockatoo, although this was not able to be confirmed. Small, medium and large hollows were present within approximately 50% of plots.

Table 4-16 Summary of Black Cockatoo findings

Feature	Species	Survey area	Extended Survey area
Sightings	Carnaby's Black Cockatoo	Carnaby's Cockatoo individuals were recorded flying and foraging within the survey area. The largest group recorded consisted of 17 birds. The locations the birds were observed is shown in Figure 10.	Carnaby's Cockatoo individuals were recorded flying and foraging within the extended survey area. The largest group recorded consisted of 12 birds. The locations the birds were observed is shown in Figure 10.
	Forest Red-tailed Black Cockatoo	Forest Red-tailed Black Cockatoo individuals were recorded flying and foraging within the survey area. The largest group recorded consisted of 4 birds. The locations the birds were observed is shown in Figure 10.	Forest Red-tailed Black Cockatoo individuals were recorded flying and foraging within the extended survey area. The largest group recorded consisted of 7 birds. The locations the birds were observed is shown in Figure 10.
Foraging	Carnaby's Cockatoo	Feeding evidence was recorded in the survey area on <i>Banksia sessilis</i> , <i>B. attenuata</i> , <i>B. grandis</i> and Jarrah. Approximately 217.06 ha of suitable foraging habitat is mapped within the survey area. Refer to Figure 10.	Feeding evidence was recorded opportunistically in the extended survey area on <i>Banksia sessilis</i> , <i>B. attenuata</i> and Jarrah. Approximately 515.06 ha of suitable foraging habitat is mapped within the extended survey area. Refer to Figure 10.
	Forest Red-tailed Black Cockatoo	Feeding evidence was recorded in the survey area on <i>Allocasuarina</i> , Marri and Jarrah. Approximately 217.06 ha of suitable foraging habitat is mapped within the survey area. Refer to Figure 10.	Feeding evidence was recorded opportunistically in the extended survey area on <i>Allocasuarina</i> , Marri and Jarrah. Approximately 515.06 ha of suitable foraging habitat is mapped within the extended survey area. Refer to Figure 10.
Breeding	Carnaby's Cockatoo	No actual breeding was recorded	One possible breeding tree was recorded near to Lake Nowergup in tree plot 23. The main hollow is approximately 20 m high with a 30 cm entrance which has extensive chews. Tree is near -31.6312 and 115.7283. This data was restricted to tree plot assessment only a detailed assessment of breeding within the extended survey areas was not undertaken.
	Forest Red-tailed Black Cockatoo	No actual breeding was recorded	One possible breeding tree was recorded near to Lake Nowergup in tree plot 23. The main hollow is approximately 20 m high with a 30 cm entrance which has extensive chews. Tree is near -31.6312 and 115.7283. This data was restricted to tree plot assessment only a detailed assessment of breeding within the extended survey areas was not undertaken.

Feature	Species	Survey area	Extended Survey area
Roosting	Both Species	Five trees were identified over two locations in and bordering the survey area. See Figure 10	No roosting was recorded although assessment was opportunistic only.
Potential Black Cockatoo Breeding Trees	Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo	570 potential Black Cockatoo breeding trees (DBH > 500 mm) were recorded during the survey. These consisted of: 413 -Tuart 132 - Jarrah 22 - Marri 2 - Flooded Gum 1 - <i>Eucalyptus</i> sp.	Black Cockatoo breeding trees were not surveyed in the extended survey area; Black Cockatoo tree plots established. (See 'BC Tree Plots' cells below for discussion on potential Black Cockatoo breeding trees.)
Potential Black Cockatoo Breeding Trees with Suitable Nesting Hollows	Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo	Of the 570 identified potential breeding trees 20 were identified to have medium to/or large hollows present suitable for Black Cockatoo breeding or demonstrating signs of historical use. These trees had from 1 to 4 hollows present and were assessed via visual inspection and/or via a pole cam (if within 12 m from ground) in August, November and January/February 2018/19. No Black Cockatoo were recorded utilising the identified hollows over the assessment period. See Appendix E for data breakdown.	Black Cockatoo breeding trees were not surveyed in the extended survey area; Black Cockatoo tree plots established.
BC Tree Plots	Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo	Tree plots not established in the survey area.	In total 29 plots were recorded with Tuart (75 trees), Jarrah (50 trees) and Marri (26 trees) present consisting of 151 trees in total. From the plot data an average of 5-6 trees were recorded per 0.25 ha. From the ratio above would constitute 3 Tuart, 2 Jarrah and 1 Marri within a 50 x 50 m plot. Of the 29 plots 3 trees demonstrated evidence of chews with one of these highly likely to be utilised by Black Cockatoo, although this was not confirmed. Small, medium and large hollows were present within approximately 50% of plots.

Table 4-17 Potential breeding trees with suitable size hollows within survey area

Tree No.	DBH (mm)	Hollows Present	Hollow Entrance Size (cm)	Hollow Heights (m)	Breeding Evidence	Hollow Depth	Hollow Angle
T73	1410	3 large	all 20 plus	7, 9, 12	no evidence of use	7m >1m, 9m 40cm, 12m 30 cm	2x vertical, 1x 45
T78	920	3 large	16, 20, 24	7, 12, 15	potential old chews	7m is 30 cm deep	slight angle
T87	2500	2 large	2x 16	12 to 15	no evidence of use	12 m 10 cm, 15 m to high	almost vertical
T103	1300	1 large	16	6	no evidence of use	1m	almost vertical
T106	1600	4 large	all 20 plus	4, 6, 8, 12	no evidence of use	4 m approx 1 m, 6m 20 cm, 8 m 1.2m	2x vertical, 2x horizontal
T236	2200	1 large 1 small	20, 5	20, 3	no evidence of use	3 m 30 cm (bees)	vertical
T239	2200	2 large 2 medium	10, 15, 15, 10	6, 8, 8.5, 20	old chews present	6 m 10 cm, 8 m 10 cm, 8.5 m 10 cm	45 and vertical
T242	1800	2 large 1 medium	20, 10, 20	8, 15, 20	Possible internal chews	8 m 90 cm	vertical
T245	2000	3 large	20, 15, 20	25, 30, 10	no evidence of use	not assessed	45
T252	1600	2 large	15, 15	15, 25	old chews present	not assessed	45
T259	1300	2 large 1 medium	20, 20, 10	10, 16, 17	no evidence of use	10 m 20 cm, 2 large look good	vertical
T299	1200	2 large	2x 20	8, 11	old chews present	8 m >1 m, 11 m 1 m	vertical
T308	750	2 large 1 small	5, 30, 20	5, 7, 4	old chews present	5 m and 7 m same hollow. 1 m, 4 m 20cm	vertical and 45
T325	800	1 large	30	7	old chews present	1.2 m	vertical
T327	950	4 large	20, 20, 15, 25	3, 5, 6, 11	old chews present	3 m 10 cm, 5 m 10 cm, 6 m 10 cm, 11m 2m	vertical and 45
T486	1100	3 medium 1 small	5, 3x 10	8, 15, 15, 17	chews present	To high to assess	
T492	1350	3 large 3 small	30, 20, 15, 3x 5	7, 10, 11	1 large extensive chews	All >1 m	vertical
T526	1130	2 large	12, 20	5, 7	no evidence of use	>1m, couldnt see base	vertical, 45

Tree No.	DBH (mm)	Hollows Present	Hollow Entrance Size (cm)	Hollow Heights (m)	Breeding Evidence	Hollow Depth	Hollow Angle
T527	940	1 large	40, 20	7	no evidence of use	1 m	vertical
T549	1030	2 large	30, 16	5, 7	no evidence of use	40 cm, not checked second	45

Table 4-18 Tree Plots undertaken in the extended survey area

Tree Plots (50 x 50 m)	Tuart	Jarrah	Marri	Total trees	Hollows	Evidence of Breeding by Black Cockatoo
Tree Plot 1		7		7	4 large hollows	No evidence
Tree Plot 2		1	2	3	No hollows	-
Tree Plot 3		1	1	2	No hollows	-
Tree Plot 4	5	1		6	No hollows	-
Tree Plot 5	4			4	No hollows	-
Tree Plot 6	5			5	No hollows	-
Tree Plot 7	7			7	2 large hollows	No evidence, bees present
Tree Plot 8	4		4	8	1 large hollow	Galah scaring on hollow no Black Cockatoo evidence
Tree Plot 9	6	1		7	No hollows	-
Tree Plot 10	6			6	1 large hollow	No evidence
Tree Plot 11	4			4	No hollows	-
Tree Plot 12	3			3	No hollows	-
Tree Plot 13		4		4	2 small hollows	Elegant Parrots nesting, no Black Cockatoo evidence
Tree Plot 14	4			4	No hollows	-
Tree Plot 15		1	7	8	No hollows	-
Tree Plot 16	7		1	8	2 large hollows	No evidence
Tree Plot 17		2	4	6	1 large hollow	No evidence, bees present
Tree Plot 18			3	3	1 large hollow	No evidence
Tree Plot 19		1	3	4	No hollows	-
Tree Plot 20		4		4	No hollows	-
Tree Plot 21		8		8	2 large hollows	No evidence
Tree Plot 22		3		3	1 small hollow	No evidence
Tree Plot 23	9			9	1 large hollow	Evidence present on hollow at 20 m high entrance of 30 cm, chews present.
Tree Plot 24	8			8	1 medium hollow	No evidence
Tree Plot 25		8		8	2 large hollows	Galah scaring on 1 hollow no Black Cockatoo evidence
Tree Plot 26	2			2	5 large and 3 medium hollows	Old chews present on 2 hollows (over 2 trees) possible Black Cockatoo, bee in another hollow
Tree Plot 27	1		1	2	No hollows	-
Tree Plot 28		5		5	No hollows	-
Tree Plot 29		3		3	No hollows	-

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Appendices