Western Ringtail Possum (*Pseudocheirus occidentalis*) Recovery Plan

Wildlife Management Program No. 58

Western Australia Department of Parks and Wildlife

February 2017

Department of
Parks and Wildlife

Australian Government

Wildlife Management Program No. 58

Western Ringtail Possum (*Pseudocheirus occidentalis*) Recovery Plan

February 2017

Western Australia Department of Parks and Wildlife
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983

Foreword

Recovery plans are developed within the framework laid down in Department of Parks and Wildlife Policy Statements Nos. 44 and 50 (CALM 1992, 1994), and the Australian Government Department of the Environment's Recovery Planning Compliance Checklist for Legislative and Process Requirements (DEWHA 2008). Recovery plans outline the recovery actions that are needed to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process. Recovery plans are a partnership between the Department of the Environment and the Department of Parks and Wildlife. The Department of Parks and Wildlife acknowledges the role of the *Environment Protection and Biodiversity Conservation Act 1999* and the Department of the Environment in guiding the implementation of this recovery plan. The attainment of objectives and the provision of funds necessary to implement actions are subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

This recovery plan was approved by the Department of Parks and Wildlife, Western Australia. Approved recovery plans are subject to modification as dictated by new findings, changes in status of the taxon or ecological community, and the completion of recovery actions. Information in this recovery plan was accurate as of October 2016.

Recovery plan preparation: This recovery plan was prepared by Kim Williams, Adrian Wayne (Department of Parks and Wildlife) and Jeff Richardson (formerly Department of Environment and Conservation).

Acknowledgments: This recovery plan was prepared with funding provided by the Australian Government. Valuable contributions include those from Brad Barton, Sarah Comer, Paul de Tores, Sandra Gilfillan, Peter Hanly, Mia Podesta, Manda Page, Mark Pittavino, Martin Rayner, Warwick Roe, Abby Thomas, Deon Utber, Ian Wilson (all from Department of Parks and Wildlife or formerly from Department of Environment and Conservation) and Barbara Jones.

Citation: Department of Parks and Wildlife (2017). Western Ringtail Possum (*Pseudocheirus occidentalis*) Recovery Plan. Wildlife Management Program No. 58. Department of Parks and Wildlife, Perth, WA.

Cover photograph: Western Ringtail Possum (*Pseudocheirus occidentalis*). Photograph: Adrian Wayne (Department of Parks and Wildlife).

Disclaimer: The State of Western Australia and its employees do not guarantee that this publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence that may arise from you relying on any information in this publication.

© State of Western Australia Government Department of Parks and Wildlife 2017

Abbreviations

CALM	Department of Conservation and Land Management, Western Australia (changed to Department of Environment and Conservation in July 2006)
DAFWA	Department of Agriculture and Food, Western Australia
DEC	Department of Environment and Conservation, Western Australia (formerly CALM; changed to Department of Parks and Wildlife July 2013)
DER	Department of Environment regulation, Western Australia (formerly part of DEC)
DFES	Department of Fire and Emergency Services, Western Australia
DOP	Department of Planning, Western Australia
DoTE	Commonwealth Department of the Environment, formerly Department of Sustainability, Environment, Water, Population and Communities
DPaW	Department of Parks and Wildlife, Western Australia (formerly DEC)
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities, now Department of the Environment
EPA	Environmental Protection Authority, Western Australia
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FPC	Forest Products Commission, Western Australia
FMP	WA Forest Management Plan 2004-2013
IBRA	Interim Biogeographical Regionalisation for Australia
IUCN	International Union for Conservation of Nature
LGA	Local government authorities
NP	National Park
NR	Nature Reserve
NRM	Natural resource management groups
RFA	Regional Forest Agreement, Western Australia
SCB	Species and Communities Branch, DPaW
SF	State forest
SWALSC	South West Aboriginal Land and Sea Council
WA	Western Australia
WAPC	Western Australian Planning Commission

Contents

Foreword ii

Abbreviations iii

Summary v

1. Introduction 1

1.1 Description 1
1.2 Conservation status 1
1.3 Distribution 1
1.4 Abundance 3
1.5 Biology and ecology 4

2. Habitat critical to survival 6

3. Threatening processes 7

3.1 Habitat loss and fragmentation 7
3.2 Predation 8
3.3 Climate change 9
3.4 Timber harvesting 9
3.5 Fire 10
3.6 Competition for tree hollows 11
3.7 Habitat tree decline 12
3.8 Un-regulated relocation of orphaned, injured and rehabilitated western ringtail possums 13
3.9 Disease 14
3.10 Gaps in knowledge 14

4. International obligations 15

5. Affected interests 15

6. Role and interests of Aboriginal people 16

7. Social and economic interests 16

8. Broader biodiversity benefits 16

9. Existing conservation measures 18

10. Management practices and policies 19

11. Guide for decision-makers 20

12. Recovery 21

12.1 Recovery goals and objectives 21
12.2 Recovery Actions 22

15. Implementation and evaluation 34

16. References 35

Summary

Species: *Pseudocheirus occidentalis*

Family: Pseudocheiridae

IBRA Regions: Swan Coastal Plain, Northern Jarrah Forest, Southern Jarrah Forest, Warren, Esperance Plains

Department of Parks and Wildlife Regions:

Swan, South West, Warren, South Coast

Department of Parks and Wildlife Districts:

Swan Coastal, Perth Hills, Wellington, Blackwood, Donnelly, Frankland, Albany

Current conservation status:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act): Vulnerable.
- WA *Wildlife Conservation Act 1950* (WC Act): Schedule 1, rare or likely to become extinct: ranked as Critically Endangered (using IUCN criteria).

Habitat critical to survival:

Habitat critical to survival for western ringtail possums is not well understood, and is therefore based on the habitat variables observed where western ringtail possums are most commonly recorded. These appear to vary between key management zones. The common themes however are high nutrient foliage availability for food, suitable structures for protection/nesting, and canopy continuity to avoid/escape predation and other threats. Long-term survival of the species requires linkages between suitable habitat patches and as such habitat critical to survival incorporates this. Vegetation communities critical to the species include long unburnt mature remnants of peppermint (*Agonis flexuosa*) woodlands with high canopy continuity and high foliage nutrients (high in nitrogen and low toxin levels); jarrah (*Eucalyptus marginata*)/marri (*Corymbia calophylla*) forests and woodlands with limited anthropogenic disturbance (unlogged or lightly logged, and a low intensity and low frequency fire history), that are intensively fox-baited and have low indices of fragmentation; coastal heath, jarrah/marri woodland and forest, peppermint woodlands, myrtaceous heaths and shrublands, Bullich (*Eucalyptus megacarpa*) dominated riparian zones and karri forest. Any habitat where western ringtail possums occur naturally are considered critical and worthy of protection.

Threatening Processes

The threatening processes operating on the western ringtail possum are complex, interactive and are often population-specific. The main threatening processes addressed in this plan are:

- Habitat loss and fragmentation
- Predation
- Climate change
- Timber harvesting
- Fire
- Competition for tree hollows
- Habitat tree decline
- Un-regulated relocation of orphaned, injured and rehabilitated western ringtail possums
- Disease
- Gaps in knowledge.

Recovery goals and objectives

This recovery plan guides recovery actions for the western ringtail possum for the next 10 years. The 10 year goal is to:

- slow the decline in population size, extent and area of occupancy through managing major threatening processes affecting the subpopulations and their habitats, and allowing the persistence of the species in each of the identified key management zones: Swan Coastal Plain, southern forests and south coast.

It is acknowledged that over the period of this plan populations fringing key management zones are likely to decline due to a range of threatening processes. A change in the conservation status of this taxon to a more threatened category is likely within the life of this plan, before the reversal of the impacts of threatening processes can take effect.

The long term goals of the recovery program for the western ringtail possum extends beyond the life of this plan but are important to state to ensure a consistent, long term strategy:

- to improve the population status, leading to a reduction in the threat status, or the future removal of the western ringtail possum from the threatened species list of the EPBC Act and the WC Act; and
- to ensure that threatening processes do not compromise the ongoing viability of the western ringtail possum population.

The specific recovery objectives for the next 10 years are, in a general order of priority[1]:

- Habitat critical for survival for western ringtail possums is identified and protected in each key management zone.
- Threatening processes that are constraining the recovery of western ringtail possums are mitigated in each key management zone.
- An evidence-based approach is applied to the management and recovery of western ringtail possums.
- The management of displaced, orphaned, injured and rehabilitated western ringtail possums aids the conservation outcome for the species.
- Increased awareness of the status of western ringtail possums and support behaviour change to mitigate anthropogenic threatening processes.

Criteria for success:

This recovery plan will be deemed successful if, within a 10 year period, all of the following are achieved:

- habitat critical for survival of the western ringtail possum is defined, identified and protected in each of the key management zones;
- threatening processes constraining recovery of western ringtail possums are identified and effectively managed in the key management zones;
- an evidence-based approach is developed and applied to the management of western ringtail possums in each of the key management zones;
- displaced and rehabilitated western ringtail possums are effectively contributing to species recovery; and
- there is increased community recognition of the status of the western ringtail possum and support towards its conservation.

Criteria for failure:

This recovery plan will be deemed unsuccessful if, within a 10 year period, any of the following occur:

- there is loss of habitat that results in localised extinction or contraction of western ringtail possums in any of the key management zones;
- threatening processes result in localised extinction or contraction of western ringtail possums in any of the key management zones;
- an evidence-based management approach is not applied to populations in any of the key management zones;
- displaced and rehabilitated western ringtail possums do not contribute to the recovery of the species; or
- there is no increased community support for western ringtail possum conservation.

[1] Note that priorities vary across the distribution of the species dependant on the type and immediacy of local threatening processes, and the level of knowledge and understanding of populations and associated threats. Thus the order of priority of the objectives may not clearly represent the priorities for each management zone. To address this objectives and associated recovery actions are assigned a priority ranking for each of the three key management zones.

1. Introduction

The western ringtail possum (*Pseudocheirus occidentalis*, Thomas 1888) is a folivorous (leaf eating herbivore) marsupial endemic to south-western Australia. Since colonial settlement it has undergone a substantial range contraction, up to 90 per cent of the predicted original range (Jones 2004). As early as 1907 it was "apparently disappearing from many places" (Shortridge 1909) and from surveys in 1985 and 1986 it was considered to have "declined alarmingly" (How *et al*. 1987). Declines in abundance and habitat continue across the range of this species (Jones *et al*. 1994a, Wayne *et al*. 2012).

1.1 Description

The western ringtail possum is a small (0.8 to 1.3kg) arboreal marsupial characterised by a slender prehensile tail (up to 40cm long) with a white tip (Wayne *et al*. 2005a, Jones 1995). It is usually dark brown (though sometimes dark grey) above, with cream or grey fur on the belly, chest and throat. The species was described from a specimen collected at King George Sound, Albany on the south coast of WA in 1876 (Stacey and Hay 2007). The western ringtail possum is readily distinguished from the common brushtail possum (*Trichosurus vulpecula*) by its shorter (usually darker) fur, smaller rounded ears and absence of a brush tail. No other large possums occur in the south-west of WA (Burbidge and de Tores 1998).

Abbott (2001) collated some names that the local Aboriginal group (the Noongars) used for the species, and recommended five of these: ngwayir ('n-waar-ear'), womp, woder, ngoor and ngoolangit.

1.2 Conservation status

The western ringtail possum has been listed as specially protected fauna that is rare or likely to become extinct under the WA *Wildlife Conservation Act 1950* (WC Act) since 1983, and is ranked as Critically Endangered in WA under Department of Parks and Wildlife policy using IUCN criteria. It is listed nationally as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and as threatened (Vulnerable category) in the IUCN Red List (IUCN 2012). Current opportunistic population monitoring trends suggest that a change in the status of this taxon to a higher level of threat is likely within the life of this plan.

1.3 Distribution

The historical and contemporary distribution of the western ringtail possum has been categorised by de Tores (2000) as:

- An inferred pre-historic range (derived from all known records including sub-fossil records): extending from Geraldton on the west coast of WA, to the Hampton Tableland on the south coast about 200 kilometres west of the WA/SA border.
- An inferred original distribution at the time of colonial settlement: extending from just north of Perth, down to just east of Albany including Pingelly and Borden.
- A known distribution (from 1990-2014): patchy occurrence along the south coast (from east of Albany to west of Walpole), the west coast (from Bunbury to Augusta), and inland populations in the lower Collie River Valley, at Harvey and at Perup NR and surrounding forest blocks near Manjimup (Fig. 1).

Total population size of the species is unknown but has been estimated to be less than 8,000 mature individuals in the wild, with a decreasing trend (Woinarski *et al.* 2014.). The area of occupancy is calculated to be less than 800km^2, using 1990-2013 data from Department of Parks and Wildlife fauna databases and 2km by 2km grids. It is however likely that this over-estimates the area of occupancy due to declines since 1990.

There have been translocations of mostly displaced or rehabilitated western ringtail possums to numerous locations since 1991. Translocation sites approved by Department of Parks and Wildlife include Leschenault Peninsula Conservation Park, Yalgorup NP, Lane Poole Reserve and Keats State Forest Block at Dwellingup, Locke NR at Busselton, Karakamia Sanctuary (predator-free wildlife sanctuary privately owned and managed by Australian Wildlife Conservancy), Gelorup bushland south of Bunbury and Perup Sanctuary (predator-free enclosure within Tone Perup NR) east of Manjimup (Fig. 1). They have persisted at only a few of these sites including Karakamia Sanctuary, Perup Sanctuary and Yalgorup NP.

1.4 Abundance

Numerous surveys have confirmed that western ringtail possums are not evenly distributed across the habitats sampled (e.g. Jones *et al.* 1994b, Jones and Hillcox 1995, Jones *et al.* 2004, Wayne 2005, Wayne *et al.* 2006, Jones and Francesconi 2007). The variation in relative abundance across a survey area reveals some of the complex habitat parameters that influence habitat quality which in turn limits densities. However, knowledge of absolute abundance is limited because of a lack of comparable population estimates and variability in survey methods across the range of the western ringtail possum (Inions 1985, Jones *et al.* 1994b, de Tores 2000, de Tores *et al.* 2004). Techniques used to census western ringtail possums commonly include spotlighting, drey (a nest typically formed from a mass of twigs) searches, distance sampling and scat counts (Wayne *et al.* 2005a; de Torres and Elscot 2010). However, variations

in survey methodology compromise comparable estimates of abundance between studies, areas and over time.

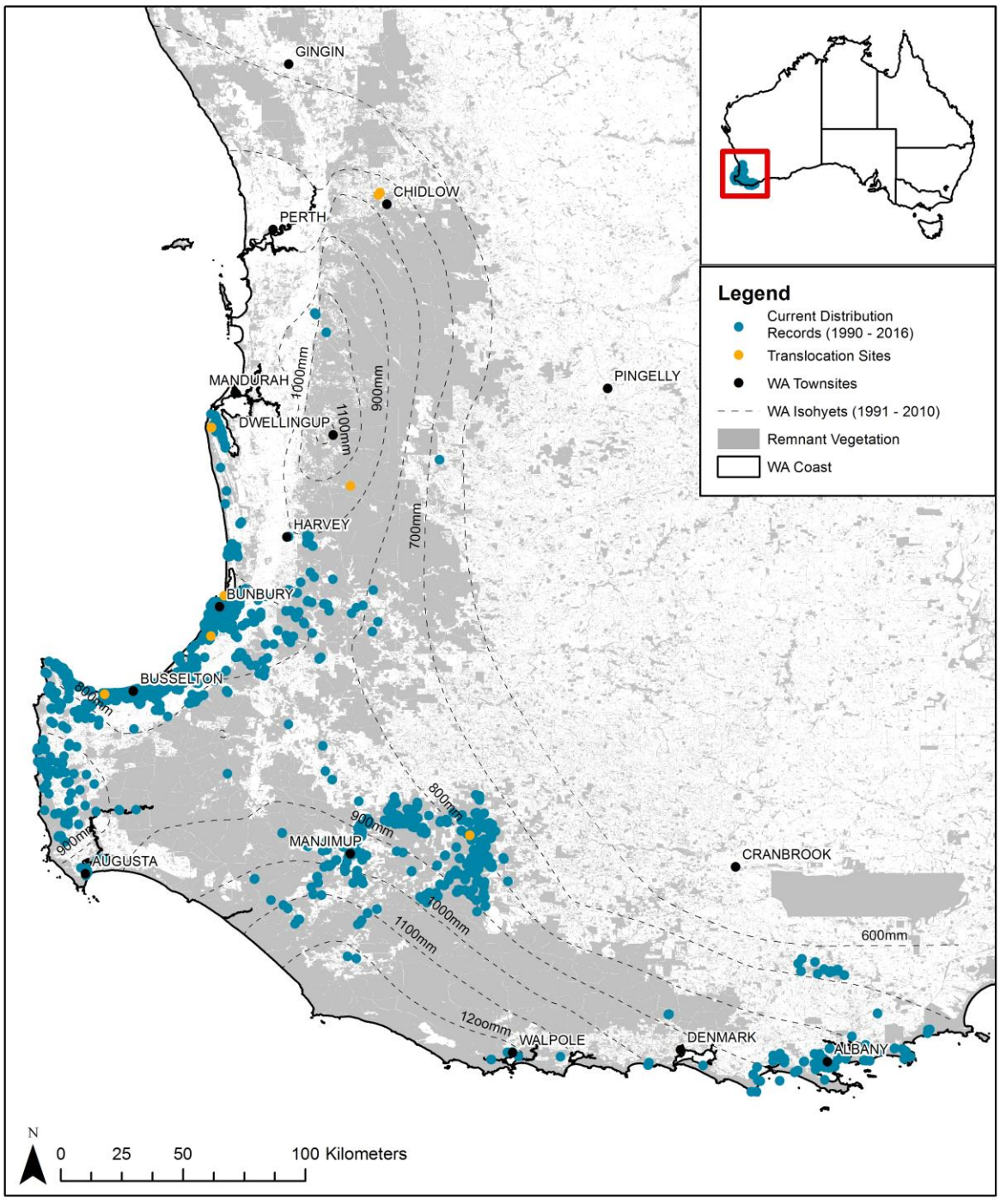

Figure 1: The known current (1990-2015) distribution of western ringtail possums in Western Australia based on the Department of Parks and Wildlife's Fauna Database records, and including translocation sites.

The highest densities of the western ringtail possum occur on the Swan Coastal Plain (Jones *et al*. 1994a, Jones 2004) and in south coast areas. Although population densities are typically not as great in the inland forest areas, the historical extent of the habitat and thus the populations in the inland forest areas was substantially greater than coastal habitats. As such the inland forest areas provides large extensive areas of suitable, although less productive, habitat that has the potential to support overall larger populations.

The number of western ringtail possums in the southern forests is not known but is considered to have been in the tens or low hundreds of thousands (A. Wayne pers. comm. 2013), and thus is thought to have been the largest population prior to 2002. A severe decline in the number of western ringtail possums of >95% (probably >99%) between 1998 and 2009 has occurred in this sub-population. Although the spatial extent of the declines is not well understood it is clear that there has been a decline at all inland forest monitoring sites (Wayne *et al*. 2012). Subsequent surveys (spotlighting, scats and camera trapping) have confirmed that western ringtail possums were still present in 2013 in a number of sites but numbers were extremely low (J. Wayne and A. Wayne pers. comm. 2013).

The Ludlow-Busselton area has long been known as the last substantial stronghold for western ringtail possums left on the Swan Coastal Plain. This Swan Coastal Plain population has been contracting since the early 1990s, mostly due to habitat loss and fragmentation from urban development and mining (Woinarski *et al*. 2014). The effect of the southwest's drying climate on the peppermint stands and canopy in this area is also considered a contributing factor of the decline (Jones and Francesconi 2007). Most of the populations within the Busselton area that have had sufficient monitoring to detect a decline over the last 5-12 years have shown declines of 20-80 per cent (Woinarski *et al*. 2014). From existing survey data, the population in the Bunbury to Dunsborough region is possibly between 2,000 and 5,000 animals (Wilson 2009; B. Jones and G. Harewood pers. comm. 2013).

While there is no quantitative data on densities and trends in the south coast populations, there is little evidence to suggest that they have declined, despite major wildfires at Two Peoples Bay NR and Mt Manypeaks NR between 2001 and 2005 (S. Comer pers. comm. 2014). Possums are frequently seen in the Albany urban and peri-urban areas where significant habitat exists in local government reserves, and strongholds for the species include Two Peoples Bay NR and Mt Manypeaks NR/Waychinicup NP, and adjoining Crown reserves (Gilfillan 2008).

1.5 Biology and ecology

In some coastal populations, western ringtail possums breed year round with breeding peaks in April to July and September to November (Jones *et al.* 1994b). The breeding season in inland jarrah forest near Manjimup is more discrete with most births in May and June and the remainder in October and November (Wayne *et al.* 2005c). Females can breed at less than 12 months of age and, although rare, can breed continuously, raising two consecutive young in a year (Ellis and Jones 1992). Litter size is usually one, although rare occurrences of litter sizes of two or three have been recorded in some populations (Jones *et al.* 1994b, de Tores 2000, Wayne *et al.* 2005c). The western ringtail possum has a gestation period of about two to four weeks and a pouch life of about three months. Young are weaned at six to eight months and disperse at eight to 12 months (How 1978, Ellis and Jones 1992, Jones *et al.* 1994b, Wayne *et al.* 2005b, Wayne *et al.* 2005c).

Reproductive output is apparently related to habitat quality. Areas of habitat with low foliage nitrogen content tend to result in lower numbers of births. Peppermint woodlands have higher foliage nitrogen content relative to jarrah forest habitats, which may be why lower numbers of births are observed in the jarrah forest (Jones *et al.* 1994b, Wayne *et al.* 2005c). Habitat quality may also influence sex ratios. A ratio of one-to-one may be indicative of a stable population, while a female bias can occur in an expanding population in high quality habitat, and a male bias in declining or marginal habitat (Jones *et al.* 1994b).

The diet of the possums almost exclusively comprises the dominant or co-dominant upper and mid-storey myrtaceous plants: peppermint, marri and jarrah (Jones *et al.* 1994b). In urban areas the western ringtail possum may also feed on introduced garden species (Burbidge and de Tores 1998, Williams and Barton 2012). Western ringtail possums prefer young leaves, which have lower lignin content, often higher nitrogen levels and are more digestible (Ellis and Jones 1992). They are coprophagic, ingesting their initial faecal matter containing finer material derived from the caecum during the day. This helps to increase nutrient absorption from their nutrient-poor food source (Hume *et. al* 1984, Hume and Sakaguchi 1993).

Little is known of the longevity, or population age structure, of wild western ringtail possums. The oldest recorded age for western ringtail possums in the jarrah forest is four years (Wayne *et al.* 2000) and six years at Leschenault Peninsula Conservation Park on the coast north of Bunbury (de Tores 2008). There is one record of a female living to over nine years however her final years were spent in a rehabilitation facility (de Tores *et al.* 2008).

The home range of the western ringtail possum is reported on average to be less than five hectares (Jones 2001). Home ranges in the jarrah forest average 2.7ha (Wayne *et al.* 2000). Home ranges in peppermint dominated habitat are generally less than two hectares and average 0.4ha and 0.3ha for females and males respectively (Jones *et al.* 1994b). Densities as high as 20 possums per hectare have been determined in some remnants of the Busselton peppermint stands compared to about four adults per hectare in the jarrah forest (Jones 2004). There is evidence of territoriality within western ringtail

possums (Ellis and Jones 1992). Most young establish home ranges next to the natal range, but in high density groups, young disperse across distances equivalent to several home ranges (Harewood 2005).

Diurnal resting sites (hereafter called refuges) include dreys, platforms, tree hollows, hollow logs, balga (*Xanthorrhoea* spp.) skirts, under sedges, forest debris and disused rabbit warrens (Jones *et al*. 1994b, Wayne *et al*. 2000, Wayne 2005). Dreys range from rough platforms to more elaborate roughly spherical arboreal nests constructed from vegetation, and are generally built where hollows are absent (de Tores *et al*. 1998). In suburban situations the species may also rest in roof spaces and other dark cavities. Western ringtail possums generally use between two and seven refuges in their home range, but can use an average of 20 or more refuges over a year (Jones *et al*. 1994b, Ninox 1999a, Wayne *et al*. 2000).

Tree hollows are important across the range of the western ringtail possum. Hollow abundance has been positively correlated with possum abundance in peppermint/tuart (*Eucalyptus gomphocephala*) associations (Jones and Hillcox 1995) and generally constitutes more than 70 per cent of the refuges used by western ringtail possums in the jarrah forest (Wayne *et al*. 2000, Wayne 2005). Western ringtail possum nests are also found in balga of an old age and height, generally where the balga supports a fallen tree or is easy to access from the canopy (Driscoll 2000). Deep hollows and balga skirts may be particularly important for populations in the warmer/drier areas of the western ringtail possum's distribution to help reduce thermal stress (Jones *et al*. 1994a, Driscoll 2000, Wayne *et al*. 2005b).

Western ringtail possums are known to be susceptible to heat stress and can overheat at ambient temperatures of 35ºC and above (Yin 2006). Western ringtail possums have been observed to use evaporative cooling in hot weather by applying saliva to the forelimbs or panting (Jones *et al*. 1994b). Jones *et al*. (1994b) also observed that in areas where dreys were used, western ringtail possums went to the ground over several hot days.

A lack of phylogeographic structuring from western ringtail possum mitochondrial DNA analysis suggests that historically, populations were interconnected as one large population. This is consistent with the original distribution at the time of colonial settlement (Wilson 2009). Population subdivision and microsatellite genetic differentiation has been a result of more recent patterns of population separation, exacerbated by habitat clearing and fragmentation occurring over the last ~180 years — when colonial settlers started to utilise the forests in south-western Australia (Ward *et al*. 2001). Wilson's (2009) microsatellite DNA analysis revealed three discrete populations existing with some as little as 30km apart. Populations in the southern forests showed slightly higher genetic variation than populations within the Swan Coastal Plain at Busselton and Gelorup (Wilson 2009). A recent study of a 200ha area near Busselton indicated that limited dispersal of western ringtail possums may result in population structuring at even finer-scales, and that genetic structuring was evident in continuous habitat over distances up to 600m (Yokochi 2015) but further work is needed to determine if similar patterns are found in other western ringtail populations.

2. Habitat critical to survival and important populations

Three key management zones have been identified and are highlighted in Figure 2. These are areas known to currently, or previously support large numbers of western ringtail possums. Western ringtail populations within these key management zones are considered the most important extant populations at present. It is recognised that there are records of occurrences outside these areas, and that there may be other important populations identified during the life of the plan after more comprehensive survey, monitoring and mapping is undertaken. This approach recognises that recovery actions should be strategically prioritised to those populations where they will be most effective. Western ringtail possums recorded outside of these three key management zones could be managed with the same general priorities and recovery actions assigned to the nearest key management zone unless further review indicates they should be managed differently.

The three key management zones identified currently are:

1. Swan Coastal Plain zone: the peppermint woodlands and peppermint/tuart forests on the southern extremity of the Swan Coastal Plain, extending from north of Bunbury to Augusta, but principally around Busselton.
2. Southern Forest zone: Jarrah forests near Manjimup where peppermint is generally absent (Jones 2004, Wayne *et al.* 2005a, 2005c, 2006).
3. South Coast zone: a diverse range of vegetation types between Walpole and Cheynes Beach, but principally in near-coastal limestone heath, jarrah marri thicket woodland and forest, riparian, peppermint woodland and karri forest vegetation.

Habitat critical to survival for western ringtail possums is not well understood, and based on occurrence records, appears to vary between key management zones. As such habitat critical for survival is described below for each management zone based on the habitat variables observed where western ringtail possums are most commonly recorded. The common themes however are high nutrient foliage availability for food, suitable structures for protection/nesting, and canopy continuity to avoid/escape predation, and other threats. Long-term survival of the species requires linkages between suitable habitat and as such habitat critical to survival should not be limited to only the habitat described below but linkages between. Any habitat where western ringtail possums occur naturally are considered critical and worthy of protection.

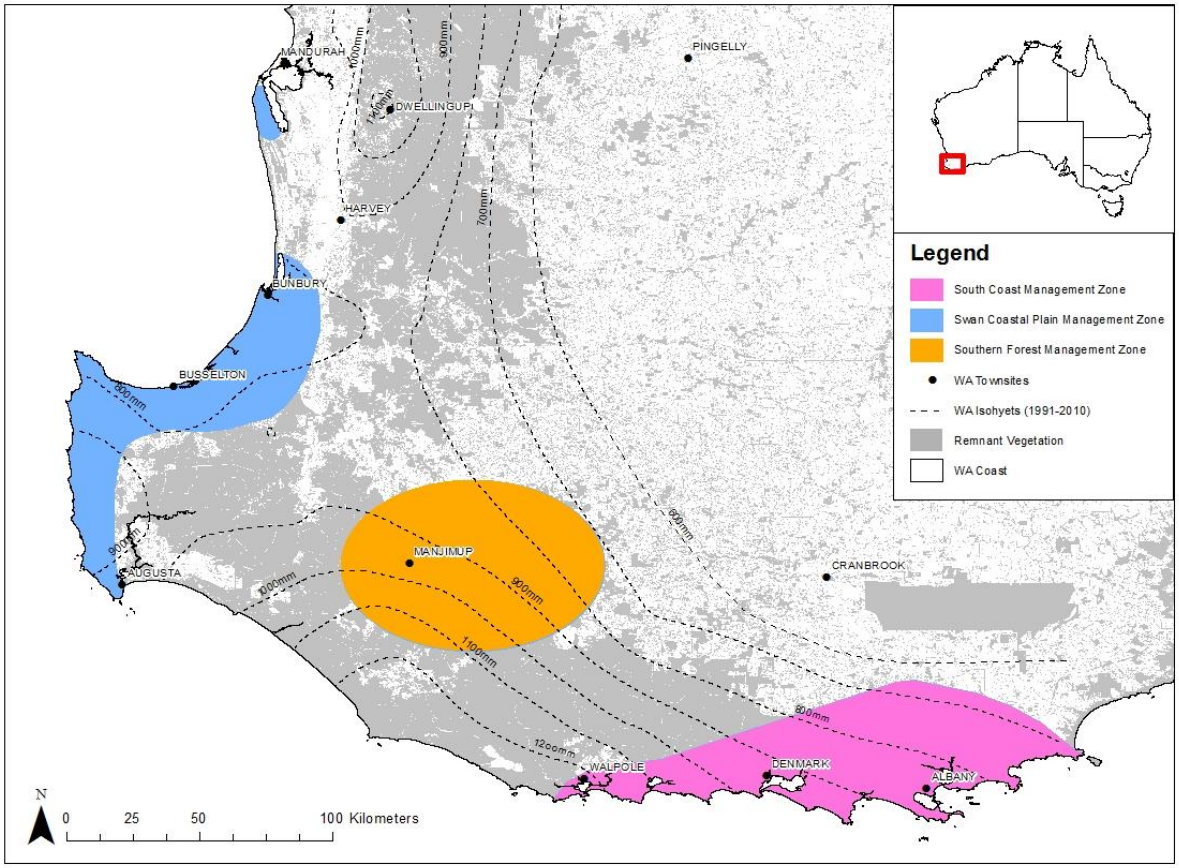

Figure 2: The three key management zones for western ringtail possums.

Populations on the Swan Coastal Plain management zone (Fig. 2) are associated with stands of myrtaceous trees (usually peppermint trees *(Agonis flexuosa)*) growing near swamps, water courses or floodplains, and at topographic low points which provide cooler and often more fertile conditions (Jones 2001, de Tores *et al.* 2004). Habitat critical to survival comprises long unburnt mature remnant peppermint woodlands with high canopy continuity and high nutrient foliage with minimal periods of summer moisture stress, and habitat connecting patches of remnants (Jones *et al.* 1994b, Jones *et al.* 2004, Wayne *et al.* 2006). These habitats are considered critical to the survival of the species given the optimal densities that they can support. However the extent of fragmentation between remnant patches and continued loss or degradation has important implications on the long-term viability of the populations that depend on them.

Populations in the southern forest management zone (Fig. 2) occur mainly in jarrah or marri dominated forests, in adjacent stands of riparian vegetation often with an overstorey of flooded gum (*Eucalyptus rudis*) and extending to wandoo (*Eucalyptus wandoo*) forests to the north-east of Manjimup and karri (*Eucalyptus diversicolor*) forests from Northcliffe to west of Manjimup (DEC 2012c). Habitat critical to survival comprises forests with limited anthropogenic disturbance (unlogged or lightly logged, and a low intensity and low frequency fire history), that are intensively fox-baited and have low indices of fragmentation (Wayne *et al*. 2005a, Wayne *et al*. 2006). The milder warm/dry summers of this region compared with inland forests further north, the lower frequency and extent of high intensity wildfires and potentially greater protection from introduced predators are all likely to be key factors that account for why much of the habitat in the southern forests around Perup has been critical for their persistence here, compared with their disappearance elsewhere.

Populations in the south coast management zone (Fig. 2) are associated with a diverse range of habitats including coastal heath, jarrah/marri woodland and forest, peppermint woodlands, myrtaceous heaths and shrublands, Bullich (*Eucalyptus megacarpa*) dominated riparian zones and karri forest. In the vegetation associations mapped in the Albany urban area by Sandiford and Barrett (2010), most records were from coastal limestone heath vegetation unit 5b. Little is known of the relative abundance of the western ringtail possum within and between vegetation types, including the vegetation types where they have been recorded in the broader Denmark to Mt Manypeaks area. As such the habitat critical to survival in the south coast management zone cannot currently be clearly defined so all remnant habitat is considered important. The milder climate of the South Coast is likely to become increasingly important or critical to the survival of the species in a warming and drying climate trend and the sensitivities this species has to drought and heat and the anticipated climate change effects on the forage and shelter quality of vegetation upon which this species depends (Molloy *et al.* 2014).

The western ringtail possum is also found within plantations of pine (*Pinus* spp.) and blue-gum (*Eucalyptus globulus*) typically within remnant vegetation associated with drainage lines and watercourses through plantations. Dreys have been constructed within these species (K. Williams pers. obs.). Dreys and animals have also been sighted in exotic tree plantations, particularly along edges next to native forest, around Manjimup (A. Wayne pers. comm. 2013). It is suspected that these plantations may provide shelter but depending on the species, are unlikely to be a food source (K. Williams pers. comm. 2013).

High western ringtail possum population densities have been recorded in urban settings, particularly where mature peppermint trees have been retained which have large, dense and overlapping canopies (Harewood 2008). This habitat type appears to provide a variety of nutritious browse items, artificial watering which buffers vegetation against the impacts of a drying climate, alternative habitat connections (fences, powerlines) and alternative shelter/roosts in buildings. It is possible that western ringtail possums have benefited from this development and adapted to the urban setting (Shedley and Williams 2013), however there are also risks that are potentially associated with urban environments.

3. Threatening processes

The threatening processes operating on the western ringtail possum are complex, interactive and are often population specific. For instance, habitat loss and fragmentation from urban development are considered the most important and immediate threatening processes in coastal and near-coastal populations in the Swan Coastal Plain and South Coast zones. By comparison, western ringtail possum populations in extensive, publicly-owned (managed by the Department of Parks and Wildlife) jarrah forests in the Southern Forest zone are considered to be at more risk from introduced predators, climate change, timber harvesting and fire. To some extent this is influenced by land tenure, and the amount and fragmentation of suitable remnant habitat. Figure 3 and Table 1 generally present these different influences in each of the management zones. For this exercise, suitable habitat was determined using the *National Vegetation Information System* (NVIS v4.1) and a Maxent species distribution model. The mapped remnant vegetation types that contain suitable tree species for the western ringtail possum (ie. *Agonis flexuosa* and associated *eucalyptus/corymbia* species) were extracted from the NVIS database and forms the basis of potentially suitable habitat. The Maxent species distribution model was used to identify a broad climatic envelope that contains suitable environmental conditions for the western ringtail possum (modelling post-1996 species records against a suite of regional-scale environmental variables). This broad Maxent-derived climatic envelope was used to constrain (or restrict) the geographic extent of the NVIS-based potentially suitable habitat.

This process identified most of the remnant vegetation within the management zones as being potentially suitable habitat for the western ringtail possums. In reality it is known that some of the patchiness of contemporary populations can be accounted for by habitat quality - namely continuity of canopy, availability of suitable diurnal refuges, and foliage nutrient value and leaf toxins (Wayne *et al.* 2006) (also refer to Section 2: Habitat critical for survival). As such, this model only provides a broad indication of the proportions of possible suitable habitat (and its distribution) across land tenure types in each management zone. However, based on this some general characteristics for each management zone can be calculated (Table 1). The Southern Forest zone has the most remaining remnant vegetation (67.9%) with the majority represented in State Forests (54%) followed by protected areas (33%). In contrast, both the Swan Coastal and South Coast zones have much less remnant vegetation (35.6% and 32.2% respectively) with the majority represented in non-conservation estate (other land tenure).

Table 1: The area and proportions of suitable habitat in each management zone, and the different land tenure types in each (Figure 3).

Management Zone	Total area (km^2)	Area of remnant vegetation (km^2)	% remnant vegetation	% in protected areas	% in State Forest	% in other tenure
Swan Coastal Plain	3123.18	1112.60	35.6	24	32	44
Southern Forest	4168.15	2830.18	67.9	33	54	13
South Coast	4059.30	1308.69	32.2	40	7	53

The relatively short life span and annual fecundity rate of one young per mature female means the ramifications of reduced survivorship are great for this species. To maintain population size a female needs a minimum of two successful reproductive seasons that result in 100 per cent offspring survival to maturity. Anything that negates this may threaten the viability of the population (Wayne *et al.* 2006).

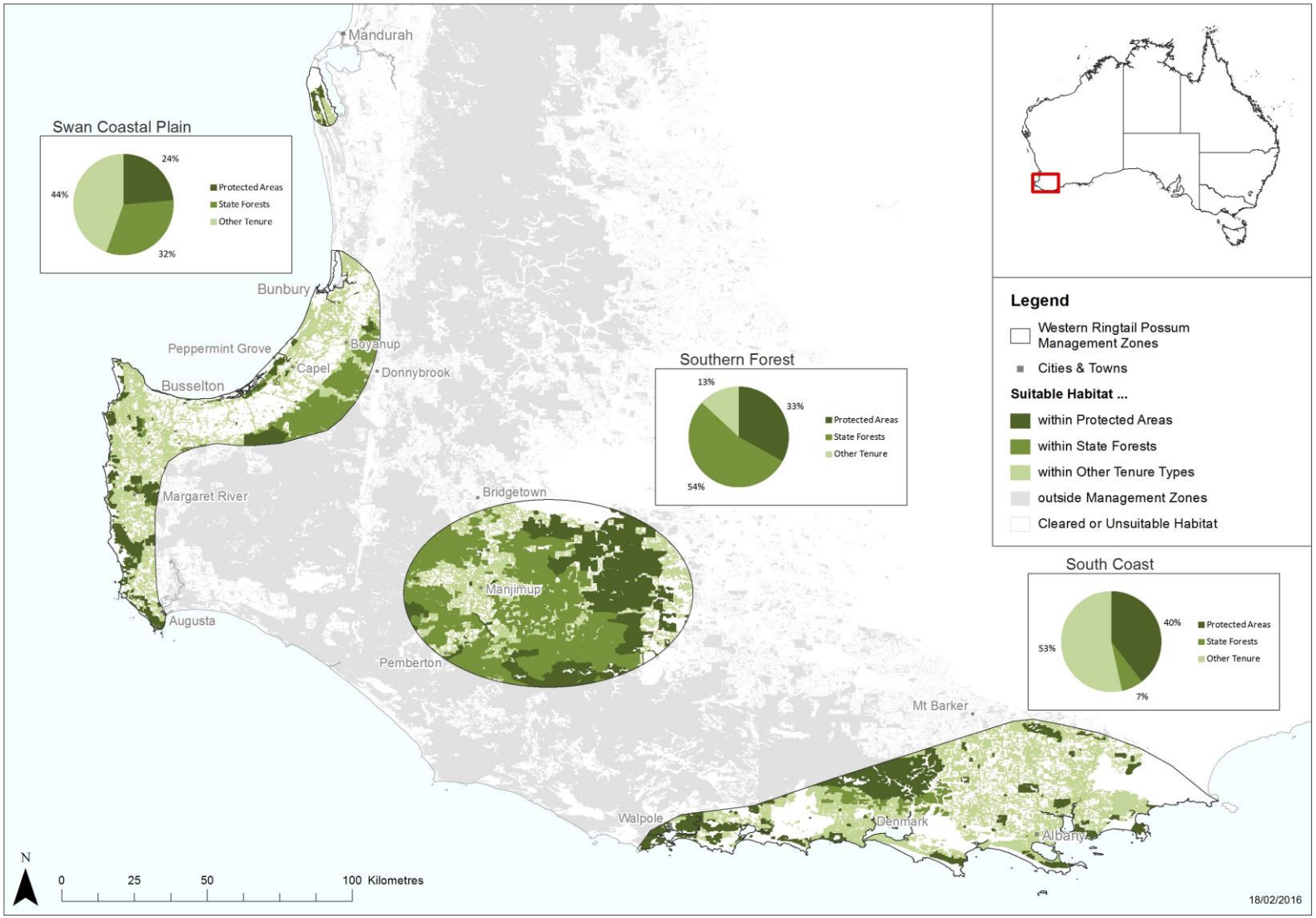

Figure 3: Suitable habitat in each management zone showing different land tenure types within each. Note suitable habitat is a broad definition based on a species distribution

model and broad vegetation type mapping. Modelling and map produced by Department of the Environment, 2016.

3.1 Habitat loss and fragmentation

The loss and fragmentation of native vegetation cover is identified as one of the principle factors threatening western ringtail populations. This is due to their high dependence on midstorey and overstorey vegetation for food, shelter and protection from predators. The long-term viability of populations is further compromised by the size of, and connectivity between, habitat remnants.

The selective nature of land clearing for agriculture of the most fertile, productive and mesic land is likely to have removed much of the higher quality western ringtail possum habitat (Wayne *et al.* 2006). Some of those riparian valleys which were not cleared for cultivation were dammed and flooded (B. Jones pers. comm. 2002). Furthermore, fragmentation by agriculture, timber plantations and urban development has been associated with reduced western ringtail possum abundance and/or increased densities in the remaining remnants (de Tores *et al.* 2004, Wayne *et al.* 2006). Some of these remnant patches are considered to be overpopulated and overgrazed by possums (B. Jones pers. comm. 2002).

Dispersing to and from remnants patches can be restrictive, and increases exposure to cat, dog and fox predation. Habitat patches within the urban areas are surrounded by roads, which cause direct habitat loss, facilitate feral predator movement (May and Norton 1996) increase the risk of road kills and restrict movement. Barriers such as waterways can also restrict movement. (Yokochi 2015).

A study conducted along a road identified as a road kill hotspot for the species in the Swan Coastal Management Zone found 10% of mortalities were attributed to road kills and 70% were attributed to fox predation (Yokochi 2015). Western ringtail possum can be electrocuted when using power lines as connection corridors in fragmented urban landscapes and some research has been undertaken into the use of rope bridges to facilitate possum movement (Yokochi 2015), however, the efficacy of this in different situations is yet to be proven.

3.2 Predation

The European fox (*Vulpes vulpes*) and cats (*Felis catus*) are known to be major predators of the western ringtail possum, which is exacerbated by the predator naivety they display (Jones *et al.* 1994b, de Tores *et al.* 1998, Wayne *et al.* 2000, Jones *et al.* 2004, Wayne *et al.* 2005c). These predators have been implicated in the disappearance of natural and translocated populations of the western ringtail possum and they are likely to be responsible for the lack of translocation success with this species (Wayne *et al.* 2000, Grimm and de Tores 2009, Clarke 2011).

Susceptibility to predation is increased in western ringtail possums when animals need to come to the ground. This may be due to a lack of continuity in canopy cover (Jones *et al.* 2004) or because of natural and/or anthropogenic changes such as logging and fire in jarrah/marri forests (Wayne *et al.* 2000, Wayne *et al.* 2005a, Wayne *et al.* 2006). In hot weather western ringtail possums may come to the ground to find respite from the heat and this may also make the species more susceptible to fox and cat predation (Yin 2006).

Fox baiting is intended to reduce fox numbers, but it is thought it may also lead to an increase in numbers of, and/or predation by, other predators, such as cats, chuditch (*Dasyurus geoffroii*), wedge-tailed eagles (*Aquila audax*) and south-western carpet python (*Morelia spilota imbricata)* (Risbey *et al*. 2000, Wayne *et al*. 2005c, Clarke 2011, Williams and Barton 2012).

In urban environments predation or injury by domestic dogs can be frequent (de Tores *et al*. 1998). High levels of dog ownership within the City of Busselton create dog densities that are four to eight times greater per hectare than the average fox density in the south-west forests (K. Williams pers. comm. 2006). However it is noted that not all domestic dogs predate on native fauna, and that domestic cats also have an impact in urban environments.

3.3 Climate change

Western ringtail possums are among the species most likely to be impacted by recent and predicted climate change in the south-west because they have very specific habitat requirements, have a poor ability to migrate and have lost large areas of habitat (de Torres 2009; Molloy *et al*. 2014). In addition they are sensitive to drought-induced stress. Over the past 30 years there has been an approximate 20 per cent decline in rainfall in the south-west of WA, with more reductions in rainfall and increased temperatures predicted due to global climate change (Timbal 2004). Changes in these and other associated factors such as fire regimes and the intensity and frequency of severe weather event could result in further contraction of the species to the most fertile and mesic remnants of their extant range (Wayne 2005, Jones and Francesconi 2007). Species distribution modelling using bioclimatic variable predicted a reduction of up to 60 per cent in the range of western ringtail possums and its habitat towards the south-west by 2050 (Molloy *et al*. 2014).

Sensitivity to heat and drought-induced stress may result in the loss of canopy density, and quality and condition of food trees, and subsequently lead to an impact on western ringtail possum populations. Drought stress in riparian vegetation and deaths of western ringtail possums have been observed at several localised sites in the lower Swan Coastal Plain (B. Jones and K. William pers. obs. 2007). Elevation in atmospheric carbon dioxide (CO_2) is known to lead to reduced nitrogen concentrations in foliage, increased fibre content of leaves and higher levels of toxic secondary metabolites (Lawler *et al*. 1997, Coley 1998, Kanowski 2001). It is therefore likely that population densities of herbivorous arboreal marsupials in many forests will decline over future decades (Hume 1999).

There is little known about the predicted effects of climate change on frost incidence and severity in south-western WA. Frosts have already been observed to cause extensive foliage damage and localised deaths of potential feed trees (A. Wayne and K. Williams pers. obs. 2006). If frosts do increase in frequency and intensity due to a drying climate this may result in localised population reductions or localised extinctions.

Climate change is also implicated in increased activity of some pathogens and insects affecting habitat trees on which western ringtail possum depend (refer below under section 3.7 'Habitat tree decline').

It should be noted, however, that mitigation of climate change itself is outside the scope of this recovery plan, but consideration of the effects of climate change as a secondary effect on other processes which may threaten western ringtail possum needs to be incorporated into threat mitigation.

3.4 Timber harvesting

In the jarrah/marri forests in the Manjimup area, abundances of western ringtail possums in timber harvested areas are lower compared to areas unlogged or last logged in the 1960s (when logging practices were less intense) (Wayne *et al.* 2006). There is a significant increase in mortality during and immediately after harvesting disturbance. In a study by Wayne *et al.* (2000) up to 17.6 per cent of animals in an area logged died directly from the felling of their refuge sites during harvesting. Studies by Wayne *et al.* (2001) show that in the years following logging activities the local population subsequently collapsed, with spotlight sightings declining by more than 80 per cent (Jones 2004), and have remained almost undetectable along the three 10 kilometre spotlight transects since 2000 (Wayne *et al.* 2000, Wayne *et al.* 2005a, Wayne *et al.* 2012).

The use of balga (*Xanthorrhoea* spp.) as a shelter may be reduced in areas logged due to a reduction in shade from the upper strata (which may cause the microclimate (context) to be hotter/drier), the removal of balga through physical disturbance during logging and the removal of skirts in post logging fires (Driscoll 2000). However, studies suggest it takes less time for a balga to be of a suitable age for western ringtail possum habitat than it does to form a hollow in a eucalypt (Driscoll 2000).

Timber harvesting also substantially increases western ringtail possum vulnerability to predation, especially from foxes and cats, because of the reduction in canopy continuity, the loss of refuges (such as hollow bearing trees and balga), and the creation of access routes for predators within the forest. As a consequence, the average life expectancy of individuals within a study area during the harvesting process was 40 per cent less than individuals within adjacent unlogged forest (Wayne *et al.* 2000).

Given the expected average life span of four to five years for western ringtail possums in undisturbed jarrah forest and sexual maturity at about one year of age, the reduction in survivorship from timber harvesting is expected to at least half the reproductive output of females. The ability of the population to recover from timber harvesting is therefore substantially reduced, at least in the immediate term (Wayne *et al.* 2000, Wayne *et al.* 2001). Changes to forest harvesting and management practices have been instigated to assist in mitigating such impacts (e.g. Conservation Commission of Western Australia 2013) (refer to section 9 for further details).

3.5 Fire

In jarrah forests western ringtail possum abundance has been related to fire intensity and history. Abundance was higher in areas where fire intensity had been low or in areas not burnt for more than 20 years (Wayne 2006). Wayne *et al.* (2005a) and Wayne (2006) identified four putative effects of fire on the western ringtail possum: reduced availability of food resources, loss of refuge (shelter) sites, reduced

canopy continuity and/or death of individuals either directly or indirectly (for example increased vulnerability to predation). Western ringtail possums sheltering in flammable sites (in dreys, under balga skirts, or among ground sedges) risk being asphyxiated by smoke or directly burnt (B. Jones pers. comm. 2002).

Other habitat types such as heaths and peppermint-over-heaths on the south coast are prone to fire. These vegetation communities can carry hot fires leaving little available post-fire habitat for the western ringtail possum (S. Comer pers. comm. 2013).

Coastal peppermint forests in the Bunbury/Busselton region are rarely affected by fire (Jones *et al*. 1994a). However, regrowth after small patch fires may be important for local population recovery in the long-term (Jones *et al*. 2004). The swift growth of the population at Locke NR during the late 1980s was apparently linked to the fire regrowth mosaic following a patch burning program. Appropriate patch burning may evolve into an important management tool for offsetting the effects of contemporary habitat destruction events (for example logging, urbanisation) (Jones *et al*. 2004). There are considerable anecdotal reports of western ringtail possums favouring epicormic eucalypt flushes.

3.6 Competition for tree hollows

Western ringtail possum survivorship has been shown to be negatively associated with high numbers of the sympatric common brushtail possum (*Trichosurus vulpecula*) (Clarke 2011). Brushtail possums are larger, more mobile, more aggressive and have been frequently observed evicting western ringtail possums from hollows (How and Hillcox 2000, Wayne 2005, Wayne *et al.* 2006). The common brushtail possum is thus a potential competitor with the western ringtail possum for habitat resources. The extent to which this occurs is largely unresolved, though the high dependence of both species on tree-hollows implies that there may be competition where tree hollows are limited (Wayne 2005).

There is a clear pattern for ascendancy of brushtail possums over western ringtail possums in the changing environment of the south-west (Jones 2004). The accumulated impacts of tree removal, patch clearing and burning of remnants has forced a contraction of the distribution of possum species in the south-west and has increased competition with brushtail possums for the shrinking resource and stands of good possum habitat (B. Jones pers. comm. 2002, Grimm and de Tores 2009).

A number of other threatening processes may exacerbate the competition pressures between western ringtail and common brushtail possums. There are concerns that an increase in fox control in areas where western ringtail and common brushtail possums occur together may give brushtail possums a greater advantage (due to their greater amount of time spent on the ground) leading to increased competition pressure on western ringtail possums (Wayne *et al*. 2006). In Harvey, where western ringtail possum habitat is confined to riparian peppermints, B. Jones (pers. comm.) noted an increase in brushtail possum density (and a concomitant decrease in western ringtail possum numbers) after abutting vegetation had been burnt. Harvesting of plantations that contain or abut western ringtail possums may

reduce habitat area and/or displace common brushtail possums into western ringtail possum habitat leading to competition (Grimm and de Tores 2009).

Competition may not apply ubiquitously across the distribution of the western ringtail possum. Evidence of sympatric existence can be found at Perup NR where there has been sustained fox baiting since 1977. Relatively dense populations of both possum species have persisted historically, and have apparently switched numerical dominance several times over this period (P. Christensen, N. Burrows and G. Liddelow pers. comm.).

Other indigenous and introduced species may also compete with western ringtail possums for tree hollows. The European honeybee (*Apis mellifera*) competes significantly for tree hollows with the common brushtail possum (Wood and Wallis 1997) and hence probably western ringtail possums. Some hollow nesting birds including the introduced rainbow lorikeet (*Trichoglossus haematodus*) and the expanding little corella (*Cacatua sanguinea*) are also potential competitors with western ringtail possums for hollows.

3.7 Habitat tree decline

As western ringtail possums are obligate folivores, they are at threat from habitat tree decline, which reduces the quality of their habitat and food sources. The main pathogens and insects that cause habitat tree decline for western ringtail possums are described below.

Phytophthora dieback is caused by a microscopic soil-borne organism, *Phytophthora cinnamomi,* that can cause extensive changes in the structure and floristic composition of susceptible vegetation communities (Department of the Environment 2014, Garkaklis *et al.* 2004). The extant range of the western ringtail possum coincides with the distribution of *Phytophthora* dieback in jarrah forests and heaths.

The known canker pathogen *Neofusicoccum australe* has been found to be causing severe dieback symptoms of peppermint trees. *Neofusicoccum australe* is a common fungal endophyte, which is capable of causing disease in a stressed host plant. The factors causing this stress are not yet known, however, climate change is seen as the driving force in the apparent range expansion of this normally minor disease (Dakin *et al.* 2010). An unknown canker pathogen (possibly *Neofusicoccum australe)* is having a significant impact on *Allocasuarina* spp. at Mount Gardner (S. Comer pers. comm. 2013). Western ringtail possum dreys are often observed in *Allocasuarina* spp. along the south coast.

In Western Australia, Armillaria root disease is caused by the endemic pathogen, *Armillaria luteobubalina*. The pathogen colonises sapwood and spreads from tree to tree below ground via root contacts. It is widespread in south-west native forests, woodlands and coastal heathlands. *Armillaria* can cause juvenile tree mortality, root mortality resulting in reduced growth rate, and an increased probability of windthrow in mature trees leading to gap formation in stands (Robinson 2012). Armillaria

is causing tree decline on the south coast, damaging several species including *Hakea* spp. and *Allocasuarina* spp. (S. Comer pers. comm. 2013).

Myrtle rust (*Puccina psidii* s.l.) is part of a group of fungi that infects the Myrtaceae family of plants. First detected in New South Wales in 2010, it has already spread to Queensland and Victoria. It has not yet reached WA, but this is probable. The potential for it to impact on WA bushland and western ringtail possum habitat is high, with peppermint being one of the most severely damaged species. Myrtle rust produces masses of powdery bright yellow or orange-yellow spores on infected plant parts, and produces lesions on young, actively growing leaves and shoots. Rust spores are highly transportable, most commonly transmitted by wind, but also by pollinators and the movement of infected material (Dumbrell 2011).

The jarrah leafminer (*Perthida glyphopa*) is an insect species that has a caterpillar stage which lives between the outer surfaces of jarrah leaves and feeds on the green leaf tissue. This diminishes vigour and deteriorates crown condition as branches progressively die back from their tips (Wills 2009).

Gumleaf skeletoniser (*Uraba lugens*) is a moth which feeds differentially on a range of eucalypts, with jarrah and marri being intermediate larval food hosts. Consecutive warm winters lead to damaging outbreaks that may substantially reduce tree leaf area across extensive areas (tens or hundreds of thousands of hectares) for months or years. Protracted and extensive outbreaks in the past may explain the apparent absence of western ringtail possums from large areas of otherwise seemingly good habitat, such as much of the forests between Manjimup and Nannup (A. Wayne pers. comm.). Given current knowledge of climate change predictions, outbreaks are expected to become more common in the southern jarrah forest leading to higher levels of canopy defoliation (Farr 2009).

Tuart decline is most severe at Yalgorup NP, likely to be caused by several factors including pathogens, insects, hydrological changes, nutrient enrichment, climatic changes and even competition with peppermint. This has led to a decline in tuart health at Yalgorup NP and may amplify if these stressors increase in the future (Barber and Hardy 2006). The recently discovered dieback pathogen *Phytophthora multivora* has also been implicated in tuart decline and may be a cause of habitat tree loss in tuart forests south of Mandurah (Scott *et al.* 2009, Scott *et al.* 2012).

All of these processes impact western ringtail possums at different intensities, in slightly different ways and across different regions. However, all pathogens and insects listed cause some level of reduction of tree foliage and canopy resulting in a reduction of food source and shelter, and as a follow-on effect reduced condition and fecundity, and increased predation pressure for western ringtail possums. Death and a reduction in growth of susceptible trees will alter the structure of the vegetation, and may remove suitable western ringtail possum habitat over time. The swiftness and severity of some of these pathogens and insects could also lead to localised extinctions of western ringtail possums, particularly in isolated populations or remnants.

3.8 Un-regulated relocation of orphaned, injured and rehabilitated western ringtail possums

Issues can arise in populated areas where people co-occur with western ringtail possums. Injury and death to possums occur through loss of habitat from further urban development, exposure to increased traffic, electrocution on power lines when used as transport corridors, poisoning and attack from domestic dogs and cats. Possums may pose a nuisance to humans by taking residence in buildings and other structures and feeding on, or causing damage to, gardens. These issues often result in relocation or rehabilitation and eventual release of injured or orphaned possums.

Approximately 200 western ringtail possums per year enter rehabilitation in the Busselton area. They are rescued by volunteer wildlife rehabilitators or the general public. Between 50-100 animals per year are thought to successfully survive the rehabilitation process and are released (Williams and Barton 2012). As there may be a number of sources for these relocations and a number of individuals or groups involved, they are not always correctly recorded or relocated to suitable and registered relocation sites, nor monitored for post-release survival. Unregulated releases can affect monitoring programs, artificially extend known geographic range, spread diseases, increase pressure on existing habitat, disturb resident western ringtail possums at release sites, genetically mix populations and may even cause death of western ringtail possums through predation or inappropriate habitat availability at release sites. Unregulated releases may also contravene the regulations of the WC Act and the WA *Animal Welfare Act 2002*.

The appropriate coordination and management of rehabilitation and release of injured or orphaned western ringtail possums may provide greater conservation outcomes from this activity, and provide a greater incentive for the wildlife rehabilitators.

3.9 Disease

Western ringtail possums can be at a greater risk of disease due to human disturbance and exposure to exotic species and pathogens (de Tores *et al*. 2008). Cat predation may also expose western ringtail possums to toxoplasmosis infection, although investigations into the disease load of captive and wild populations has revealed only low rates of contagion (de Tores *et al*. 2008, Grimm and de Tores 2009, McCutcheon *et al*. 2010). Understanding diseases is particularly important for the management of injured and orphaned possums and translocation programs, where novel diseases may be moved from place-to-place and diseases may be harboured in cages.

A drying climate may expose western ringtail possums to more physiological diseases. Low rainfall years can result in a lack of fresh growth on which the possums survive. In such situations, possums may resort to eating older growth leaves which may have elevated levels of calcium and toxicity. These in turn may lead to physiological dysfunctions as has been observed by some wildlife rehabilitators (Barbara Jones pers. comm. 2013). Whilst this phenomenon has not been scientifically validated it may be worthy of further investigation.

3.10 Gaps in knowledge

Limited short term studies and anecdotal accounts have contributed most of the knowledge on the western ringtail possum. An understanding of the ecology and conservation status has also been constrained by the difficulty in surveying (detection of) this species (Inions *et al.* 1989, Jones *et al.* 1994b, de Tores 2000).

Some of the shortfalls in knowledge include:

- A lack of information on most populations that are small, isolated, and/or at the margins of the extant distribution, including the Waroona, Harvey, Collie, Shannon, Lower Warren and D'Entrecasteaux areas.
- Robust survey methods appropriate for the various habitats of western ringtail possums that can provide reliable estimates of population density and/or abundance (as distinct from uncalibrated indices and indirect measures of abundance).
- No strategic or co-ordinated long-term monitoring program across the species range that can quantify and track population trends over time.
- The causes for decline are not completely understood.
- The relative importance and extent of threatening processes is generally not known for the species or for individual populations.
- Factors influencing population persistence in urban environments.
- Understanding the factors that improve the success of translocations.
- Habitat restoration/creation parameters/prescriptions and effectiveness.

4. International obligations

This plan is consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that Convention. The species is not listed under the appendices to the United Nations Environment Program World Conservation Monitoring Centre's (UNEP-WCMC) Convention on International Trade in Endangered Species (CITES), and this plan does not affect Australia's obligations under any other international agreements.

5. Affected interests

The western ringtail possum and its habitat occur across south-west WA on, and adjacent to many different land tenures. Thus there may be many interests potentially affected by this recovery plan. In most cases, little impact upon current land use is likely; however, to achieve the objectives of this plan there may be an effect on land use planning and landowners who may wish to develop land or change their management practices. Landholders and land management agencies may thus be affected through statutory planning and land use and environmental impact assessment processes, when seeking to alter the landscape or undertake actions that may cause any of the resulting effects to the western ringtail possum as outlined in Section 11 Guide to Decision Makers. Where populations occur on lands other than those managed by Department of Parks and Wildlife, permission has been, or will be sought from the managers before recovery actions are undertaken on their land.

Interests potentially affected by, or involved, in the implementation of this recovery plan include:

- private and commercial land owners and managers;
- local government authorities;
- non-government organisations;
- State government agencies (for example Department of Parks and Wildlife, Department of Water, Department of Mines and Petroleum, Environmental Protection Authority (EPA), Forest Products Commission (FPC), WA Planning Commission (WAPC);
- Commonwealth government (DoTE);
- traditional owners and managers (for example SWALSC); and
- development and infrastructure providers.

6. Role and interests of Aboriginal people

The *Conservation and Land Management Act 1984* and the WC Act provide rights for Aboriginal people to undertake certain activities for customary purposes. They recognise the special connection Aboriginal people have to the land and the existence, or otherwise, of native title rights.

Department of Parks and Wildlife will enter into collaborative discussions with Aboriginal people in the regions identified in this plan and ensure consideration of their role and interests in the implementation of this plan. Input and involvement will be welcomed from any Aboriginal groups that have an active interest in areas that the ngwayir/western ringtail possum occurs, and their involvement in recovery team representation will be sought. The Aboriginal Heritage Sites Register, maintained by the Department of Indigenous Affairs, will be used to identify significant sites near these populations. However, not all significant sites are listed on the register, and on-going liaison will be maintained with local Aboriginal community representatives to ensure appropriate input to proposed recovery actions.

SWALSC, an Aboriginal umbrella group, covers the areas considered in this plan. Comment was sought from the council about aspects of the plan, particularly about the proposed on-ground actions.

7. Social and economic interests

The implementation of this recovery plan has the potential to have social or economic impacts through the identification and recommendation to protect significant habitat in urban and near-urban areas. Western ringtail possums occur within a variety of habitats spread out across public and private lands. Some proponents of particular land uses, for example agriculture, forestry, mineral extraction and urban or industrial land development, may need to demonstrate through statutory processes that they will have no significant impact on western ringtail possums or that any impacts can be adequately mitigated. Such requirements would be in place irrespective of this plan, and this plan will provide some clear direction for the implementation of such measures.

Control of introduced predators may have a social impact if pets ingest toxic baits that have been laid for western ringtail possum protection. However, Parks and Wildlife risk management strategies, including media releases warning the public of the risk that baits pose to domestic animals, and signage denoting baited areas, are undertaken as a part of the Department's baiting programs.

8. Broader biodiversity benefits

In working towards effective conservation of the western ringtail possum, other species with similar habitat needs to the western ringtail possum are likely to benefit. Such threatened fauna species include Baudin's cockatoo (*Calyptorhynchus baudinii*), brush-tailed phascogale (*Phascogale tapoatafa* ssp. (WAM M434)), chuditch (*Dasyurus geoffroii*), Carnaby's cockatoo (*Calyptorhynchus latirostris*), forest red-tailed black cockatoo (*Calyptorhynchus banksii naso*), malleefowl (*Leipoa ocellata*), noisy scrub-bird (*Atrichornis clamosus*), numbat (*Myrmecobius fasciatus*), quokka (*Setonix brachyurus*) and woylie (*Bettongia penicillata ogilbyi*). An improved understanding of the similar and competing habitat requirements for these species may also be achieved. Increases to chuditch numbers through recovery actions may lead to increased predation of western ringtail possums in areas where they co-occur.

A number of declared rare flora occur at sites where western ringtail possums are located and are thought to share similar habitat; these include Augusta kennedia (*Kennedia lateritia*), Bussell's spider-orchid (*Caladenia busselliana*), Carbanup king spider-orchid (*Caladenia procera*), Christine's spider orchid (*Caladenia christineae*), giant spider-orchid (*Caladenia excelsa*), Harrington's spider orchid (*Caladenia harringtoniae*), long-leaved daviesia (*Daviesia elongata* subsp. *elongata*), round-leafed honeysuckle (*Lambertia orbifolia* subsp. Scott River Plains) and the southern tetraria (*Tetraria australiensis*). These species may benefit where recovery actions improve their habitat. Many records for priority flora are also located within western ringtail possum habitat, and locations of priority flora should be sought before undertaking recovery actions in an area which have the potential to disturb native vegetation.

The recovery actions put in place for the western ringtail possum may potentially be of benefit to the following threatened and priority ecological communities (TECs and PECs):

- *Corymbia calophylla* - *Eucalyptus marginata* woodlands on sandy clay soils of the southern Swan Coastal Plain (TEC)
- *Corymbia calophylla* woodlands on heavy soils of the southern Swan Coastal Plain (TEC)
- *Corymbia calophylla, Melaleuca rhaphiophylla, Banksia littoralis, Eucalyptus rudis, Agonis flexuosa* low open forest with seasonal subsoil moisture (Dunsborough area) (PEC)
- *Eucalyptus cornuta, Agonis flexuosa* and *Eucalyptus decipiens* forest on deep yellow-brown siliceous sands over limestone (PEC)
- *Eucalyptus rudis*, *Corymbia calophylla*, *Agonis flexuosa* Closed Low Forest (near Busselton) (PEC)
- Southern *Eucalyptus gomphocephala-Agonis flexuosa* woodlands (PEC)
- Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands (PEC).

The distribution of this species overlaps with the following EPBC Act-listed threatened ecological communities:

- Corymbia calophylla – *Kingia australis* woodlands on heavy soils of the Swan Coastal Plain
- Corymbia calophylla – *Xanthorrhea preissii* woodlands and shrublands of the Swan Coast Plain
- Shrublands and Woodlands of the eastern Swan Coastal Plain
- Shrublands on southern Swan Coastal Plain ironstones
- Claypans of the Swan Coastal Plain
- Proteaceae Dominated Kwongkan Shrublands of the Southeast Coastal Floristic Province of Western Australia
- Scott River Ironstone Association.

These communities contain habitat used by the western ringtail possum and some actions to protect this habitat will benefit the western ringtail possum and the threatened and priority ecological communities.

9. Previous and existing conservation and management actions

A summary of the activities implemented against the recovery actions outlined in the 1998 interim recovery plan (Burbige and de Tores 1998) are summarised below.

9.1 Conservation of western ringtail possums in public lands managed by CALM.

This recovery action focused on the need for appropriate habitat management, including fox control, and monitoring of selected populations, on land managed by the Department of Conservation and Land Management (CALM, now the Department of Parks and Wildlife). Ongoing introduced predator control within selected conservation reserves has occurred and continues to occur as part of the Department of Parks and Wildlife's Western Shield program and the Integrated Fauna Recovery Program in the South Coast management zone. These include fox baiting and more recently the incorporation of feral cat baiting. Monitoring of populations using spotlighting techniques has been established and continues in areas of the conservation estate in the Southern Forest Management Zone. Robust standard monitoring methods has been investigated and published for the jarrah forest areas (e.g. Wayne *et al.* 2005a, Wayne *et al.* 2005b) but are yet to be developed and implemented for the various other habitats of western ringtail possums.

Furthermore, this recovery action included the continuation of research into the effects of forest management for timber production, and the revision and implementation of silvicultural guidelines arising from the research. There has been much work undertaken in this area resulting in improved protocols and published guidelines including an overarching forest management strategy endorsed at both state and commonwealth levels (Forest Management Plan 2014-2023; Conservation Commission WA 2013), fire management guidelines for western ringtail possums (Wayne 2006) and fire management guidelines for Tuart Woodlands (Wayne 2006, FMS 2008). Parks and Wildlife and the FPC have developed a Fauna Distribution Information System (FDIS) database which uses the associations between fauna, vegetation complexes and physical variables such as temperature and altitude to predict the presence of fauna (including the western ringtail possum) (Christensen *et al.* 2004). If species which are known to be sensitive to timber harvesting activities are present, management actions such as increased control of introduced predators in harvest coupes are implemented. There is ongoing refinement of targeted fauna survey procedures to validate the FDIS and inform

management actions and flora to inform timber harvesting activities (Christensen *et al.* 2004). This system also promotes increased predator control in and around harvesting coupes where ringtail possum populations are likely to be present. There is ongoing refinement of targeted fauna survey procedures to validate the FDIS and inform management actions (e.g. Forest Products Commission 2015; Procedure 46 Targeted fauna surveys within pure and mixed karri forest).

In parts of the western ringtail possum's range where timber harvesting occurs (Fig. 3) there has been modification of silvicultural guidelines including:

i. the retention of more key habitat elements within harvest coupes; such as hollow-bearing trees, large logs, logs with hollows, stumps and second storey species such as balga (*Xanthorrhoea* spp.), with an overall focus on maintaining stand complexity and structural diversity;
ii. the retention of grouped habitat (mature trees and second storey species) to facilitate canopy connectivity in retained habitat;
iii. an increase in the frequency of 1080 fox baiting during and immediately after timber harvesting disturbance to reduce the vulnerability of western ringtail possums to fox predation; and
iv. the establishment of a network of 'Fauna Habitat Zones' that incorporate western ringtail possum habitat requirements (>100 ha each, > 50,000 ha in total) across the forest estate available for timber harvesting. For example in 2014 the area available for timber harvesting in the western ringtail possum management xones, contains 51,390 ha of informal reserves and fauna habitat zones.

There have also been substantial additions to the formal reserve system, particularly National Parks (Conservation Commission WA 2004, 2013). For example, between 2000 and 2014, the area of National Parks within the western ringtail possum management zones has increased by 53,826 ha, mostly coming from former State Forests.

It remains a priority for this plan to continue to mitigate threatening processes that constrain recovery of the species, especially on public land (see Objective 2). The need to develop and implement monitoring is also urgently required.

9.2 Minimising impacts of land developments

In the previous interim recovery plan land developments in coastal areas between Bunbury and Augusta, and near Albany were identified as having the potential to degrade or destroy western ringtail possum habitat. The plan recommended re-zoning and development applications be referred to CALM, conditions be placed to retain habitat and allow translocations. Some progress has been made including ongoing heightened awareness of western ringtail possum conservation requirements with local and State government planning authorities, through statutory and local government planning approvals, including conditions placed on developments to deal with impacts on the western ringtail possum.

Since the 1998 interim plan, the *Environment Protection and Biodiversity* (EPBC) *Act 1999* came into effect resulting in the requirement to refer actions that may impact threatened species to the Australian

Government. Furthermore, in 2005, the 2004 amendments to the *Environmental Protection Act 1986* for the regulation of clearing of native vegetation came into effect which provides for the protection of threatened species to be considered in any vegetation clearing assessment.

State and Commonwealth project approval offset requirements have resulted in some revegetation and rehabilitation of areas around the Busselton and Bunbury areas. An EPBC Act Policy Statement titled significant impact guidelines for the vulnerable western ringtails possum in the southern Swan Coastal Plain, has been produced to guide stakeholders in determining whether a proposed action is likely to have a significant impact on the species. An increased recognition of the impacts of clearing and development in the Swan Coastal Plain Management Zone has resulted in the Western Ringtail Action Group assessing localised habitat within the Busselton urban area to identify priority areas for protection and corridors, revegetating these areas with peppermint trees, raising awareness in the community, and training community members in surveying techniques.

Department of Parks and Wildlife have reviewed western ringtail possum habitat availability from Binningup to Dunsborough and east to the Whicher Range. The review provides a basis for the identification, protection and enhancement of key habitats and aims to provide a greater level of habitat definition and prioritisation than previously reported (Shedley and Williams 2014). Currently this is being used as a basis to identify and prioritise habitat values during the assessment phase of development approvals, and forms the basis for maintaining or enhancing corridors and linkages between core habitat areas.

9.3 Management of derelict western ringtail possums

A number of community driven wildlife rehabilitation groups have formed which focus on western ringtail possums (e.g. Possum Centre Busselton INC., FAWNA, Native Animal Rescue) and a number of individual wildlife rehabilitator's work with western ringtail possums. It is likely that the dedication of these groups and individuals has increased the ability to rehabilitate this species and some guidelines have been developed by these groups. However, the majority of the relocations that were monitored (see sections 1.3 and 9.4) have failed. There remains no consultative and coordinated approach to this activity, which was identified in the previous plan as being required to maximise conservation benefit from wildlife rehabilitation efforts. This remains a recovery action required as part of this plan mostly to reduce the risk to wild populations, but also to improve reintroduction success.

9.4 Translocations (existing and proposed)

At the time the last recovery plan was published, it was thought that translocations had been successful and could be a viable recovery tool for this species. Since then, it has been determined that very few have been successful (see section 1.3). Clarke (2011) undertook the most comprehensive study to date on the outcomes of translocating displaced and rehabilitated western ringtail possums to three locations. This study indicated that high mortality rates were recorded and the majority of deaths were

attributed to predation, but that complex interactions of health, predation, habitat quality and inter-specific competition were likely to influence translocation success. Since this study, no approved translocations have been undertaken except a trial into a fenced, introduced predator-free enclosure which was required due to displacement from a development in Busselton. In this plan it is considered that relocation should only be undertaken as a last resort and until we better understand the factors that improve the success of translocations as a viable recovery tool.

9.5 Education, liaison and communication.

Some of the achievements in relation to education, liaison and communication are listed below to demonstrate progress against this recovery action.

- Production of guidelines for care and an information pamphlet aimed at educating residents of Bunbury and Busselton about western ringtail possum issues.
- Release of a pamphlet called "Living with Possums" aimed at educating urban residents on how to deter and what to do with 'problem' brushtail and western ringtail possums.
- The 'Peppies for Possums' community Natural Resource Management (NRM) project, developed and implemented a western ringtail possum school education program, a tourism program, and a community awareness and engagement program, in conjunction with the community, and undertook infill planting and revegetation efforts.
- Department of Parks and Wildlife developed a dedicated webpage for western ringtail possums (www.dpaw,wa,gov.au/plants-and-animals/threatened-species-and-communities/threatened - animals/351-western-ringtail-possums).

9.6 Research

Research or knowledge gaps were not specifically addressed in the former interim recovery plan but there have been six tertiary student studies undertaken on the western ringtail possum since its publication. These studies have been undertaken on a variety of topics and have also contributed to many of the actions above. Topics include barriers to movement (PhD, Yokashi 2015), importance of preserving trees in development sites (Honours, Harring-Harris 2014), translocation success (PhD, Clarke 2011), genetics (Honours, Wilson 2009), physiology (Honours, Yin 2006), ecology in the jarrah forest (PhD, Wayne 2005) and refuge use (Honours, Driscoll 2000). In addition there has been research undertaken by Department of Parks and Wildlife staff, and some investigations by private consultants in relation to environmental impact assessments and conditions of vegetation clearing or development.

10. Management practices and policies

Management practices (policies, strategies, plans) that have a role in the protection of the species include but are not limited to the following:

- Policy Statement No. 35 Conserving threatened species and ecological communities (DPaW 2015)Corporate Guideline No. 35 Listing and recovery of threatened species and ecological communities (DPaW 2015)
- Corporate Guideline No. 36 Recovery of threatened species through translocation and captive breeding or propagation (DPaW 2015)
- Policy Statement No. 3 Management of Phytophthora disease (DPaW 2015)
- WA Forest Management Plan 2014-2023 (Conservation Commission WA 2013)
- *Western Shield* Fauna Recovery Program Draft Interim Strategic Plan 2009-2010 (DEC 2008)
- Guidelines for Protection of the Values of Informal Reserves and Fauna Habitat Zones, SFM Series, Guideline No. 4 (DEC 2009a)
- Guidelines for the Selection of Fauna Habitat Zones, SFM Series, Guideline No. 6 (DEC 2010)
- Protocol for measuring and reporting on the key performance indicators of the Forest Management Plan 2004-2013, SFM Manual No. 2 (DEC 2011)
- South Coast Regional Fire Management Plan 2009-2014 (DEC 2009b)
- Perup Management Plan 2012 (DEC 2012a)
- Chuditch Recovery Plan (DEC 2012b)
- Woylie Recovery Plan (Yeatman and Groom 2012)
- Quokka Recovery Plan (DEC 2013)
- Western Australian Government Environmental Offsets Policy (Govt of WA 2011)
- EPBC Act environmental offsets policy (DSEWPaC 2012)
- EPBC Act Policy Statement 3.10 – Significant impact guidelines for the vulnerable western ringtail possum (*Pseudocheirus occidentalis*) in the southern Swan Coastal Plain, Western Australia (DEWHA 2009)
- Survey guidelines for Australia's threatened mammals. (DSEWPaC 2011)
- Shire of Busselton Environmental Strategy (EMRC 2004)
- Stirling-Harvey Redevelopment Scheme Stirling-Harvey pipeline and Harvey Reservoir Management Strategy for the Western Ringtail Possum (Ninox Wildlife Consulting 1999a, 1999b)
- Shire of Augusta Margaret River Biodiversity Conservation Strategy (SAMR 2005)
- Busselton Wetlands Strategy (WAPC 2005)
- Fire Management Guideline: S8- Ngwayir (Western Ringtail Possum) (Wayne 2006)
- Fire Management Guideline: E4- Tuart Woodlands (FMS 2008)

- Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (Department of the Environment 2014)
- Threat abatement plan for predation by European red fox (DEWHA 2008a)
- Threat abatement plan for predation by feral cats (DEWHA 2008b).

11. Guide for decision makers

Under the Commonwealth EPBC Act any person proposing to undertake actions that may have a significant impact on listed threatened species (including the western ringtail possum) should refer the action to the relevant Minister in accordance with the EPBC Act requirements. The Minister will determine whether the action requires EPBC Act assessment and approval. As these provisions relate to proposed future actions, they can include actions which may result in increased impact from existing threats or potential threats, and actions which may result in a new threat.

Whether or not an action is likely to have a significant impact depends upon the sensitivity, value and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts. The potential for an action to have a significant impact will therefore vary from case to case (DEWHA 2009).

Actions occurring within habitat critical to survival that result in any of the following may have a significant impact on the western ringtail possum:

- clearing/loss of western ringtail possum habitat;
- decrease in canopy continuity and canopy condition in western ringtail possum habitat;
- decrease in food availability;
- decrease in refuge site availability;
- increased likelihood of predation on the western ringtail possum;
- increased likelihood of competition of the western ringtail possum with other fauna; or
- reduced ability of the western ringtail possum to disperse.

12. Recovery

12.1 Recovery goals and objectives

This recovery plan guides recovery actions for the western ringtail possum for the next 10 years. The 10 year goal is to:

- slow the decline in population size, extent and area of occupancy through managing major threatening processes affecting the subpopulations and their habitats, and allowing the persistence of the species in each of the identified key management zones: Swan Coastal Plain, southern forests and south coast.

It is acknowledged that over the period of this plan populations fringing key management zones are likely to decline due to a range of threatening processes. A change in the conservation status of this taxon to a more threatened category is also possible within the life of this plan, before the reversal of the impacts of threatening processes can take effect.

The long term vision of the recovery program for the western ringtail possum extends beyond the life of this plan but is important to state to ensure a consistent, long term strategy:

- to improve the conservation status, leading to a reduction in the threat status, or the future removal of the western ringtail possum from the threatened species list of the EPBC Act and the WC Act; and
- to ensure that threatening processes do not compromise the ongoing viability of the western ringtail possum population.

The specific recovery objectives for the next 10 years are listed below in a general order of priority. This priority order is based on the recovery needs of the species over the next 10 years. However, priorities will vary across the distribution of the species depending on the type and immediacy of local threatening processes, and the level of knowledge and understanding of populations and associated threats. Thus the order of priority of the objectives may not clearly represent the priorities for each management zone. To address this, each objective is assigned a priority ranking for each of the three key management zones (see Figure 2 for approximate location of key management zones). This approach is also taken for prioritising the recovery actions below. The three levels of priorities should be interpreted as follows:

- Priority 1: Taking prompt action is necessary in order to mitigate the threats and ensure the persistence of the species.
- Priority 2: Action is necessary to mitigate threats and work towards the long-term recovery of the species.
- Priority 3: Action is desirable, but not critical to recovery at this point in time but will provide for longer term maintenance of recovery.
- N/A: not relevant in this key management zone.

Objective		Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority
1	Habitat critical for survival for western ringtail possums is identified and protected in each key management zone.	1	1	1
2	Threatening processes that are constraining the recovery of western ringtail possums are mitigated in each key management zone.	1	2	1
3	An evidence-based approach is applied to the management and recovery of western ringtail possums.	1	1	2
4	The management of displaced, orphaned, injured and rehabilitated western ringtail possums aids the conservation outcome for the species.	1	3	2
5	Increased awareness of the status of western ringtail possums and support behaviour change to mitigate anthropogenic threatening processes.	1	2	1

Criteria for success:

This recovery plan will be deemed successful if, within a 10 year period, all of the following are achieved:

- habitat critical for survival of the western ringtail possum is defined, identified and protected in each of the key management zones;
- threatening processes constraining recovery of western ringtail possums are identified and effectively managed in the key management zones;
- an evidence-based approach is developed and applied to the management of western ringtail possums in each of the key management zones;
- displaced and rehabilitated western ringtail possums are effectively contributing to species recovery, and
- there is increased community recognition of the status of the western ringtail possum and support towards its conservation.

Criteria for failure:

This recovery plan will be deemed unsuccessful if, within a 10 year period, any of the following occur:

- there is loss of habitat that results in localised extinction or contraction of western ringtail possums in any of the key management zones;
- threatening processes result in localised extinction or contraction of western ringtail possums in any of the key management zones;
- an evidence-based management approach is not applied to populations in any of the key management zones;
- displaced and rehabilitated western ringtail possums do not contribute to the recovery of the species; or,
- there is no increased community support for western ringtail possum conservation.

12.2 Recovery Actions

Recovery actions associated with each of the recovery objectives identified for the recovery of the western ringtail possum are described below. All recovery actions are assigned a priority ranking for each of the key management zones separately (see Section 12.1 for priority ranking definitions and Figure 1 for approximate location of key management zones).

Objective 1: Habitat critical for survival for western ringtail possums is identified and protected in each key management zone

It is recognised that the loss of existing or potential habitat critical for the survival of western ringtail possums will not only result in a loss of individuals and populations, but also reduce the ability for recovery into the future. To prevent further habitat loss or degradation, habitat critical for survival, as well as potential habitat and habitat connectivity need to be defined, identified and mapped. This will provide an important tool for local and landscape scale management. Identification of habitat critical for survival presents numerous challenges including defining characteristics and thresholds and contextualising data at the landscape level, to allow for continuity between areas. There will be habitat critical for survival on both private and public lands and this presents further challenges in relation to protection. Once identified and protected, habitat will need to be effectively managed, this aspect is covered separately under Objective 2.

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
1.1	Develop a decision support tool to assist in habitat management based on: • habitat characteristics required for western ringtail possum occupation and density thresholds; • priority landscape level habitat linkages within zones; and • identification of key habitat.	1	1	1	– Habitat characteristics and thresholds are defined. – Important ecological linkages are identified and mapped. – Existing and potential habitat is mapped and ranked.	DPaW

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
1.2	Identify and implement effective strategies to achieve the protection of higher ranked habitat, on public and private land, in each of the key management areas. Strategies may include: • investigating mechanisms to enhance the protection afforded to identified high quality habitat; • protection of western ringtail possum habitat values in the assessment of development proposals by environmental regulation agencies; • encouraging planning authorities to facilitate the creation of habitat reserves and linkages when amending town planning schemes or developing land use structure plans; • liaising with local and state government planning agencies to implement strategies to mitigate the effect of development, and provide for management of high quality habitat.	1	2	1	Effective strategies to protect high value habitat have been implemented on both public and private land.	DPaW, DER, EPA, DoTE, DOP, WAPC, LGA
1.3	Utilise and enhance species distribution modelling to identify refuges or future suitable habitat to mitigate the climate pressures.	1	1	1	Interpretation of climate related species distribution modelling completed.	DPaW, Researchers

Objective 2: Threatening processes that are constraining the recovery of western ringtail possums are mitigated in each key management zone

The impact of threatening processes is complex and interactive for this species. They not only involve habitat loss (see objective 1) but also a variety of other factors. The relative importance of the processes threatening the western ringtail possum varies across the species' range and through time. At any one locality, several threatening processes may be interactive (for example Wayne *et al*. 2000, Wayne 2005, Wayne *et al*. 2006). Such threatening processes need to be identified and managed to reduce their impact on the conservation of western ringtail possum.

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
2.1	Work with fire management agencies to implement improved fire management strategies that minimise the impact of fire prevention, fuel reduction and fire suppression activities on western ringtail possums and their habitat, without increasing the risks of large, higher intensity fires.	2	1	1	Fire management actions have minimal negative impacts on western ringtail possums without increasing the risks of large, higher intensity fires.	DPaW, DFES, LGA
2.2	Implement management strategies to minimise, or compensate for the impacts of disease, pathogens or insects that are likely to impact western ringtail possum habitat quality, including Myrtle Rust surveillance, *Phytophthora* dieback hygiene protocols etc.	1	2	1	Important and high quality habitat is not significantly impacted by disease, pathogen/insects.	DPaW, LGA

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
2.3	Implement effective, integrated introduced predator control programs on DPaW managed land and seek to have a coordinated approach to control of introduced predators across different land tenures to maximise effectiveness.	2	1	1	Introduced predator control programs on DPaW managed lands are effective. Predator control programs are undertaken in a coordinated way across land tenures in key management zones.	DPaW, NRM groups, LGA
2.4	Develop and implement hygiene protocols for all activities in which western ringtail possums are handled or translocated.	1	2	1	Hygiene protocols are written and utilised by researchers, consultants and wildlife rehabilitators.	DPaW
2.5	In accordance with other management strategies, develop and implement control measures for hollow-using introduced pest species where identified as a threat.	2	2	2	Areas where hollow-using pests are impacting western ringtail possums are identified and effective control strategies are implemented.	DPaW, DAFWA, LGA
2.6	Implement management strategies to protect important habitat trees and habitat of extant populations during planning, timber harvest and other forest management activities under the FMP.	N/A	2	N/A	Important western ringtail possum habitat trees and habitat of extant populations are protected in forest management areas consistent with the FMP.	DPaW, FPC
2.7	Implement a process to ensure research and management actions associated with western ringtail possums (including offsets) are consistent with the conservation and recovery objectives for the species.	1	1	1	Offsets are used to benefit western ringtail possum recovery.	DER, EPA, DoTE, DPaW

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
2.8	Evaluate and enhance the effectiveness of management practices associated with threat mitigation, including fire management and predator control. For example: • pre and post fire baiting • pre and post fire fauna monitoring • quantifying habitat characteristics pre and post fire events.	1	1	1	Fauna management strategies maximise the likelihood of western ringtail possum persisting after a disturbance event.	DPAW, Researchers
2.9	Assess relative impacts of biotic factors constraining recovery, including competition (with brushtail possums and pest hollow competitors), pathogens, fauna disease, foliage nutrients etc.	3	1	2	Management actions relating to biotic factors prioritised.	DPaW, Researchers
2.10	Support and develop programs aimed at identifying, restoring or creating suitable habitat, including ecological linkages for the species.	1	2	2	Effective programs are undertaken that create additional western ringtail possum habitat and ecological linkages.	DPaW, DER, EPA, LGA, WAPC
2.11	Assess the outcomes and relative conservation values of different mitigation strategies to determine the highest value for money and conservation benefit, including habitat creation, rehabilitation, relocations, artificial habitat connectors etc.	1	1	2	Assessment of mitigation strategies complete and value of outcomes determined.	DPaW, Developers, Researchers

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
2.12	Improve scientific understanding of the benefits of an urban environment, strategies to enhance urban environments, and its role in the future conservation.	2	3	2	Improved information to influence urban planning and design.	DPaW, LGA, Researchers, Developers

Objective 3: An evidence-based approach is applied to the management and recovery of western ringtail possums

Applying an evidence-based management approach requires pursuing the gaps in our knowledge required to make strategic and effective decisions. For western ringtail possums, a large part of this is effective monitoring and evaluation which can enable the detection of population trends and responses to management actions or other variables. Undetected declines in some populations, or increase of threats could cause a rapid contraction of the species distribution and/or decrease in population size before effective intervention is able to occur.

As the western ringtail possum is a relatively elusive species and is difficult to trap or detect at low numbers there are several areas where knowledge of the abundance and distribution of is lacking. A full understanding of the distribution of the species including low density populations and reasonable measures of population size will enable a more accurate assessment of the species conservation status and provide data and information to determine status and trends. This information can then be used to evaluate management effectiveness and ensure that decisions and strategies are evidence-based.

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
3.1	Develop consistent and reliable protocols for monitoring population size, extent and area of occupancy to ensure that data are comparable over time, while noting that different areas may require different techniques.	1	1	1	Monitoring protocols are developed to evaluate population changes over time.	DPaW, Researchers Consultants

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
3.2	Standardise monitoring protocols for other variables known, or suspected, to influence western ringtail possums such as brushtail possum density, predator density, climatic variables, site productivity and habitat condition, quality and variability.	1	1	1	Monitoring protocols are developed for influencing factors.	DPaW
3.3	Establish a long-term monitoring and evaluation program to detect population changes, within defined sites.	1	1	1	Monitoring, evaluation and reporting program established that can reliably detect rates and magnitudes of population change.	DPaW
3.4	Develop information management system for storing, retrieving and analysing data, including recording absences and survey effort.	1	1	1	Information management system used to store, retrieve and analyse data as per monitoring protocols.	DPaW
3.5	Investigate and trial new methodologies and technologies for detecting low density populations of western ringtail possums.	2	2	2	New technologies investigated.	DPaW, Researchers, Consultants
3.6	Survey areas where western ringtail possums have been known to occur within the last 10 years, areas at the edge of known distributions, and areas with suitable habitat to clarify distribution (i.e. extent of occurrence) and occupancy (i.e. area of occupancy).	1	1	1	Accurate distribution of western ringtail possums is mapped and extent of occurrence and area of occupancy accurately calculated.	DPaW. Researchers, Consultants
3.7	Identify and map extant populations across the species range.	3	3	3	Extant populations are mapped.	DPaW

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
3.8	Use Population Viability Analyses (PVA) to forecast population viability and extinction risk.	2	2	2	Health and extinction risks determined.	DPaW, Researchers
3.9	Determine the genetic characteristics of the remnant western ringtail possum populations to sufficiently inform appropriate management within and between populations, including fine-scale structuring to inform need and location of local linkages	3	3	3	Information on genetic characteristics inform management actions.	DPaW, Researchers
3.10	Improve knowledge of the novel benefits and costs of habitat in urban environments and their role in the conservation of western ringtail possums.	1	3	2	The characteristics and conservation value of urban western ringtail possum habitats are better defined.	

Objective 4: The management of displaced, orphaned, injured and rehabilitated western ringtail possums aids the conservation outcome for the species

Orphaned, injured and rehabilitated possums typically come from urban areas where they have been displaced or injured. Wildlife rehabilitators care for these animals until they can be released. Some animals are released as part of approved translocation programs (de Tores 2005), though an unknown number are released that are not part of a formal process and their fates are unknown. Improved conservation outcomes can be achieved with better management of this activity.

Western ringtail possums may also be displaced by approved land development or land use intensification. As part of impact mitigation, capture and relocation of animals that will be displaced may be set as approval conditions by the regulating authorities. The coordinated and well planned implementation of such relocations is essential to maximise the survival of displaced animals, as well as optimising long term benefits for the conservation of the species. However, studies have shown that survival rates are very low after relocation and thus they should only be undertaken as a last resort. Improved relocation methods are required and need to be demonstrably effective before relocations are considered an effective offset, and before wild to wild translocations can be adopted as a viable recovery action.

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
4.1	Develop rehabilitation protocols and standard operating procedures to manage and ensure best-practice rehabilitation and release of orphaned and injured western ringtail possums.	1	3	2	Formal rehabilitation and release protocols developed and used by stakeholders. Strategic sites identified and monitored. Success of rehabilitation quantified.	Wildlife Rehabilitators, DPaW, Developers, Consultants

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
4.2	Where the need to relocate animals is unavoidable, develop protocols and standard operating procedures, and identify appropriate sites considering climate change modelling, habitat assessment modelling etc.	1	3	2	Relocation protocols developed and applied to all relocations. Criteria developed to select appropriate relocation sites.	DPaW
4.3	Regularly review the outcomes of translocations to ensure translocation protocols are both evidence-based and best-practice.	1	2	2	Protocols for release of relocated and/or translocated animals are evidence-based and use best-practice.	DPaW, Wildlife Rehabilitators, Consultants

Objective 5: Increased awareness of the status of western ringtail possums and support behaviour change to mitigate anthropogenic threatening processes

While the presence of western ringtail possums in the urban areas confronts wildlife managers with many challenges, it also increases opportunities for people to re-connect with nature in the urban context. Community groups are already active in the conservation of the western ringtail possum and are involved by reporting sightings, assisting with surveying and monitoring, and engaging with local government seeking preservation of habitat. Local involvement should be encouraged to help with the conservation effort and increase awareness of the species, particularly in areas of high development potential.

Despite the involvement of some members of the public and previous educational initiatives over many decades, there remains a general lack of broad scale awareness of the conservation status and plight of the species within the community. At the urban interface this manifests itself as apathy towards conserving habitat and for a small group, intolerance to 'living with possums'. Targeted effort to increase community understanding will assist in improving support for conservation of western ringtail possums.

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
5.1	Develop information aimed at increasing community understanding and gaining support for western ringtail possum conservation issues and management.	1	3	1	An observed increase in community support including behavioural change.	DPaW, LGA
5.2	Encourage, co-ordinate and enhance the involvement of groups engaged in western ringtail possum conservation.	2	3	3	Improved coordination of community groups.	DPaW, LGA, Community Groups
5.3	Increase awareness of the species conservation requirements in areas of high development potential.	1	3	1	Increased awareness of conservation requirements and observed behavioural change.	LGA, WAPC, DOP, DPaW

Action	Description	Swan Coastal Plain Zone Priority	Southern Forest Zone Priority	South Coast Priority	Performance Criteria	Responsibility
5.4	Adopt a proactive role to reduce illegal activities that threaten western ringtail possums, and support regulatory actions through the relevant agency.	2	2	2	A reduction in illegal activities.	DPaW, LGA, DER, WA Police

+

14. Implementation and evaluation

The coordination and implementation of this recovery plan will be overseen by the Western Australian Department of Parks and Wildlife. This may involve formation of a western ringtail possum working group/s consisting of representatives directly involved in addressing recovery actions and management of western ringtail possum populations, habitats and threats. Department of Parks and Wildlife recognises that partnerships will need to be developed to assist in the coordination and delivery of the recovery actions.

This plan will be implemented for a minimum of 10 years from the date of its approval, or until replaced by another approved plan. Department of Parks and Wildlife, in consultation with relevant partners, will review and evaluate the performance of this recovery plan, and in particular the performance against the success criteria. The recovery plan must be reviewed at intervals of no longer than five years, or sooner if necessary. All western ringtail possum recovery initiatives will be documented and made available for the periodic reviews. The recovery plan may be revised in light of such review and as other information or research findings become available.

The estimated cost of implementing this Recovery Plan is $3,555,000 over the first years (Table 2). However, this estimated figure does not include costs associated with the ongoing management of habitat by the Department of Parks and Wildlife, other government agencies and private land owners, including the baiting of Department land currently associated with the Western Shield Program and fire management. Nor does it include costs associated with mitigating loss of habitat due to development that may be approved and undertaken over the next five years. These estimated do not account for inflation over time.

Table 2: Summary of costs associated with recovery objectives over the first five years of this Recovery Plan.

Recovery Objective	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Habitat critical for survival for western ringtail possums is protected in each key management zone.	$100,000	$125,000	$85,000	$60,000	$60,000	$430,000
Threatening processes that are constraining the recovery of western ringtail possums are mitigated in each key management zone.	$175,000	$110,000	$125,000	$90,000	$130,000	$630,000
An evidence-based approach is applied to the management and recovery of western ringtail possums.	$550,000	$610,000	$460,000	$360,000	$160,000	$2,140,000
The management of displaced, orphaned, injured and rehabilitated western ringtail possums aids the conservation outcome for the species.	$25,000	$75,000	$75,000	$25,000	$25,000	$225,000
Increased awareness of the status of western ringtail possums and support behaviour change to mitigate anthropogenic threatening processes.	$50,000	$20,000	$20,000	$20,000	$20,000	$130,000
Annual cost	$900,000	$940,000	$765,000	$555,000	$395,000	$3,555,000

15. References

Abbott, I. (2001). Aboriginal names of mammal species in south-west Western Australia. *CALMScience* **3**: 433-486.

Barber, P. and Hardy, G. (Eds) (2006). Research into the cause and management of tuart decline: report of Phase 1 activity (July 2003-June 2006) and Phase 2 objectives (March 2006-Feb 2009). Murdoch University, Western Australia.

Burbidge, A.A. and de Tores, P. (1998). *Western ringtail possum* (*Pseudocheirus occidentalis*) *interim recovery plan, 1997-1999. Interim Recovery Plan Number 17***.** Western Australian Threatened Species and Communities Unit, Department of Conservation and Land Management, Wanneroo.

Christensen, P.; Liddelow, G. and Hearn, R. (2004). *Assessment of vertebrate fauna prior to disturbance - timber harvesting and prescribed burning in the forests of western Australia. The Forest Fauna Distribution Information System.* Department of Conservation and Land Management, Manjimup.

Clarke, J. R. (2011). *Translocation outcomes for the western ringtail possum* (*Pseudocheirus occidentalis*) *in the presence of the common brushtail possum* (*Trichosurus vulpecula*): *health, survivorship and habitat use*. (Doctoral dissertation) Murdoch University, Western Australia.

Coley, P.D. (1998). Possible effects of climate change on plant/herbivore interactions in moist tropical forests. *Climatic Change* **39**: 455-472.

Conservation Commission of Western Australia (2004) *Forest Management Plan 2004-2013*. Perth, Western Australia.

Conservation Commission of Western Australia (2013). *Forest Management Plan 2014-2023*. Perth, Western Australia.

Dakin, N.; White, D.; Hardy, G.E. and Burgess, T.I. (2010). The opportunistic pathogen, *Neofusicoccum australe*, is responsible for crown dieback of peppermint (Agonis flexuosa) in Western Australia. *Australasian Plant Pathology,* **39** (2): 202-206.

de Tores, P.J. (2000). Review of the distribution and conservation status of the Western ringtail possum, *Pseudocheirus occidentalis* (Thomas), and recommendations for management.

de Tores, P.J. (2005). *A proposal for translocation of the Western ringtail possum,* Pseudocheirus occidentalis*, an arboreal marsupial endemic to the south-west of Western Australia*. Department of Conservation and Land Management, Perth.

de Tores, P.J. (2008). Western ringtail possum. In: Van Dyck, S. and Strahan, R. (Eds) *The Mammals of Australia*. Reed New Holland, Sydney, Australia p 253-255.

de Tores, P.J. (2009*). A summary of research by Department of Enviornment and Conservation, Murdoch University and Curtin University on the western ringtail possum (*Pseudocheirus occidentalis*) on the southern Swan Coastal Plain and recommendations relevant to*

current research proposals. Report prepared for the Commonwealth Department of Enviornment, Water, Heritage and the Arts, Canberra, Australia.

de Tores, P.J. and Elscot, S. (2010). Estimating the population size of a threatened arboreal marsupial: use of distance sampling to dispense with ad hoc survey techniques. *Wildlife Research,* **37:** 512–523

de Tores, P.J.; Hayward, M.W. and Rosier, S.M. (2004). The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*. Case studies: *Western Shield* Review - February 2003. *Conservation Science Western Australia* **5** (2): 235-257.

de Tores, P.J.; Rosier, S.; Jackson, J.; Clarke, J. and Aravidis, L. (2008). Working to conserve the western ringtail possum. *Landscope* **25**: 54-61.

de Tores, P.J.; Rosier, S.M. and Paine, G. (1998). Conserving the western ringtail possum. *Landscope* **13:** 28-35.

Department of Environment and Conservation (DEC) (2008). *Western Shield Fauna Recovery Program Draft Interim Strategic Plan 2009-2010*. Unpublished report Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2009a). *Guidelines for Protection of the Values of Informal Reserves and Fauna Habitat Zones,* Department of Environment and Conservation, Sustainable Forest Management Series, SFM Guideline No. 4.

Department of Environment and Conservation (DEC) (2009b). *South Coast Regional Fire Management Plan 2009-2014*. Unpublished Report. Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2010). *Guidelines for the Selection of Fauna Habitat Zones*, Department of Environment and Conservation, Sustainable Forest Management Series, SFM Guideline No. 6.

Department of Environment and Conservation (DEC) (2011). *Protocols for Measuring and Reporting on the Key Performance Indicators of the Forest Management Plan 2004-2013*, Department of Environment and Conservation, Sustainable Forest Management Series, SFM Manual No. 2.

Department of Environment and Conservation (DEC) (2012a). *Perup management plan 2012*, Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2012b). *Chuditch (Dasyurus geoffroii) Recovery Plan. Wildlife Management Program No. 54*. Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2012c). *Records held in DEC's Threatened Fauna Database and threatened fauna files*. Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2013). *Quokka Setonix brachyurus Recovery Plan. Wildlife Management Program No. 56.* Department of Environment and Conservation, Perth.

Department of the Environment (2014). *Threat abatement plan for disease in natural ecosystems caused by Phytophthora cinnamomi*. Commonwealth Government of Australia, Canberra.

Department of Environment, Water, Heritage and the Arts, Canberra. (DEWHA) (2008a). *Threat abatement plan for predation by European red fox*. Department of Environment, Water, Heritage and the Arts, Canberra.

Department of Environment, Water, Heritage and the Arts (DEWHA) (2008b). *Threat abatement plan for predation by feral cats.* Department of Environment, Water, Heritage and the Arts, Canberra.

Department of Environment, Water, Heritage and the Arts (DEWHA) (2009). *Nationally threatened species and ecological communities, EPBC Act policy statement 3.10 - Significant impact guidelines for the vulnerable western ringtail possum (Pseudocheirus occidentalis) in the southern Swan Coastal Plain, Western Australia*. Department of Environment, Water, Heritage and the Arts, Canberra.

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2008). *Recovery Planning Compliance Checklist for Legislative and Process Requirements*. <http://www.environment.gov.au/biodiversity/threatened/publications/recovery/guidelines/pubs/recovery-checklist.pdf> (accessed January 2013).

Department of Parks and Wildlife (DPaW) (2015). *Policy statement No. 35 Conserving threatened species and ecological communities*, Department of Parks and Wildlife, Perth.

Department of Parks and Wildlife (DPaW) (2015). *Corporate Guideline No. 35 Listing and recovery of threatened species and ecological communities, D*epartment of Parks and Wildlife, Perth.

Department of Parks and Wildlife (DPaW) (2015). *Corporate Policy No. 36, Recovery of threatened species through translocation and captive breeding or propagation*, Department of Parks and Wildlife, Perth.

Department of Parks and Wildlife (DPaW) (2015). *Policy statement No. 3 Management of Phytophthora disease*, Department of Parks and Wildlife, Perth.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011) *Survey guidelines for Australia's threatened mammals.* Commonwealth Government of Australia, Canberra.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012) *EPBC Act environmental offsets policy.* Commonwealth Government of Australia, Canberra.

Driscoll, A. (2000). *A comparison between the insulation qualities of hollows in trees and nests in balga (Xanthorrhoea preissii): study relating to habitat used by the western ringtail possum (Pseudocheirus occidentalis*). (Honours thesis), Australian National University, Canberra.

Dumbrell, I. (2011). *Department of Agriculture and Food Gardennote 501 – Myrtle rust*. Department of Agriculture and Food, Western Australia.

Eastern Metropolitan Regional Council (EMRC) (2004). *Shire of Busselton Environment Strategy*. Eastern Metropolitan regional Council, Environmental Services, Belmont Western Australia.

Ellis, M. and Jones, B. (1992). Observations of captive and wild western ringtail possums *Pseudocheirus occidentalis*. *Western Australian Naturalist* **19:**1-10.

Environment Australia (2001). *Threat abatement plan for dieback caused by the root-rot fungus Phytophthora cinnamomi*. Environment Australia, Canberra.

Farr, J. (2009). *DPaW Science Division Information Sheet 12 - Gumleaf skeletoniser in the jarrah forest*. Department of Environment and Conservation, Western Australia.

Fire Management Services (2008). *Fire management guideline: E4 - Tuart Woodlands*. Department of Environment and Conservation, Perth.

Forest Products Commission (2015). *Procedure 46; Targeted fauna surveys within pure and mixed karri forest*. <http://www.fpc.wa.gov.au/content_migration/_assets/documents/environment/fsc/procedure-46-targeted-fauna-surveys.pdf > (accessed March 2016)

Garkaklis, M.J.; Calver, M.C.; Wilson, B.A. and Hardy, G.E. (2004). Habitat alteration caused by an introduced plant disease, *Phytophthora cinnamomi*: a potential threat to the conservation of Australian forest fauna. In: *The Conservation of Australia's Forest Fauna* (second edition). D. Lunney (ed). Royal Zoological Society of New South Wales, Mosman, NSW, Australia. pp 899 – 913.

Gilfillan, S. (2008). *Western Ringtail Possum (Pseudocheirus occidentalis) Survey and Data Collection in the Greater Albany Area*. Phase 1 Final Report. Prepared for Department of Environment and Conservation, Albany Regional Office.

Government of Western Australia (2011). *Western Australian Government Environmental Offsets Policy*. Government of Western Australia.

Grimm, H.L and de Tores P.J. (2009). *Some aspects of the biology of the common brushtail possum (Trichosurus vulpecula) and the threatened western ringtail possum (Pseudocheirus occidentalis) in a pine plantation scheduled for harvesting and in adjacent tuart and peppermint woodland near Busselton, Western Australia*. Report prepared for the Forest Products Commission, Government of Western Australia.

Harewood G (2008). *An assessment of the distribution and abundance of Western Ringtail Possum (Pseudocheirus occidentalis) in Busselton urban public reserves*. Unpublished report prepared for Geocatch, November 2008.

Harewood, G. (2005). *Western Ringtail Possum Survey, Gwindinup North Mineral Sands Mine*. Unpublished report prepared for Bemax Resources, Bunbury, Western Australia.

Harring-Harris, K. (2014). *The importance of preserving peppermint threes (Agonis flexuosa) in development sites and providing alternative rest sites for western ringtail possums (Pseudocheirus occidentalis)*. (Honours thesis), The University of Western Australia.

How, R. A. (1978). Population strategies of four species of Australian possums. In: *Ecology of Arboreal Folivores*. G.G. Montgomery (ed). Smithsonian Institution Press, Washington.

How, R.A. and Hillcox, S.J. (2000). Brushtail possum, *Trichosurus vulpecula*, populations in south-western Australia: demography, diet and conservation status. *Wildlife Research* **27**: 81-89.

How, R.A.; Dell, J. and Humphreys, W.F. (1987). The ground vertebrate fauna of coastal areas between Busselton and Albany, Western Australia. *Records of the Western Australian Museum* **13**(4): 553-574.

Hume, I. D. and Sakaguchi, E. (1993). A Scheme for the Functional Classification of mammalian

Hindgut fermenters. In: *Abstracts. Sixth International Theriological Congress. University of New South Wales, Sydney, Australia. 4-10 July 1993.* M.L. Augee (ed.) University of New South Wales: Sydney, Australia.

Hume, I.D. (1999). *Marsupial Nutrition*. Cambridge University Press, Cambridge, UK.

Hume, I.D.; Foley, W.J. and Chilcott, M.J. (1984). Physiological mechanisms of foliage digestion in the greater glider and ringtail possum (Marsupialia: Pseudocheiridae). In: *Possums and gliders*. Smith, A, and Hume, I. (eds.). Surrey, Beatty and Sons: Chipping Norton, N.S.W.

Inions, G. (1985). *The interactions between possums, habitat trees and fire*. (Honours Thesis) Australian National University, Canberra.

Inions, G.B.; Tanton, M.T. and Davey, S.M. (1989). Effect of fire on the availability of hollows in trees used by the common brushtail possum, *Trichosurus vulpecula* Kerr, 1792, and the ringtail possum, *Pseudocheirus peregrinus* Boddaerts, 1785. *Australian Wildlife Research* **16**: 449-458.

IUCN (2012). *IUCN Red List of Threatened Species*. Version 2012.2. <www.iucnredlist.org>. (accessed March 2013).

Jones, B. (2001). *A report on the conservation status and future management of the ringtail possum population in the Harvey River valley*. Draft report to the Water Corporation, Perth.

Jones, B.A. (1995). Western ringtail possum. In: *The mammals of Australia*. R. Strahan (Ed). Australian Museum / Reed New Holland, Australia

Jones, B.A. (2004) The possum fauna of Western Australia: decline, persistence and status. In: *The Biology of Australian Possums and Gliders*. R.L. Goldingay and S.M. Jackson (eds). Surrey Beatty & Sons, Chipping Norton, pp. 149-160.

Jones, B.A. and Francesconi, M. (2007). *An important local population of the Western Ringtail Possum, Pseudocheirus occidentalis: a 2006 survey study of the population and habitat in the Busselton localities of Siesta Park and Kealy*. Unpublished report prepared for Geocatch.

Jones, B.A. and Hillcox, S. (1995). A survey of the possums *Trichosurus vulpecula* and *Pseudocheirus occidentalis* and their habitats in forest at Ludlow, Western Australia. *Western Australian Naturalist* **20**: 139-150.

Jones, B.A.; How, R.A. and Kitchener, D.J. (1994a). A Field Study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae). I. Distribution and Habitat. *Wildlife Research* **21**: 175-187.

Jones, B.A.; How, R.A. and Kitchener, D.J. (1994b). A Field Study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae). II. Population studies. *Wildlife Research* **21**: 189-201.

Jones, B.A.; Meathrel, C.E. and Calver, M.C. (2004). Hypotheses arising from a population recovery of the Western ringtail possum *Pseudocheirus occidentalis* in fire regrowth patches in a stand of *Agonis flexuosa* trees in south-western Australia. In: *Conservation of Australia's Forest Fauna*. D. Lunney (ed). Royal Zoological Society of New South Wales, Mosman, NSW. pp. 656 - 662.

Kanowski, J. (2001). Effects of elevated CO_2 on the foliar chemistry of seedlings of two rainforest trees from north-east Australia: Implications for folivorous marsupials. *Austral Ecology* **26**: 165-172.

Lawler, I.R.; Foley, W.J.; Woodrow, I.E. and Cork, S.J. (1997). The effects of elevated CO^2 atmospheres on the nutritional quality of *Eucalyptus* foliage and its interaction with soil nutrient and light availability. *Oecologia* **109**: 59-68.

May, S.A. and Norton, T.W. (1996). Influence of fragmentation and disturbance on the potential impact of feral predators on native fauna in Australian forest ecosystems. *Wildlife Research* **23** (4): 387-400.

McCutcheon, H.; Clarke, J.; de Tores, P.J. and Warren, K. (2010). Health status and translocation success of wild and rehabilitated possum. Proceedings of the *National Wildlife Rehabilitation Conference* 2007.

Molloy, S.W., Davis, R.A. and Van Etten, E.J.B. (2013). Species distribution modelling using bioclimatic variables to determine the impacts of a changing climate on the western ringtail possum (*Pseudocheirus occidentals*; Pseudocheiridae). *Environmental Conservation* **41** (2): 176-186.

Ninox Wildlife Consulting (1999a). *Stirling-Harvey Redevelopment Scheme: Part 1: Stirling-Harvey pipeline and interim management strategy for the Western Ringtail Possum*. Perth: unpublished report for the Water Corporation.

Ninox Wildlife Consulting (1999b). *Stirling-Harvey Redevelopment Scheme: Part 2: Harvey Reservoir fauna management plan and management strategy for Western Ringtail Possum*. Perth: unpublished report for the Water Corporation.

Risbey, D.A.; Calver, M.C.; Short, J.; Bradley, J.S. and Wright, I.W. (2000). The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* **27**: 223-235.

Robinson, R. (2012) *Armillaria root disease in karri regrowth forests*. Information Sheet 45. Department of Environment and Conservation – Science Division, Western Australia.

Sandiford, E.M. and Barrett, S. (2010). *Albany Regional Vegetation Survey: Extent, Type and Status. A project funded by the Western Australian Planning Commission, South Coast NRM and the City of Albany for the Department of Environment and Conservation.* Unpublished report. Department of Environment and Conservation, Western Australia.

Scott, P.M.; Burgess, T.I.; Barber, P.A.; Shearer, B.L.; Stukely, M.J.C.; Hardy, G.E. and Jung, T. (2009). *Phytophthora multivora* sp. nov., a new species recovered from declining *Eucalyptus*, *Banksia*, *Agonis* and other plant species in Western Australia. *Persoonia* **22**: 1–13.

Scott, P.M.; Jung, T.; Shearer, B.L.; Barber, P.A.; Calver M. and Hardy, G.E. (2012). Pathogenicity of *Phytophthora multivora* to *Eucalyptus gomphocephala* and *Eucalyptus marginata*. *Forest Pathology* **42**(4): 289–298.

Shedley, E. and Williams, K. (2014). *An assessment of habitat for Western Ringtail Possum (Pseudocheirus occidentalis) in the southern Swan Coastal Plain*. Unpublished report for the Department of Parks and Wildlife, Bunbury, Western Australia.

Shire of Augusta-Margaret River (SAMR) (2005). Shire of Augusta–Margaret River Biodiversity Conservation Strategy: A Discussion Paper.

Shortridge, G.C. (1909). Pseudocheirus occidentalis. *In: An Account of the Geographical Distribution of the Marsupials and Monotremes of South-West Australia Having Special Reference to the Specimens Collected During the Balston Expedition of 1904-1907*. pp. 803-48.

Stacey, R. and Hay, A. (2007). *Museum: The Macleays, their collection and the search for order*. Cambridge University Press, United Kingdom.

Timbal, B. (2004). Southwest Australia past and future rainfall trends. *Climate Research* **26**: 233-249.

Ward, D.J.; Lamont, B.B. and Burrows, C.L. (2001). Grasstrees reveal contrasting fire regimes in eucalypt forest before and after European settlement of southwestern Australia. *Forest Ecology and Management* **150**, 323-329.

Wayne, A. (2005). *The ecology of the koomal (Trichosurus vulpecula hypoleucus) and ngwayir (Pseudocheirus occidentalis) in the jarrah forests of south-western Australia*. (Doctoral dissertation) Australian National University, Canberra.

Wayne, A. (2006). *Fire management guideline: ngwayir (western ringtail possum)*. Department of Conservation and Land Management, Manjimup.

Wayne, A.; Rooney, J.; Ward, C.; Wheeler, I. and Mellican, A. (2001). *Spotlight surveys to investigate the impacts of timber harvesting and associated activities within the jarrah forest of Kingston State Forest, with particular reference to the koomal (Trichosurus vulpecula) and ngwajir (Pseudocheirus occidentalis*). Department of Conservation and Land Management, Manjimup.

Wayne, A.; Ward, C.; Rooney, J. and Wheeler, I. (2000). *The immediate impacts of timber harvesting and associated activities on the Ngwajir (Pseudocheirus occidentalis) in the Jarrah forest of Kingston State Forest Block*. Department of Conservation and Land Management, Manjimup.

Wayne, A.F.; Cowling, A.; Lindenmayer, D.B.; Ward, C.G.; Vellios, C.V.; Donnelly, C.F. and Calver, M.C. (2006). The abundance of a threatened arboreal marsupial in relation to anthropogenic disturbances at local- and landscape- scales in Mediterranean-type forest in Western Australia. *Biological Conservation* **127**: 463-476.

Wayne, A.F.; Cowling, A.; Rooney, J.F.; Ward, C.G.; Vellios, C.V. and Lindenmayer, D.B. (2005b). A comparison of survey methods for arboreal possums in jarrah forest, Western Australia. *Wildlife Research* **32**: 701–714.

Wayne, A.F.; Cowling, A.; Rooney, J.F.; Ward, C.G.; Wheeler, I.B. and Lindenmayer, D.B. (2005a). Factors affecting the detection of possums by spotlighting in Western Australia. *Wildlife Research* **32**: 689–700.

Wayne, A.F.; Rooney, J.F.; Ward, C.G.; Vellios, C.V. and Lindenmayer, D.B. (2005c). The life history of Pseudocheirus occidentalis (Pseudocheiridae) in the jarrah forest of south-western Australia. *Australian Journal of Zoology* **53**: 325–337.

Wayne, A.F.; Ward, C.G.; Vellios, C.V.; Maxwell, M.; Wilson, I.; Wayne, J.; Ward, D.B.; Liddelow, G.; Renwick, J. and Orell, P. (2012). *Ngwayir (Pseudocheirus occidentalis) declines in the*

Upper Warren, the issue in brief. Internal Report. Department of Parks and Wildlife, Perth.

Western Australian Planning Commission (WAPC) (2005). *Busselton Wetlands Conservation Strategy*. Western Australian Planning Commission, Perth.

Williams, K. and Barton, B. (2012). *Western Ringtail Possum Pseudocheirus occidentalis translocation proposal for various locations*. Unpublished report for the Department of Environment and Conservation, Perth.

Wills, A. (2009). *DPaW Science Division Information Sheet 16 - Jarrah Leafminer a damaging pest of jarrah forest*. Department of Environment and Conservation, Western Australia.

Wilson, K. (2009). *Quantifying the Genetic Effects of Habitat Fragmentation on the Western Ringtail Possums (Pseudocheirus occidentalis) in South-West Western Australia*. (Honours thesis), Murdoch University, Western Australia.

Woinarski J.C.Z; Burbidge A.A. and Harrison P.L. (2014). *The 2012 action plan for Australian mammals*. CSIRO publishing.

Wood, M.S., and Wallis, R.L. (1997). Potential competition for nest sites between feral European honeybees (*Apis mellifera*) and common brushtail possums (*Trichosurus vulpecula*). *Australian Mammalogy* **20**: 377-381.

Yeatman, G.J. and Groom, C.J. (2012). *National Recovery Plan for the woylie Bettongia penicillata. Wildlife Management Program No. 51*. Department of Environment and Conservation, Perth.

Yin, H.K. (2006). *The metabolic and hygric physiology of Western Ringtail Possum (Pseudocheirus occidentalis)*. (Honours thesis), Curtin University of Technology, Western Australia.

Personal Communication References

A. Wayne – Adrian Wayne (DPaW Science and Conservation Division)

B. Jones – Barbara Jones (Environmental Consultant)

G. Harewood – Greg Harewood (Environmental Consultant)

G. Liddelow – Graham Liddelow (DPaW Science and Conservation Division)

J. Wayne – Julia Wayne (DPaW Warren Region)

K. Williams – Kim Williams (DPaW South West Region)

N. Burrows – Neil Burrows (DPaW Science and Conservation Division)

P. Christensen – Per Christensen (FPC)

S. Comer – Sarah Comer (DPaW South Coast Region)