Distribution and status of the Red-tailed Phascogale *Phascogale calura*

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Abstract

The red-tailed phascogale once extended widely across semi-arid and arid Australia, but is now entirely confined to the southern wheatbelt of Western Australia occupying less than 1% of its former range. Here it occurs in a portion of the Avon Wheatbelt, Jarrah Forest, Mallee, and Esperance Plains biogeographical regions. The species persists only in areas that have been extensively cleared for agriculture and where the remaining bushland is highly fragmented. It does not appear to extend into unfragmented habitat in either the Jarrah Forest to the west or Mallee region to the east. It occurs primarily in woodland habitat with old growth hollow-producing eucalypts, primarily wandoo *Eucalyptus wandoo* or York Gum *E. loxophleba*, but records from the periphery of its current range appear to come from a broader range of habitats including shrublands and various mosaics of woodland, shrubland, and scrub-heath.

Key factors limiting persistence are likely to be fragmentation of habitat that is likely to greatly increase the risks associated with dispersal; a shortage of suitable nesting hollows in many vegetation associations; and predation by feral and domestic cats and by foxes. These factors, particularly fragmentation and lack of suitable nesting hollows, suggest that the species' long-term persistence in areas beyond the wandoo belt is far from assured.

Additional keywords: fragmentation, feral cat, tree hollows, fire, dasyurid

Introduction

The red-tailed phascogale *Phascogale calura* is a small semi-arboreal and insectivorous dasyurid that now persists only in the far south-west of Western Australia (Bradley *et al.* 2008). It is listed as 'endangered' under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, as 'fauna that is rare or likely to become extinct' under the Wildlife Conservation Act in Western Australia, and as 'near threatened' by the IUCN Red List of Threatened Species. The species was first reported from near Williams in

Western Australia in 1843 (Gould 1863), with subsequent surveys extending its range to the junction of the Murray and Darling Rivers in eastern Australia in the mid-nineteenth century (Krefft 1866), to central Australia in the late nineteenth century (Parker 1973), and to Well 44 on the Canning Stock Route in Western Australia in 1931 (Burbidge and Fuller 1979). A live specimen was also apparently taken in or near Adelaide at some time prior to 1888 (Wood Jones 1923). Unfortunately, for all localities other than south-west Western Australia, these were both the first and the last records for this species.

The current range of the species is now limited to south-west Western Australia, where it coincides with a region of intensive agriculture known as the wheatbelt. In excess of 90% of native habitat in this region has been cleared for cropping in the past 100 years and remaining habitat remnants are often small and fragmented (Saunders 1989). Phascogale typically occupy remnant woodlands in upland areas where mature wandoo *Eucalyptus wandoo* and rock sheoak *Allocasuarina heugeliana* are adjacent (Kitchener 1981; Short *et al.* 2011). In lowland areas they typically occur along riverine corridors and lake margins, often in areas of mature York gum *E. loxophleba* and swamp sheoak *Casuarina obesa* (Short *et al.* 2011). These habitats provide an abundance of hollows and a continuous canopy.

Key ongoing threats to red-tailed phascogale include loss of habitat to salinity and land clearing, the increasing fragmentation of remaining habitat by incremental loss of roadside vegetation, and the loss of old-growth paddock trees to facilitate use of larger agricultural equipment (Short *et al.* 2011). Domestic cats are known predators of phascogale (Gould 1863), and so it is likely they are also vulnerable to predation by feral cats and foxes. However, the scale of impact is unknown. Foxes *Vulpes vulpes* are widespread and abundant in habitat used by phascogale. Feral cats *Felis catus* are also present but their abundance relative to foxes is unknown.

We collated the available information on the distribution of red-tailed phascogale and supplemented this with survey for the species in a large number of remnants of native vegetation in the Western Australian wheatbelt, focused largely on the south-western boundary of the species range (Short *et al.* 2011). We have used these data to establish:

- The current distribution of the species and any evidence of recent ongoing decline;
- Key vegetation associations still occupied by the species in south-west Western Australia;
- The likely impact of feral and domestic cats on the species; and
- An assessment of its current status.

Methods

Distribution of phascogale

Information on the distribution of phascogale within Australia was collated from the literature, records of the Western Australian Museum, trapping and community sightings sourced from the Department of Environment and Conservation (DEC), and a register of community sightings maintained by the Wagin Woodanilling Landcare Zone in the period 2005 onwards.

Community records of phascogale obtained by the Wagin Woodanilling Landcare Zone were solicited from community members from Wagin and surrounding areas by displaying images of phascogale in newsletters, posters in shopfronts, articles in local newspapers and magazines, school talks, and at a stall and display at the annual regional show – the Wagin Woolarama – over a 4 year period.

In addition, we built on the past distribution data with trapping conducted in the wheatbelt between Narrogin and Kojunup (reported in Short *et al.* 2011) and some sparse trapping in the central wheatbelt near Narembeen and Hyden in the years 2004 - 2009.

Data Analysis

Data were collated and added to a GIS for display and analysis. The data were filtered to remove obvious errors (such as where latitude and longitude did not match the site name or where the description of the animal did not reasonably describe phascogales), duplicate records, and data with low certainty. Records were categorised to region by the Interim Biogeographic Regionalisation for Australia (IBRA 6.1). Areas of former and current range were determined by creating minimum convex polygons around either all or post-1990 points and calculating areas using a GIS. Four clear outliers were omitted from the calculation of post-1990 range (Jerdacuttup, Marvel Loch, Hyden and Dwellingup). Each record from Western Australia was assigned a vegetation association by overlaying records over a layer for Beard's vegetation (Beard 1980, Hopkins *et al.* 2002) on the GIS. If there were several vegetation associations in close proximity to a particular point then one with an obvious *Eucalyptus* over-storey was chosen (compared with say heath or samphire, etc).

Results

Distribution

Table 1 gives a summary of records from the literature, Western Australian Museum, Department of Environment and Conservation (DEC), community records (including DEC), and additional trapping records from Short *et al.* (2011). These are shown at the Australia-wide scale in Figure 1 and the regional scale for south-west Western Australia in Figure 2. Sub-fossil records were derived from Lundelius (1957), Kendrick and Porter (1973), Smith and Medlin 1982, Baynes (1987, 1990), Tunbridge (1991), Baynes and Baird (1992), Baynes and Jones (1993), and McKenzie *et al.* (2000). Records for the desert regions of central eastern Western Australia were sourced from Burbidge *et al*. (1988), who obtained them by interviewing Aborigines and showing them skins of a range of possible species. They considered three records to be current at that time (early 1980s) and nine to be within the living memory of informants.

A number of locations, particularly key nature reserves, were represented by many specimens and/or trapping records (e.g. Dryandra Forest, Yornaning Nature Reserve, Dongolocking Nature Reserve, Tutanning Nature Reserve and Wagin town). Records were subsumed to a single location if they appeared to be from a discrete patch of remnant bushland or reserve. Community records within two kilometres of another community record or of a remnant known to contain phascogale were similarly subsumed to a single location. This gave 231 discrete locations. Of these, 142 (61%) were post-1990.

Records showed a strong concentration of current positive records in the Western Australian wheatbelt with a tongue of sub-fossil records extending across the Great Australian Bight towards South Australia with sub-fossil records on the Eyre Peninsula and Flinders Ranges in South Australia and historic records in Adelaide (Wood Jones 1923) and at the Murray-Darling junction (Krefft 1866) (Figure 1). Other records form a cluster in central Australia and include Aboriginal records presumed to date from *c.* 1930s to early 1980s and museum specimens from the period 1896 to 1931. In addition, there is a small cluster of sub-fossil sites on the Western Australian coast from Shark Bay to Cape Range (Baynes 1990; McKenzie *et al.* 2000).

Records in Western Australia (Figure 2) show a tight concentration in the southern wheatbelt in a band some 150 km long in a north-south direction from Brookton to Katanning and about 80 km wide from about Williams to Dumbleyung. Sparse outlying records extend

to the west to the margin of the jarrah (*E. marginata*) forest and to the east to Hyden and Newdegate and to the south to Bremer Bay. Extreme outliers are recent specimen records from Jerdacuttup, some 200 km to the east of other records (1997), a specimen from Dwellingup (1988) in the jarrah forest well beyond the wheatbelt, and a sighting record from south of Marvel Loch (south of Southern Cross, 1998) at the eastern margin of the wheatbelt.

Outlying records for which a gender could be determined were invariably male. These included museum specimens from Bremer Bay, Boddington, Dwellingup, Jerramungup (2 specimens collected several years apart), Jerdacuttup, and Beverley. A community specimen from Hyden was also male. Two records of phascogale at Kojunup included a male and a female.

There appears to be a very sharp northern margin to the current range at an east-west line from Beverley to Hyden, for which there is no obvious explanation, particularly given that the past distribution extended well to the north-east. There is a single museum record from Beverley in 2000, some 35-40 km north of populations in Boyagin, Weam, Pingeculling and Tutanning Nature Reserves. Historic records from the far south (Cape Riche, 1905; Cranbrook, 1929) and south-west (Bridgetown approximate location 1910) are not matched by recent records.

Records for the eastern margins of the current range are largely derived from community sightings and appear scattered and sporadic relative to those in the core range. Trapping in several of the larger nature reserves in the north-east (Bendering, North Karlgarin, Dragon Rocks) yielded records in the 1970s but not subsequently. Similarly, the presence of a population suggested by a comparatively recent specimen record collected by a community member from north of Hyden was not confirmed by subsequent trapping. Much of this eastern portion of the wheatbelt coincides with the Mallee region (Table 2), a region where a comparatively low percentage of records are of recent (post-1990) origin. Hence, it is unclear how persistent and secure populations are in this region.

The southern coastal fringe (Esperance Plains region) has few records and a comparatively low percentage of recent origin (Table 2). Again, little is known of the persistence and security of populations of phascogale in this region.

Figure 2 also shows sites where trapping has been conducted and has not recorded phascogale. These include major surveys of wheatbelt reserves in the early and mid-1970s (summarised in Kitchener *et al.* 1980) and the Goldfields in the late 1970s and early 1980s

(introduced by Biological Surveys Committee Western Australia 1984). Similarly, fauna surveys in the deserts of Western Australia (e.g. Burbidge *et al.* 1976, McKenzie and Burbidge 1979, Burbidge and McKenzie 1983) have not revealed the presence of phascogale. Few records have been detected near the south coast despite extensive trapping (e.g. Chapman 1995; Orell 2004; A. Sanders, pers. com.).

Figure 3 highlights the apparent recent (post-1990) absence of phascogale from 1) a broad band across the north-east of the current range of phascogale, extending from Beverley to Narembeen, Hyden and Newdegate, and 2) from Katanning to the southern coast. However, there are community records for a site to the south of Marvel Loch (an unconfirmed community sighting in 1998); to the north-east of Hyden (a specimen collected in 2008), Newdegate (a specimen in 1993); and Jerdacuttup (a specimen from 1997). Collectively, these records suggest the species might still persist along the eastern margin of the wheatbelt and possibly in the adjoining uncleared woodland.

Status

Phascogale apparently contracted from eastern Australia by the mid to late nineteenth century, from Central Australia by the 1920s, and the deserts of Western Australia by the 1970s. That contraction in range appears to have continued into recent times with populations apparently being lost from the central and eastern wheatbelt of Western Australia since the mid-1970s. Based on post-1990 records, phascogale appear to now only persist in *c.* 28,000 km^2 of the Western Australian wheatbelt; < 1% of their former known range of *c.* 2.8M km^2. Given that 84% of that area has been cleared for agriculture and that a portion (say 25%) of remaining remnant vegetation may not be suitable habitat, the area currently occupied by phascogale is likely to be closer to 3,000-3,500 km^2.

The most recent decline in range of the phascogale appears to have been a step change associated with the clearing of woodland vegetation surrounding remaining reserves such as Bendering and North Karlgarin Nature Reserves in the 1960s and 1970s. It is unclear whether such declines are continuing in the eastern wheatbelt. These declines, as major as they are, do not qualify the species for threatened status under IUCN guidelines (IUCN 3.1). To qualify at the lowest category of threatened (i.e. Vulnerable) a species must be subject to very immediate declines (within the past 10 years or three generations).

Hence, the red-tailed phascogale is classified as 'Near Threatened' using IUCN Red List criteria (Friend 2008). The basis of that classification is that the "population of this species is

probably less than 10,000 mature individuals and it might be decreasing, but not at a rate of 10% over 10 years. Thus it is close to qualifying as Vulnerable under criterion C."

Distribution by IBRA region and vegetation association

Some 66% of records were from the Avon Wheatbelt region, 10.9% from Mallee, 10.7% from Jarrah Forest, 1.7% from Esperance Plains, and 10.7% from other regions (Table 2). The Avon Wheatbelt also had the highest percentage of recent (post-1990) records, followed by Jarrah Forest, Esperance Plains and Mallee. Aboriginal records, many early records beyond Western Australia, and sub-fossil records were scattered across at least 19 other bioregions. However, none of these records are post-1990.

Most records, across bioregions, came from medium woodland (77.5%), or from mosaics of woodland and other vegetation associations (5%) (Table 3). The next most common vegetation association was 'succulent steppe', a broad categorization that included woodlands of York gum and/or swamp sheoak towards the bottom of the catena (10%). Other associations occupied by phascogale included shrublands (6.25%), bare rock (presumably reflecting the fringing vegetation of rock sheoak around granite outcrops) (<1%), medium forest (< 1%), and hummock grassland with low open tree steppe (< 1%).

Wandoo is listed as a key species in most associations occupied within both Avon Wheatbelt and Jarrah Forest – both medium woodland and succulent steppe. Phascogale locations were also recorded in powderbark wandoo (*E. accedens*) and York gum associations. Within the Mallee bioregion, a more diverse array of major tree species characterise vegetation associations – York gum, salmon gum (*E. salmonophloia*), morrel (*E. longicornis*), and various mallee-form species (tall sand mallee *Eucalyptus eremophila*, redwood *E. transcontinentalis*, and black marlock *E. redunca/E. angusta*). Yate (*E. occidentalis*) may be a key species on the Esperance Plains (A. Sanders, pers. com.) and desert bloodwood (*Corymbia chippendalei*) is likely to be important in desert sites, including the Great Sandy Desert (Burbidge *et al.* 1988).

Records that appear to be geographical outliers occur in habitat not typical for the species (e.g. jarrah-marri medium forest at Dwellingup in the far west; tallerack *E. pleurocarpa* mallee heath at Jerdacuttup in the far south-east).

Dynamics of phascogale presence

Red-tailed phascogale have been recorded at least once in 40 nature reserves and/or national parks and 19 other Crown reserves. However, there have been no post-1990 records in Bendering Nature Reserve, North Karlgarin Nature Reserve, Dragon Rocks Nature Reserve (Table 4), Whinbin Rock Nature Reserve, or the Badjebup town site reserve. Greater than three annual positive trapping records have only been recorded for 11 reserves; a further ten sites have been trapped several times with a mix of positive and negative results (Table 4). Several sites may have apparently gained phascogale, several appear to have lost the species. The apparent losses come from some of the biggest reserves known to have contained phascogale. Most have been trapped over several years with a reasonable trapping effort (800 trap nights p.a. with cages and Elliotts over three years for Dragon Rocks Nature Reserve; 400 p.a. for four years at North Karlgarin Nature Reserve; 260 p.a for four years at Bendering Nature Reserve: Orell 2004). While little is known of the ecology of phascogale in mallee, shrubland and heath vegetation, it seems likely that there is only limited suitable habitat for the species in reserves dominated by such vegetation associations (e.g. Dragon Rocks Nature Reserve (McKenzie *et al.* 1973), Fitzgerald River National Park, North Karlgarin and Bendering Nature Reserves). It is unclear whether the apparent gains are due to the vagaries of trapping or are real gains. Johns Well Nature Reserve and Nature Reserve #5339 are in typical wandoo / rock sheoak habitat, while those from Tarin Rock, North Tarin Rock and adjoining unnamed reserves (#38379 and 16776) are in mallee habitat where nesting hollows may be in short supply.

The size distribution of reserves in which phascogale have been trapped is skewed strongly to small reserves (< 500 ha), with most in reserves of less than 250 ha. Fourteen reserves are > 500 ha (Figure 4), but three (North Karlgarin, Bendering and Dragon Rocks NRs) have no post-1990 record and several others (Lake Magenta NR, Fitzgerald River National Park, Tarin Rock and North Tarin Rock NRs) have few records and limited suitable habitat for phascogale. For others, much of the habitat is degraded by salinity (Arthur River, Flagstaff, and possibly Chinocup Nature Reserves). Hence it is likely that the species' ongoing persistence will depend on their survival in small reserves. This is likely to require effective dispersal between reserves and between reserves and nearby remnant vegetation.

Persistence with respect to rainfall

Records of phascogale have been recorded from locations ranging from *c.* 300-600 mm of mean annual rainfall (Kitchener 1981). However, sites with no post-1990 records are typically from the drier (< 400 mm) locations. These include western New South Wales (Wentworth: 286 mm), southern Northern Territory (Alice Springs: 284 mm; Barrow Creek: 319 mm; Tennant Creek: 370 mm), the deserts of Western Australia (Giles: 282 mm; Balgo Hills 349 mm) and the eastern wheatbelt (Hyden: 341 mm; Narembeen: 341 mm). Sites where phascogale persist tend be within a tight band of 400 – 500 mm of average annual rainfall (e.g. Katanning: 422; Wagin 433 mm; Pingelly: 446 mm; Narrogin: 494 mm, and Williams: 487 mm).

Insights from community records

Forty two of 112 community records (38%) were of phascogale killed or captured by domestic cats or where a pet cat was strongly implicated (Table 5). In most cases, the cat was not seen to kill the phascogale, but rather delivered it either dead or alive to its owner. Often observers reported multiple kills by their cat over several weeks or over successive years. Nearly 76% of community sightings were linked to buildings (farm house, farm buildings, or a house on the fringe of country towns). Of those 43 records of phascogale observed in and around buildings but where domestic cats were not implicated, some were inside houses (14), and others were seen immediately outside houses on verandahs, walls, guttering, roof, screen door, or lawn (15), and others were observed drowned in water around buildings (4). Observers reported phascogale nesting in a shoebox, suitcase, letterbox, and wall vent in and around buildings or built structures (e.g. Short and Stone 2009).

Community records not linked to domestic cats were most frequent in summer and winter, coinciding with the independence of young and the male die-off respectively (Table 5). A χ^2 value assuming equal probability by season approached significance ($\chi^2_3 = 7.28$; P = 0.063). In contrast, cat kills were more evenly spread throughout the year, suggesting domestic cats actively hunt and kill phascogale rather than just collecting and depositing animals that have died from other causes ($\chi^2_3 = 1.47$; P = 0.690).

Discussion

John Gilbert collected the type specimen of *Phascogale calura* at the "Military Station on the Williams River", 150 km south-east of Perth (-33.104ºS, 116.716ºE) in the earliest years of

European settlement of Western Australia in 1843. Gilbert commented "For this new animal I was indebted to a domestic cat who had captured it in the night. The soldiers informed me that they had often met with it in the storeroom of the Station, but they could give me no other information respecting it, except that specimens with much larger or more bushy tails were sometimes seen" (Gould 1863). This record is on the far western margin of the ~~known former~~ range of the species. Interestingly, Phascogale still occur in the vicinity, are still being brought in by domestic cats, and are still observed in and around buildings.

Records of specimens and sub-fossils collected since the 1840s reveal that this species had a broad distribution across arid and semi-arid Australia. The distribution of phascogale extended from the south-west of Western Australia north as far as Cape Range and into the deserts of Western Australia and the Northern Territory and through to western New South Wales. A specimen was collected in Adelaide in the nineteenth century and there is a band of sub-fossil material extending from west to east to the south of the Nullarbor Plain to the Eyre Peninsula and the Flinders Ranges.

However, the distribution of this species has greatly contracted and the species now appears to be confined to the wheatbelt in southwest Western Australia – less than 1% of its former known range. The few records of living specimens from New South Wales (1857), South Australia (prior to 1888), and the Northern Territory (prior to 1912) were by and large the first and the last. Phascogale appear to have persisted in the deserts of Western Australia to a later date (with a specimen from the Canning Stock Route in 1931 and Aboriginal observations to perhaps the 1980s (Burbidge *et al.* 1988)), but there is no recent evidence to suggest they still occur there.

The red-tailed phascogale appears to have declined within the Western Australian wheatbelt in comparatively recent times. The species was recorded in the central eastern wheatbelt at Bendering and ~~West~~ North Karlgarin Nature Reserves in the 1970s (Kitchener *et al.* 1977) and at what is now Dragon Rocks Nature Reserve by McKenzie *et al.* (1973). However, Friend and Friend (1993) failed to capture phascogale during surveys at Bendering and North Karlgarin Nature Reserves in the early 1990s. This widespread absence from the central and eastern wheatbelt has been confirmed by trapping in Bendering, North Karlgarin, Roe and Dragon Rocks Nature Reserves in the period 1998 – 2001 (Orell 2004).

Phascogale were trapped in the central and eastern wheatbelt at or just after a period of extensive clearing for farmland (Muir 1977; Chapman 1978) that would have greatly reduced

the available habitat for this species. McKenzie *et al*. (1973) believed the species at Dragon Rocks Nature Reserve was dependent on salmon gum woodland and lamented the lack of such habitat remaining after land clearance – the majority of vegetation remaining in the reserve being mallee and scrub formations.

At least one specimen of phascogale has been caught in Lake Magenta Nature Reserve, a large reserve predominantly of mallee vegetation, in the south-eastern wheatbelt. This animal, caught in 2003, was reported trapped from a small area of salmon gum woodland embedded within extensive mallee habitat (M. Graham, pers. com.). In addition, there have been several community sightings in the eastern wheatbelt (see below), suggesting that some scattered populations of phascogale may persist in the eastern wheatbelt and adjoining woodlands.

Phascogale were reported historically also from sites along the south coast and adjacent areas of Western Australia (Cape Riche 1905, Cranbrook 1929, Bremer Bay 1984). It appears that phascogale still occur in very isolated locations in this region. Chapman (1995) recorded the species in Fitzgerald River National Park in a survey in 1985-87. Friend and Friend (1993) recorded the species on the north-western margin of Fitzgerald River National Park in the early 1990s. Orell (2004) reported the capture of red-tailed phascogale within Fitzgerald River National Park during monitoring in 1999-2002, but the species was caught only in one year of four (1999) of standardised trapping. Trapping over a 4-5 year period at other sites along the south coast including Stirling Range National Park, Porongurup National Park, Waychinnicup Nature Reserve, Moir Track at the eastern end of Fitzgerald River National Park, Cape Le Grand National Park and Cape Arid National Park did not reveal the presence of this species (Orell 2004). Similarly, extensive trapping (*c.* 4500 trap nights with Elliott traps) within the Esperance Plains bioregion in the 1990s and early 2000s (e.g. Fitzgerald River National Park, Corackerup Nature Reserve, Peniup Reserve, Pallinup River, Gairdner Nature Reserve, Jerdacuttup Lakes Nature Reserve, Bandalup Hill) caught only a single phascogale (A. Sanders, pers. com.).

An important source of information regarding the distribution of phascogale has come from farming communities in the Western Australian wheatbelt. Friend and Friend (1993) made an appeal for sightings through television stations in July 1991 and the Wagin Woodanilling Landcare Zone and Wildlife Research and Management made appeals through local newspapers, newsletters and through placing posters in shop windows in wheatbelt

towns in the period 2005 – 2009. Community records make up some 26% of the available records for the species.

Community sightings of phascogale are often from in or around farm buildings that are substantially removed from extensive areas of remnant vegetation, suggesting that the species can successfully move around the current fragmented rural landscape. Some sightings are from areas on or beyond the fringe of the current known range of the species as confirmed by trapping. Friend and Friend (1993) reported a community sighting of the species to the east of Hyden and a specimen collected by a member of the public near Newdegate in the eastern wheatbelt. They also reported a community sighting from near Dardanine in the far south-west and beyond the margin of the species then known range. The Dardanine observation was followed up by a successful capture during trapping. More recently, community sightings and/or specimens have been reported from the far eastern margin of the wheatbelt from Marvel Loch in the north (1998), through Hyden (2008), to Jerdacuttup (1997) in the far south and from the jarrah forest in the west (Dwellingup). It is unclear whether these represent extant populations. It is possible that phascogale may be inadvertently transported to new sites, perhaps by nesting or sheltering in hay bales that are shifted between locations.

Intrinsic factors predisposing species to decline

The semelparous life history of phascogale, where males die-off each year at the end of the breeding season (Bradley 1987, 1997), may increase the susceptibility of this species to decline (Kitchener 1981; Foster *et al.* 2006). In addition a substantial number of females apparently die after weaning their first litter (Bradley 1987). Friend and Scanlon (1996a) found only about 14-30% of females in a wild population survived into their second year and 3-4% into their third season.

~~Nothing~~ Little is known of dispersal behaviour in red-tailed phascogale but, if it follows that of brush-tailed phascogale (Soderquist and Lill 1995), is likely to be strongly male biased. Given that nine of 10 red-tailed phascogale considered outliers to their current range in the Western Australian wheatbelt were male suggests the same is true in this species. In the brush-tailed phascogale home range establishment ~~be~~ by males was contingent on the presence of females. An emigrating male was recorded moving 4.3 km in one night; with some moving greater than 6 km. Females typically moved less far during dispersal but many were recorded moving > 1 km (Soderquist and Lill 1995). About half of females stayed in their natal range and half moved to a nearby adjacent site. Hence, the recolonisation of

vacant habitat in a fragmented ecosystem is likely to require first the establishment of a female followed by a male in the same season. The likelihood of this will become more remote with increasing distance from an existing population and where the quality and continuity of corridors of native vegetation linking remnant vegetation are poor.

Lactating females typically leave their young in the nest from late August to early September (Friend and Scanlon 1996a), the timing likely linked to food availability in that season. At the time when young are first left in the nest at *c.* 44 days of age, they are small and largely naked (Foster *et al.* 2006), and, by analogy with brush-tailed phascogale, are unable to regulate their own temperature (Soderquist 1993). Hence, quality nesting hollows are likely to be of great importance to successful breeding in this species. The female constructs a large and elaborate nest within the hollow to deposit young in. This is typically a ball of wool, fur, feathers, and grass that has high insulative properties. The female typically chooses a nest site with a small entrance (to exclude predators and competitors) and a large internal volume (J. Short and A. Hide, pers. obs.). Tree hollows with these characteristics vary by tree species but are likely to be in short supply in some habitat types (Short *et al.* 2011), particularly in areas where woodlands are replaced by mallee or shrubland. The selective clearing of woodland habitat in farming areas (Yates *et al.* 1999) is likely to have exacerbated this shortage, particularly within the Mallee and Esperance Plains bioregions.

In contrast, factors likely to allow the species to persist across a broad range of habitat types include its ability to exploit a range of food types (Kitchener 1981; Stannard *et al.* 2010); to use a wide range of sites for shelter during the non-breeding season (Friend and Friend 1993), and, by analogy with brush-tailed phascogale, its apparent ability to move widely around the landscape including crossing open paddocks (van der Ree *et al.* 2006).

While primarily insectivorous (92% of scats in one study contained arthropods, chiefly spiders, beetles and cockroaches) they also fed on birds (51.6% of scats), small mammals (33.3% of scats), plant material (27.4% of scats) and the occasional reptile (Stannard *et al.* 2010). They might also feed on the nectar of *Banksia* (Baxter and Chapman 2011). Female red-tailed phascogale have home ranges averaging between 1.4 and 8.7 hectares, while males have ranges that may exceed 80 hectares during the breeding season (Friend and Friend 1993). Movements of males of up to a kilometre during the breeding season were recorded, including one movement of 800 m within a 24 period (Friend and Friend 1993; Bradley 1997). Brush-tailed phascogale have been detected crossing gaps of 225 m to nest trees: (van

der Ree *et al.* 2006). The willingness and ability of red-tailed phascogale to cross agricultural land would be important to persisting in a fragmented environment such as the wheatbelt.

Extrinsic factors likely influencing decline

Fragmentation

Red-tailed phascogale have been recorded from *c.* 60 nature reserves, other reserves, and national parks in trapping within south-west Western Australia. However many of these nature reserves are small and isolated by intervening farmland. Phascogale are also widespread in remnant bushland on farms, particularly in the western wheatbelt (Short *et al.* 2011). It seems likely that despite the apparent physical isolation of remnants and reserves, phascogale in some areas of the western wheatbelt (for example, near Wagin, Dongolocking, and Narrogin) can move widely around the landscapes using corridors of native vegetation along riverine corridors, road verges and paddock boundaries. For example, we have recorded a female nesting in a building in a 1.8 ha remnant surrounded by farmland and isolated from any substantial remnant vegetation. The nearest patch of vegetation (9.3 ha) was 4 km away by corridor and 2.5 km by line of sight across cultivated paddocks. The nearest substantial remnant (184 ha) was 6.5 km in a direct line from the nest site.

Clearly, this is a very different view to the species response to fragmentation than that of Kitchener (1983), who believed the species was now confined to a small number of reserves greater than 450 hectares in area. There are examples of phascogale being trapped in wheatbelt reserves where many years of prior trapping has failed to reveal their presence (for example, Lake Magenta, Tarin Rock and North Tarin Rock Nature Reserves), which suggest that phascogale may be able to move considerable distances to recolonise vacant habitat. However, Short *et al.* (2011) found that patches of remnant vegetation greater than 5 kilometres from a site occupied by phascogale tend to be unoccupied, suggesting a limit to the species ability to cross agricultural land given the current corridor network. Widely separated remnants and a paucity of continuous corridors are common in many parts of the wheatbelt, and may likely preclude successful dispersal by phascogales.

Short *et al.* (2011) emphasised the importance of large areas of contiguous habitat, such as riverine corridors and the fringing vegetation around the perimeter of lakes that formed an extended chain across the landscape. Also important were clusters of remnants in close proximity, often connected by corridors of native vegetation. Key examples were the many

remnants making up the Dongolocking Nature Reserve near Wagin and those forming Highbury State Forest near Narrogin.

Domestic and feral cats and foxes

Community records of red-tailed phascogale provide a clear indication of the vulnerability of this species to predation by cats. The spread of records across the seasons suggest that domestic cats actively and successfully hunt phascogale, rather than just gathering up and delivering males during the winter die-off. Little is known of the role of feral cats, but their number and role may be limited by the widespread presence of foxes through the farming landscape. Martin *et al.* (1996) recorded a single small dasyurid in 30 stomachs of feral cats (nine of which were empty) collected in rural Western Australia. Orthoptera (grasshoppers and crickets), introduced rodents, and birds were the most abundant items. While small dasyurids were not a major component of the diet of rural cats, making up < 1% by percentage and volume, the small sample and the lack of precise information on where cats came from relative to sites likely occupied by phascogale make this information difficult to interpret. Small dasyurids were more important in pastoral areas (*c.* 10% of the diet), indicating that feral cats are more than capable of including these in their diet when available. While we have established that phascogales are frequently predated by domestic cats (and, by extension, feral cats) we know nothing of the population level impacts of cat predation on this species.

Friend *et al.* (1994) and Friend and Scanlon (1995, 1996a, b) examined the impact of foxes on phascogale across a number of reserves in the western wheatbelt between Brookton and Wagin. Population numbers were monitored by trapping between March and June in nine reserves over three years. Seven reserves were baited to control foxes (three for > 5 years at the commencement of the study; four from commencement) and two were unbaited controls. They found some apparent impact of foxes on phascogale numbers but this was less than that of drought.

The current distribution of phascogale in the Western Australian wheatbelt appears to have an abrupt northern boundary. Kitchener (1981) suggested that the survival of phascogale might be dependent on presence of fluoroacetate-bearing plants and the protection they afford by secondary poisoning of foxes and cats. He noted the higher concentrations of these plants in the southern wheatbelt. However, Short *et al.* (2011) found the species to be

widely distributed in the southern wheatbelt, regardless of the local presence of such fluoroacetate-bearing plants.

Another factor which may influence the intensity of predation on phascogale by foxes, feral cats and native predators such as owls may be the relative abundance of house mice. House mice are typically rare in many of the remnant bushland sites we have trapped (Short *et al.* 2011), but may be more common around farm storage points for grains and hay. House mice may plague at times in the wheatbelt (e.g. autumn 1975: Kitchener and Chapman 1978; Morris and Kitchener 1979) and at these times are likely to provide an elevated food base for foxes, cats, owls and other predators. This may lead to enhanced breeding and survival of predators, resulting in intensified predation on other prey items, particularly when mice numbers subsequently collapse.

Both species of phascogale may actively prey on house mice. For example, "the natives [presumably local European farmers] of Western Australia stated that they [brush-tailed phascogale] frequented farms in search of mice" (Troughton 1967). One farmer from the Wagin area reported that red-tailed phascogale would be regularly seen around haystacks and would commonly leave the remains of mice as turned-out skins (Alan Thompson, pers. com.).

Loss of tree hollows

Hollows, particularly for maternal nesting, may be a scarce resource, as evidenced by the frequent use by phascogale of nest boxes when available in the wild, their frequent use of man-made structures in and around farm houses, and the strong association between the presence of phascogale and tree species with a high frequency of hollows (particularly wandoo and York gum) (Short *et al.* 2011). The recent absence of ~~Phascogale~~ phascogale from nature reserves in the Mallee bioregion may be largely due to a scarcity of suitable hollows. The original vegetation of the Mallee region was a complex mosaic of mallee, woodland and kwongan, with the woodland preferentially cleared over the past 100 years. The occasional sightings and specimens within this region may be linked to the limited areas of remnant woodland remaining after land clearing for agriculture.

Drought and climate change

Kitchener (1983) reported that phascogale now occur only between the 300 – 600 mm isohyets of annual rainfall. He emphasised the importance of reliable rainfall for a species with a semelparous strategy of reproduction, due to the risks associated with reproductive

failure in any one year and suggested this as an explanation for the loss of the species from the semi-arid and sub-tropical parts of its former range (Kitchener 1981). We have identified that most sites from which phascogale have disappeared have an annual average rainfall of < 400 mm. Friend and Scanlon (1996a, b) suggested that red-tailed phascogale were particularly susceptible to drought, based on a decline of 20% between successive years in a standardised trapping program across nine reserves. Friend and Scanlon (1996a) found a relationship between numbers of phascogale trapped in autumn and total rainfall for the previous year. They suggested that dry years impacted on invertebrate food supply, resulting in poorer recruitment of phascogale into the population. This suggested that phascogale might be at risk from a several consecutive years of below-average rainfall, particularly as only a comparatively small proportion of females live and breed for 2-3 years.

This apparent vulnerability of this species to drought and to runs of dry years suggests that their future status in south-west Western Australian may be threatened by the declining trend in winter rainfall (3-4% decline per decade) evident over much of the last century (Pittock 1988), with a further decline of up to 10% projected for coming decades to 2030 relative to 1961-1990 baseline (CSIRO 2007). While no evidence for such an impact is available, it would seem prudent to re-monitor the species after any extreme sequence of dry years.

Fire

Kitchener (1981) suggested that one reason for the persistence of the species in the Western Australian wheatbelt was because "some of these reserves are protected from too frequent burning" and thus have "floristically and structurally rich climax vegetation". Fire was used extensively during the clearing of native vegetation in the pioneering phase of land development for agriculture (Lloyd 1998), but is now actively suppressed. Parsons and Gosper (2011) found that fire was infrequent in small remnants within the wheatbelt, more frequent in large remnants, and most frequent in uncleared areas beyond the eastern boundary of the wheatbelt. Fire frequency may be a major factor limiting the persistence of phascogale in the extensive areas of woodland to the east of the wheatbelt.

The future

While the recent history of phascogale has been one of range decline, there have been some attempts to reverse this. The red-tailed phascogale has been released within the Alice Springs Desert Park (1306 ha) in 2006 (Stannard *et al.* 2010), reintroduced to Wadderin Sanctuary, a fox- and cat-free site of 430 ha in the central wheatbelt, in 2009 (Short and Stone 2009), and

to an unfenced reserve of 389 ha controlled by Australian Bush Heritage at Kojunup in the southern wheatbelt in 2010. The early indications from all have been positive, but their long-term fate is yet to be confirmed.

The coincidence of the remaining range of phascogale with a region of intensive agriculture suggests the importance of involving the farming community in the future conservation of the species. It is imperative that private land owners are given assistance to manage their remnant bush land in a way that is sympathetic to the long-term persistence of phascogale. Farmers have demonstrated a willingness to become actively involved in actions to preserve native fauna and remaining native vegetation (Short and Stone 2009).

Key future actions to further clarify the range and status of red-tailed phascogale include further surveys along the eastern and southern edge of the wheatbelt in response to persistent community observations of the presence of phascogale and the study of the ecology of natural populations in vegetation associations other than wandoo to determine how they meet their requirements for nesting hollows and for shelter. Surveys should be extended into the extensive areas of woodland to the east of the wheatbelt to further clarify their current distribution and status.

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The WA Museum and the Department of Environment and Conservation provided access to their data for which we are most grateful. We thank Tony Friend and Mal Graham for their extensive trapping efforts in the 1990s that have helped to define the current range of the species, Mike Bamford for providing additional records, Andrew Burbidge for his desert records, and Angela Sanders for providing information on her extensive trapping in the southern wheatbelt. South West Catchments Council provided funding to undertake trapping of phascogale in and around Wagin and the Wagin Woodanilling Landcare Zone and co-ordinators Danielle Perrie and Sally Thomson provided ongoing support and encouragement and access to community members. We thank Megan Stone, Arthur and Judy Kershaw and Sid Smithies and many other community volunteers for their assistance with trapping. We particularly thank all the land owners who allowed us access to their property to trap for phascogale. We thank Tony Friend, Ric How, Peter Mawson and two anonymous referees for helpful comments on earlier drafts of this manuscript.

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Table 1: Positive records and discrete locations for red-tailed phascogale.

Locations with a mix of source records attributed preferentially to 'trapped' or to most numerous.

Source	Records	Locations
Sub-fossil records	34	34
Aboriginal records	12	12
Trapping records	220	81
Community records	115	61
Museum records, excluding those included in trapped above	74	40
Reintroductions	3	3
Total	458	231

Table 2: Phascogale records by IBRA regions.

'Other' includes 1) historic records of live animals from Burt Plain, Davenport Murchison Ranges, Flinders Lofty Block, Great Sandy Desert, MacDonnell Ranges, and Murray-Darling Depression; 2) Aboriginal records from the Great Sandy Desert, Little Sandy Desert, Gibson Desert, Central Ranges and Tanami Desert; and 3) sub-fossil records from Coolgardie, Carnarvon, Eyre Yorke Block, Flinders Lofty Block, Great Sandy Desert, Hampton, Murchison, Nullarbor and Yalgoo.

Region	Total records	% of records since 1990
Avon Wheatbelt	302	83%
Mallee	50	46%
Jarrah Forest	49	69%
Esperance Plains	8	50%
Other	49	0%
Total	458	

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722 **Table 3:** Phascogale locations in Western Australia by IBRA region and Beard's vegetation
723 association (excludes sub-fossil and Aboriginal records).

Region, description of vegetation association and association number	Records
Avon Wheatbelt	
Medium woodland; York gum, wandoo & salmon gum *E. salmonophloia* (1023)	201
Medium woodland; powderbark *E. accedens* & mallet *E.* spp. (947)	32
Succulent steppe with open woodland and scrub; wandoo, salmon gum & swamp sheoak (1083)	31
Succulent steppe with open woodland and thicket; wandoo & swamp sheoak *Allocasuarina obesa* over teatree and samphire (1074)	9
Medium woodland; wandoo & mallet *E.* spp. (1073)	8
Medium woodland; wandoo and blue mallet *E. gardneri* (1085)	6
Medium woodland; wandoo, York gum and morrel *E. longicornis* (1092)	2
Medium woodland; York gum (352)	2
Medium woodland; wandoo (946)	1
Jarrah Forest	
Medium woodland; marri *E. calophylla* & wandoo (4)	27
Medium woodland; wandoo & powderbark (5)	22
Medium forest; jarrah-marri (3)	1
Medium woodlands: York gum and wandoo (7)	1
Mallee	
Shrublands; mallee scrub, redwood & black marlock (960)	10
Mosaic; medium woodland with York gum and salmon gum/shrublands; mallee scrub (1094)	6
Shrublands; mallee scrub *E. eremophila* and *E. redunca* (= *angusta*) (1075)	6
Mosaic; medium woodland salmon gum and morrel/shrubland mallee scrub of *E. eremophila* and *E. redunca* (= *angusta*) (1200)	5
Medium woodland; salmon gum & morrel (511)	4
Mosaic; Medium woodland; salmon gum / Shrublands; mallee scrub, redwood *E. transcontinentalis* & black marlock (*E. angusta*) (945)	4

Shrublands; mallee scrub, *E. eremophila* (519)	4
Mosaic; medium open woodland salmon gum & morrel/succulent steppe (1079)	3
Bare areas; rock outcrops (128)	3
Medium woodland; York gum & salmon gum (142)	2
Shrublands; scrub-heath in the Mallee Region (2048)	2
Medium woodland; salmon gum (936)	1
Esperance Plains	
Mosaic: Medium woodland; yate / Shrublands; mallee scrub, black marlock (942)	3
Shrublands; tallerack *E. pleurocarpa* mallee-heath (47)	2
Medium woodland; yate (*E. occidentalis*) (931)	1
Mosaic; shrublands mallee scrub black marlock / Shrublands; tallerack mallee-heath (940)	1
Great Sandy Desert	
Hummock grasslands with low open tree steppe; desert bloodwood on sandhills (134)	1
Total	401

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Table 4: Dynamics of presence of phascogale at particular reserves. Only sites with > three annual positive trapping sessions are included in persistent sites. The area of reserves (hectares) and IBRA region (AW Avon Wheatbelt; ESP Esperance Plain; MAL Mallee) are given also. ^The date 1990-1992 refers to a single trapping event at a given location by Friend and Friend (1993), but where no year was specified.

	Area	IBRA	Notes
Sites with apparent persistence			
Dryandra Forest F51	19,860	AW	7 annual records 1971 to 2003
Chinocup NR #18803/28395 / Pingrup	19,825	MAL	5 annual records 1951, 1952, 1953, 1994, and 1996
Boyagin NR #20610	4,845	AW	7 annual records 1990-92^ to 2003
Tutanning NR #25555	2,206	AW	7 annual records 1975 to 2004
Dongolocking NR #19082, 19083, 19096	1,350	AW	8 annual records to 1974 to 2005
Jaloran Timber Reserve #14459	440	AW	5 annual records 1990-92, 1993 to 1996
Boundain NR #17115/21067	298	AW	7 annual records: 1930, 1990-1992, 1993 to 1996 and 2004
East Yornaning NR #18952	248	AW	13 annual records 1975 to 2004
Pingeculling NR # 36519	243	AW	5 annual records 1990-92 to 1996
Highbury State Forest (West Ashby block)	117	AW	6 annual records 1990-92 to 2004
Yackrikine NR #26797	105	AW	5 annual records between 1994 and 2004
North Wagin NR #30443	62	AW	3 annual records: 1990, 1992, and 2007

Sites with apparent loss			
Fitzgerald River National Park #31737	329,000	ESP	Caught in 1985-7 and 1999, but not in 2000 to 2002
Dragon Rocks NR #36128	32,204	MAL	Caught in 1970 and 1972; not in 1998 to 2001
North Karlgarin NR #20338	5,822	MAL	Caught in 1973; not caught in 1990-92, 1998 to 2001
Bendering NR #25681	1,895	MAL	Caught in 1975 and 1976; not caught 1990-92, 1998 to 2001
Sites with apparent gain			
Lake Magenta NR #25113	107,812	MAL	No phascogale caught in 1990-92, but caught in 2003
North Tarin Rock NR #29857	2,142	MAL	No phascogale caught in 1990-92, but caught in 2003
Tarin Rock NR #25711	2,011	MAL	No phascogale caught in 1990-92, but caught in 2003
Johns Well NR #24599	385	AW	Present in 1990, not in 1992 or 1993, but caught again in 2007
Woodanilling Reserves #12374, 13145, 33938	*c.* 200	AW	Not caught in 1993, but caught in 2007
NR #5339, north-east of Katanning	40	AW	No phascogale caught in 1990-92; but caught in 2008

728 **Table 5:** Community records of phascogale categorised by type of observation

Category	Number of records (% of total)
Observed in or around buildings – killed or otherwise linked to domestic cat	42 (37.5%)
Observed in or around buildings – no observed link to domestic cat	43 (38.4%)
Sighted in bushland by day or at night often when spotlighting	12 (10.7%)
Sighted on road at night / road kill	6 (5.4%)
No sighting information recorded	9 (8.0%)
Total	112

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731 **Table 6:** Seasonality of community sightings of phascogale linked to domestic cats

Season of observation	Number of records where cats implicated	All other records
Summer – independence of the young of the year	9	19
Autumn – growth and dispersal	7	7
Winter – breeding season and male die-off	9	15
Spring –lactation and attendance at maternal nest	5	9
No date given	14	21
Total	44	71

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734 **Figure 1:** Records of red-tailed phascogale across Australia.

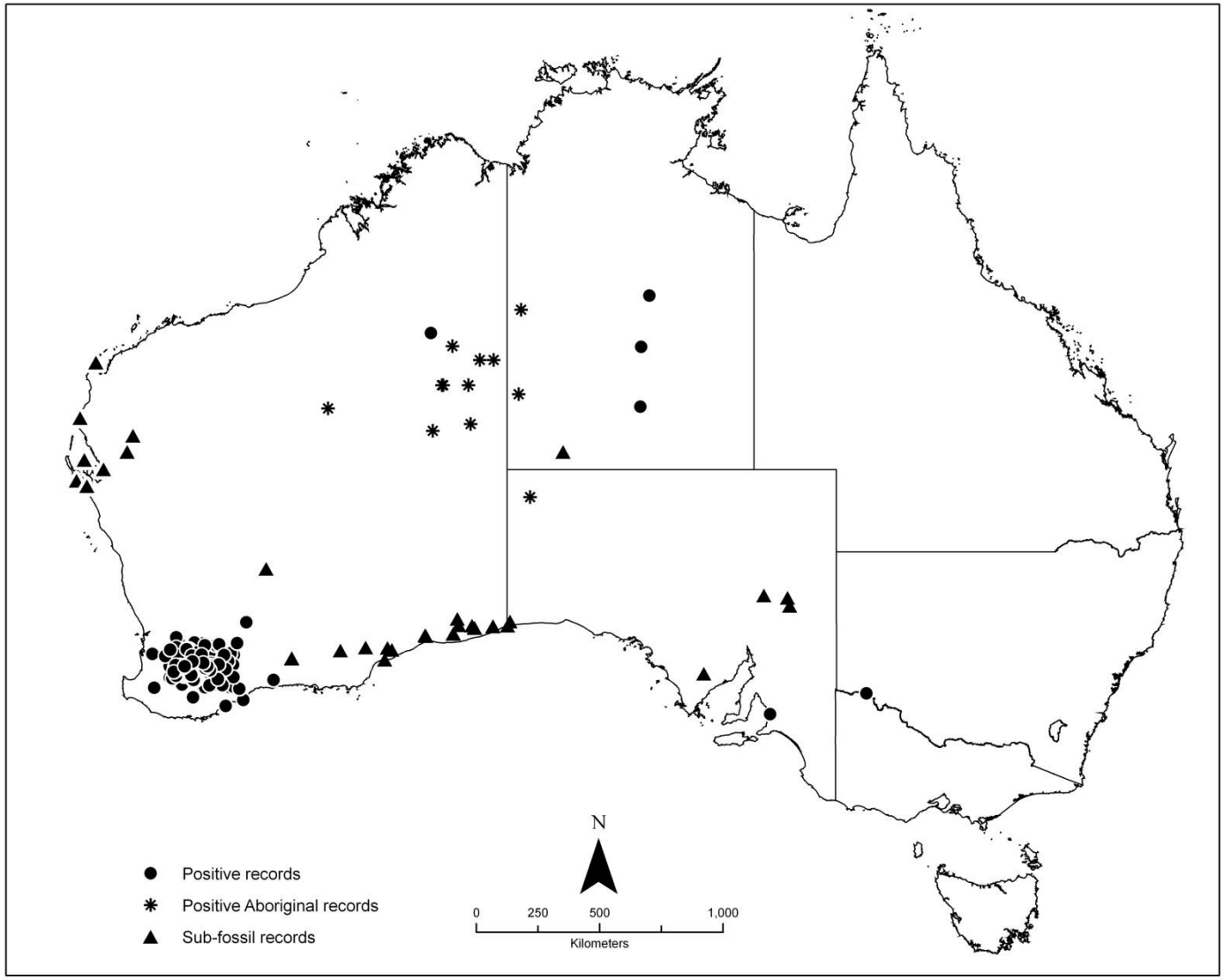

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Figure 2: Records of the red-tailed phascogale in south-west Western Australia. The shading shows the area of intensive agriculture and land clearance. Closed circles represent positive records, plus symbols represent surveys where no phascogale were caught.

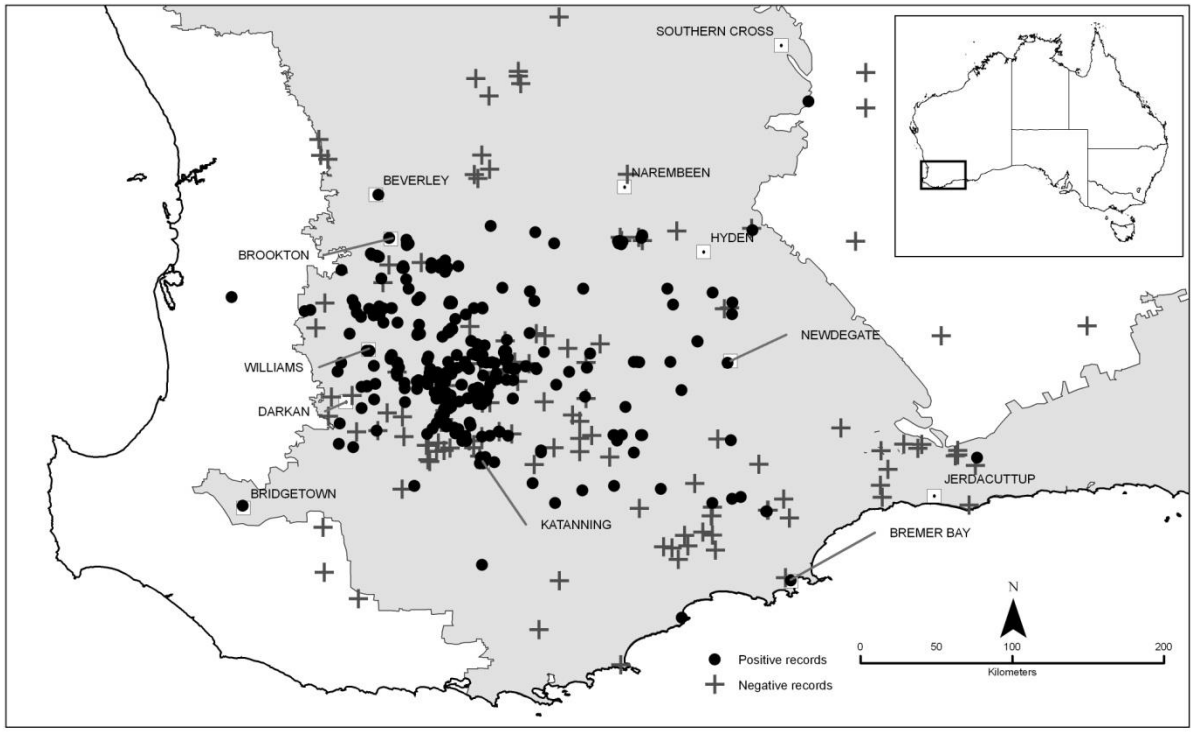
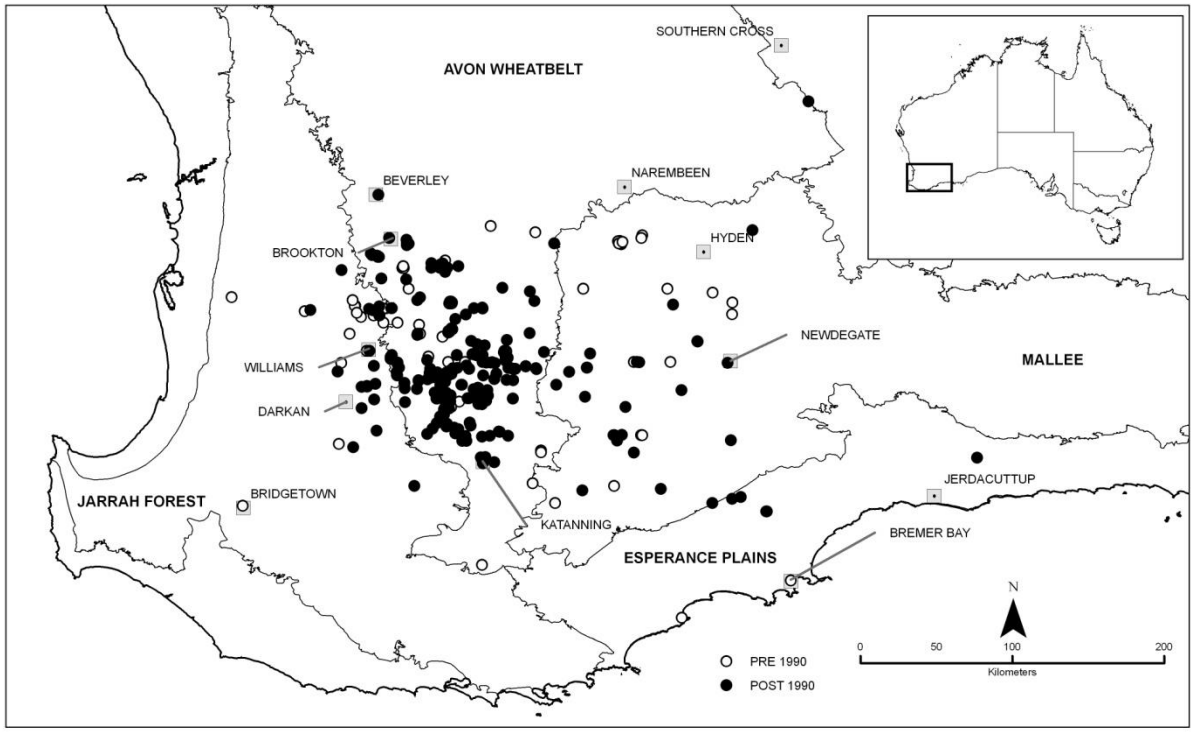


Figure 3: Positive records of red-tailed phascogale separated by date of record into those pre- and post-1990. Points are plotted against IBRA bioregions.



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749 **Figure 4:** Size distribution of reserves in which phascogale have been trapped in the Western
750 Australian wheatbelt.

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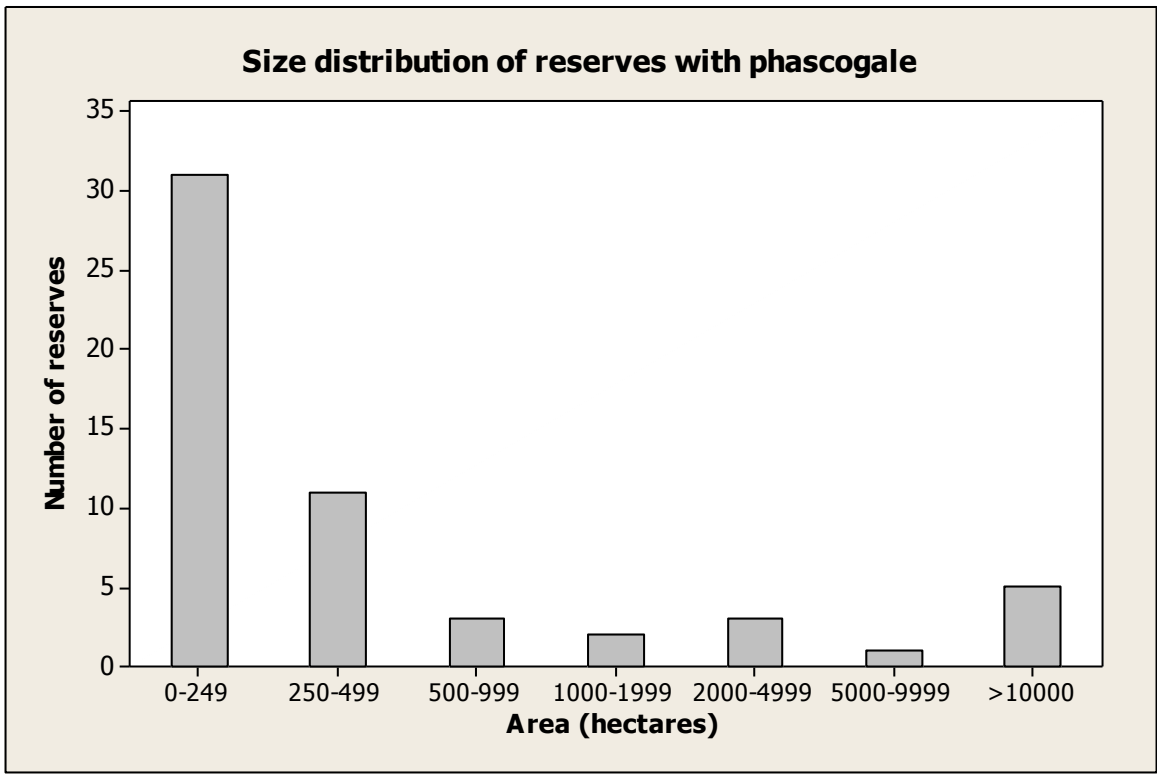

752