



Australian Government

**Department of Sustainability, Environment,
Water, Population and Communities**



Survey guidelines for Australia's threatened mammals

Guidelines for detecting mammals listed as threatened under the
Environment Protection and Biodiversity Conservation Act 1999

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HOW TO USE THESE GUIDELINES

The purpose of this document is to provide proponents and assessors with a guideline for surveying Australia's threatened non-flying mammals listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

These guidelines will help you to determine the likelihood of a species' presence or absence on your site. They have been prepared using a variety of expert sources, and should be read in conjunction with the Department of the Environment's *Significant impact guidelines 1.1 - Matters of national environmental significance*.

These guidelines are not mandatory. Proposals failing to meet these survey guidelines for reasons of efficiency, cost or validity will not necessarily default to a judgement that referral is required (that is, that a significant impact is likely), especially where the proponent issues an evidence-based rationale for an alternative survey approach. Alternatives to a dedicated survey may also be appropriate. For example, a desktop analysis of historic data may indicate that a significant impact is not likely. Similarly, a regional habitat analysis may be used to inform judgement of the likely importance of a site to the listed mammals. Proponents should also consider the proposal's impact in the context of the species' national, regional, district and site importance to establish the most effective survey technique(s).

Failing to survey appropriately for threatened species that may be present at a site could result in the department applying the precautionary principle with regard to significant impact determinations. That is, if no supporting evidence (such as survey results) is presented to support the claim of species absence, then the department may assume that the species is in fact present. The department will not accept claimed species absence without effective validation such as through these survey guidelines, other survey techniques (for example, a state guideline or an accepted industry guideline), or relevant expertise. Where a claim of absence is made, proposals should provide a robust evaluation of species absence.

Biological surveys are usually an essential component of significant impact assessment, and should be conducted on the site of the proposed action prior to referral. Surveys help to evaluate the impact on matters of national environmental significance by establishing the presence, or the likelihood of presence/absence, of a species. Before undertaking a survey, proponents may wish to contact the Australian Government Department of the Environment's relevant assessment section to discuss their project and seek advice on the appropriate survey effort and design.

Executing a survey to this standard and identifying listed species presence does not in itself predict a significant impact. The presence of a species is one of many factors that will increase the likelihood of a significant impact. Proponents should use the presence of a species as a consideration in establishing whether a significant impact is likely or certain. As part of the assessment process, sufficient information is usually required to determine if a species' presence at a site constitutes a 'population' or 'important population' as defined in the *Significant impact guidelines 1.1* publication. Information on whether the occurrence constitutes a 'population' or 'important population' will not necessarily be generated by surveys conducted using these guidelines.

These guidelines help determine presence or the probability of presence. They **do not** establish or assess species abundance, as the effort in terms of cost and time required for an abundance survey is much greater than that determining presence/absence. Effective abundance surveys would need to compare survey effort and techniques with further exploration of a proposal's context, including important population location(s), habitat importance, ecological function and species behaviour.



1. INTRODUCTION

1.1 Background

These survey guidelines provide guidance on what should be considered when planning and undertaking species presence surveys for threatened mammals relevant to a referral to the Federal Environment Minister under the EPBC Act. The individual taxa (species or subspecies) accounts in Section 4 provide a guide as to the survey methods and effort that are appropriate for assessment of whether those listed taxa occur at or near a specified site ('study area'). Consequently, the guidelines focus on assessing the presence or likelihood of presence of taxa in a study area, and not on an assessment of the abundance of individuals.

The survey guidelines are limited to recommending the effort with selected techniques to establish whether a target species is present or absent in a project area. A survey is the first step in a process towards assessing the impact of a proposed project on any threatened mammal species. The approaches in each species profile should be regarded as a minimum and should be included in any general fauna survey program that seeks to determine the presence of species of conservation significance. If threatened species are found to be present during the survey, different techniques may be required to establish if the project area contains important habitat (nest sites, foraging sites, water sources and movement corridors) for those threatened species.

If habitat suitable for a threatened species occurs in the area, and an appropriate survey is not conducted to determine presence/absence, the department may follow the precautionary principle and assume that the species is in fact present.

This document provides a comprehensive set of recommended survey techniques and sampling effort for the 75 non-marine and non-flying mammals listed as at July 2010. However, it is recognised that the EPBC Act threatened species list is dynamic and that survey guidelines are likely to be applied to some taxa not currently listed. Conversely, it is hoped that with ongoing conservation programs the populations of some taxa will recover and they can be removed from this list.

1.2 Objectives and scope

While some of the methods described lend themselves to a quantitative analysis of the results, the primary object of this document is to identify survey methods that establish at any given site either the presence, or likely absence, of individual species. Thus, the survey techniques and/or survey effort described are not necessarily the most appropriate methods for quantitative studies or studies with other objectives.

The scope of these guidelines is limited to information regarding field survey techniques. While some of the information and references provided could be used in the gathering of background information regarding the biology and/or habitat of a particular species, they are not intended to replace database searches or other 'desktop' studies that should be undertaken as part of the investigation of a given site.

The Australian Government Department of the Environment provides a number of policy statements that provide guidance on the practical application of the EPBC Act. These include: significant impact guidelines, which provide over-arching guidance on determining whether an action is likely to have a significant impact on a matter of national environmental significance protected by the EPBC Act; industry guidelines; nationally threatened species and ecological communities' guidelines; EPBC Act practices and procedures; and policy statements for regions.

1.3 Guidelines structure and use

The survey methods and effort required to detect species presence within an area is dependent on a number of factors and will vary according to extrinsic and intrinsic characteristics of the species and the locality. The survey methods recommended here are based where possible on the documented findings of previous studies reported in primary and secondary literature, including existing guidelines in some cases, and from a consultative process with expert scientists with field experience with the threatened mammal species.

The overview of survey methods (Section 3) and the species profiles (Section 4) should be reviewed in conjunction to determine the appropriate survey technique and effort required to detect a particular listed mammal species.

The guidelines are presented in both a grouped and species-specific format. The first part of the survey guidelines in section 4 groups species according to body weight, and describes the general survey techniques used to detect each species group. A brief introduction providing an overview of the recognised survey methods is given for each of the size groups.

The second part provides more detailed information regarding the particular features of each species that need to be considered and recommends a specific methodology for that species. In some cases, species have been so rarely recorded or methods have not been documented sufficiently that it may be premature to outline a survey method. In these situations a review of survey methods applied and their success rate is provided, but further research may be recommended before guidelines can be set. All of these species are, by the nature of their listing, either rare or have very restricted distributions, and therefore it is unlikely that we yet know enough about their ecology, reproduction or habitat use to say with confidence that any survey method or effort will guarantee detection. The survey methods recommended provide a baseline minimum of survey effort required, with adherence to the precautionary principal essential in the place of research results. The individual species profiles are cross-referenced with the more detailed descriptions of survey techniques and recommended survey effort for subject sites up to 5 hectares in size detailed in Section 4.



2. PLANNING AND DESIGN OF SURVEYS

For any proposal, the timing of fieldwork is critical to the surveying and reporting process. Careful consideration of the necessary lead-time is required, as it may be necessary to undertake surveys at specific times of the year depending on the ecology of the species in the subject area. Surveys over multiple years may be required where a single year's data is not adequate to detect the species or to address environmental factors. There may also be a time lag due to the availability of appropriate faunistic expertise. Proponents should make allowance for this lag when planning projects. Commissioning biodiversity surveys as early as practicable in the planning/site selection phase of a project will help avoid potential delays in approvals.

Effective surveys should always begin with a thorough examination of the literature to identify the best times, locations and techniques for surveys. The profiles in this document provide a basis for effective surveys for non-flying mammal species currently listed as threatened at a national level in Australia.

2.1 Conducting surveys in six steps

STEP 1: Identify taxa that may occur in the study area

The first stage in the design and optimisation of surveys is to generate a list of threatened mammals that could potentially occur in the study area. A process is suggested below.

(i) Characterise the study area

The boundaries of the study area must be established clearly. A detailed map of the study area should then be constructed revealing the type, locations and condition of native vegetation and important habitat features for mammals, such as water bodies, rock outcrops, and foraging sites. This process is not only critical to establishing which threatened species may occur in the area, but also in the selection of appropriate survey methods and effort. An appropriate map will aid almost every survey regardless of survey technique.

(ii) Establish the regional context

This stage requires an assessment of the habitat frequency and function. The regional context will help develop judgements of significance associated with the loss or disturbance of habitat. A useful test will involve the following questions:

- Are the habitats rare or common?
- Are the habitats likely to be critical to species persistence?
- Are the habitats likely to be permanent or ephemeral?
- How is the species likely to use the site (for example, breeding, foraging, etc)? Survey design may need to be adjusted to determine these aspects if necessary.

(iii) Identify those threatened mammals that are known to, likely to or may occur in the region

This stage involves consulting a range of sources to determine which threatened mammals could occur in the region surrounding and including the study area.

Detecting changes in the distribution of rare species is confounded by difficulties in detecting their presence as a result of their generally low abundance, and in many cases the distributions of EPBC Act listed threatened species are poorly known (details for each species are discussed in the species profiles). For this reason all surveys designed to target threatened species must consider that the species range may be subject to change either because the distribution may be becoming fragmented or be decreasing in size as result of local extinctions, or the species may be so difficult to detect that determining its range from records is an ongoing process.

There are a range of sources that should be consulted to create a list of taxa which could occur in a region. These include:

- Australian Government Department of Environment databases, including the protected matters search tool and species profiles and threats (SPRAT) database that allow you to enter the site of interest and generate predictive maps and information relating to threatened species distributions
- state, territory and local government databases and predictive models
- national and state threatened species recovery plans and teams
- reference books such as *The mammals of Australia* (Van Dyck and Strahn 2008)
- museum and other specimen collections
- published literature
- unpublished environmental impact reports, and
- local community groups and researchers.

(iv) Prepare a list of threatened taxa that could occur in the study area

This can be determined by comparing the habitat requirements of each threatened taxa identified in *stage iii* with the habitat types and features present within the study area (*stages i and ii*).

Taxa identified in this process are referred to as 'target' taxa.

STEP 2: Determine optimal timing for surveys of 'target' taxa

If it is not possible to survey for target taxa that have been previously recorded in the general location of the study area during the appropriate time of day or season, it should be assumed that these taxa do occur in the study area if suitable habitat exists (NSW DEC 2004).

Factors that should be considered when planning the timing of a survey include the time of day considered most suitable, seasonal changes in abundance and detectability, changes in species abundance between years, and sensitivity to impacts from certain survey methods at some times of year.



STEP 3: Determine optimal location of surveys

Habitat stratification

In some circumstances, the study area of interest will be small enough to allow a comprehensive search of the entire area within a reasonable period of time. The size of what is a searchable area will depend on the nature of the target taxa and the habitat and topography of the study area. For example, searching for highly cryptic species in dense scrub will take far longer than searching for large, conspicuous species in open grassland. If a comprehensive search of the whole area or target unit/habitat is feasible, then sampling will not be required as the data collected will be representative of the entire area. In many cases however, the study area will be too large to permit a complete search within a reasonable time frame, and selective searches or sampling procedures will be required (Royle & Nichols 2003).

Many study sites will be comprised of a variety of distinct habitat types, especially if the area is extensive. Some of these habitats may be unsuitable for occupancy by the targeted taxa. An effective strategy to maximise the likelihood of detecting a particular taxon is to concentrate search effort within habitat that is favoured by the targeted taxon (Resources Inventory Committee 1998). This will require that the study area is divided up, or stratified, into regions of similar habitat types.

When stratifying a study area, the study area is usually partitioned first on biophysical attributes (for example, landform, geology, elevation, slope, soil type, aspect, water depth), followed by vegetation structure (for example, forest, woodland, shrubland, sedgeland). Strata can be pre-determined based on landscape features indicative of habitat which can be derived from topographic maps, aerial photographs that show habitat types, or existing vegetation maps. Preliminary assessment of the study area prior to commencing surveys will be useful to check stratification units and further stratify the area if necessary (NSW DEC 2004). In other situations, such as the inundation of vast floodplains, there may be little alternative but to implement a form of stratified sampling based on accessibility of habitat during the course of the survey.

Stratified sampling programs are not designed according to a standard method, with the level of replication influenced by a range of factors including, but not restricted to:

- the size of the subject site
- the nature of the subject site and the available information regarding variation in biological (for example, vegetation type and structure) and physical (landform and soil type) attributes
- time and resources.

For example, a subject site of 5 hectares containing woodland, riparian and grassland habitats would require at least a survey site in each of the habitat types. If the subject site was greater than 5 hectares, then replication within each of the habitat types would likely be required. Usually the proportion of the total area of any given subject site surveyed will decrease with an increase in the size of the total area.

Focusing search efforts on favoured habitat can be a valuable strategy to maximise the likelihood of detecting target taxa. However, this approach requires that the habitat preferences of target taxa are adequately known, which for many threatened species may not be the case. The fewer the number of habitat association records that have been reported for a taxon, the more likely that any apparent habitat preference will be an artifact of the small sample. Furthermore, subsequent surveys then tend to focus on these apparently preferred habitats, which can further distort the perception of habitat preference. Consequently, investigators should not exclude particular habitat strata from survey designs unless it is well established that these habitat types are

consistently less favoured by the target taxa than other types within the study area. Where there is a limited understanding of habitat requirements, a stratified sampling design that considers all available habitat types is the best approach to increase the chances of detection.

Targeted searches

An extension of focusing search effort on preferred habitat strata is the *targeted search*. In this case, search effort is confined to particular resources or habitat features that the target taxa/taxon are known to seek out, at least for some part of the day or season. These may include flowering or fruiting trees, waterholes or rocky outcrops. Once located, these sites can be watched at appropriate times to determine if they are visited by the target taxa/taxon.

Following the desktop study, an initial habitat investigation should be undertaken to ground-truth (locate and identify) the previous threatened species records and the availability and extent of habitat variables. At this stage, the investigator should become familiar with the subject site and identify the vegetation and habitat features that should be targeted in field surveys. Transects or quadrats required to carry out a stratified and/or targeted survey program need to be established, drawing upon the information collated during the desktop investigation. Any opportunistic direct or indirect observations of fauna should be recorded; however, dedicated searches for specific habitat resources or signs of fauna activity should also be conducted after the habitat inspection.

It is important to note the recommended survey area for a species is not going to be the same throughout all habitats and pilot trapping studies are a useful way to ensure surveys are covering a sufficient area (Free & Leung 2008).

STEP 4: Establish sampling design and survey effort

The previous sections on survey timing and location highlight important strategies to help increase the chance of detection. However, replicated sampling will often be required either to reveal the target taxa/taxon or satisfy the argument that the taxon is absent or occurs at very low abundance within the study area. Information on species that occur at very low abundance may be important when considering the likelihood of a significant impact from the proposed actions. Sampling can be replicated in space (different locations at the same time) and time (same location at different times) or a combination of both (different locations at different times).

Spatial sampling

Replication in space will often be necessary to detect populations that are at low densities or clumped distribution. Even after stratification, sampling may still be required if the area of favoured habitat is large or if the habitat preferences of the target taxa are variable or poorly known. There are two basic spatial sampling designs:

- *Random sampling* – when all locations within the study area (or selected strata) have an equal chance of being sampled; and
- *Systematic sampling* – when units are spaced evenly throughout the study area (or selected strata).

Systematic sampling will generally be superior because it produces good coverage, is easier to implement and is less subject to site selection errors. It is also recommended that sampling units are placed to avoid boundaries of environmental stratification (for example, shorelines) and local disturbances such as roads, mines, quarries and eroded areas (Resources Inventory Committee 1998, NSW DEC 2004).



In general, sampling units should be positioned sufficiently far apart that individuals are unlikely to be detected from more than one sampling location, ensuring the samples are independent. The distance between sampling positions will usually depend on the territory or home range size of individuals in the target population and their detection distance. The inter-sample distance will also depend on the survey technique being employed. The number of sampling units within the study area (or strata) should be proportional to its size, a principle referred to as area-proportionate sampling (MacNally & Horrocks 2002). However, a linear increase in sample number with area will become impractical at very large study areas.

A formal sampling design, outlined above, is less critical in detection studies than abundance studies. However, a formal sampling design is still preferable for use in detection studies, especially if stratification is required (Resources Inventory Committee 1998a).

Temporal sampling

Temporal replication may be necessary to detect populations that fluctuate in abundance, occurrence or detectability with time, especially when these fluctuations are unpredictable. For example, some taxa are highly mobile and may travel through or occupy regions within their range only for brief and unpredictable periods of the year. As a result, regular sampling during and throughout the time of year when the taxa most likely to occur at the study area is desirable. Some locations may be occupied by target taxa/taxon in some years but not others, depending on environmental conditions.

Sampling over many years will rarely be feasible. In some cases, previous records can provide information on the use of such sites by particular taxa. If threatened taxa have been recorded in the general location of the study area when conditions were appropriate, it would be expected that these species will return again, unless the habitat has been irreparably changed. Where previous data is few or absent, assessment of the habitat will be vital and could provide the only indication of whether the site is likely to support these species when conditions are suitable in the future.

Temporal sampling may also be required when the study area is small. In this situation, the individuals of some taxa will have territories or home ranges that include, but are not restricted to, the study area. As a result, at any one time, some of these individuals will be absent from the study area and go undetected (Mac Nally & Horrocks 2002). Regular sampling over time is recommended as it will increase the probability that these individuals will be detected on at least one occasion. Off-study area sampling is another means to address this problem, whereby sampling is conducted in suitable habitat in the area surrounding the study area. This procedure effectively increases the study area, allowing greater spatial sampling, and enhances the probability of detecting individuals with home ranges larger than the core study area. In practice, this is a useful strategy because temporal replication is often more costly to implement than spatial replication, as additional travel may be required to and from the study area.

STEP 5: Select appropriate personnel to conduct surveys

The single most essential component of any survey is competent observers (Resources Inventory Committee 1998). EPBC Act assessors expect that surveys are conducted by appropriately experienced observers who have excellent identification skills, including familiarity with species' calls where relevant and a good knowledge of mammal behaviour, at least in relation to the taxa or group being targeted. Observers should have recognised relevant skills or experience. Where calls will be important for detection, good hearing is essential, as hearing ability can strongly affect survey results (Resources Inventory Committee 1998). Observers should also have access to appropriate equipment (for example, binoculars or torches). The need for excellent field identification skills of observers cannot be overstated.

Personnel engaged to conduct surveys on nationally threatened mammals must be familiar with the particular species, experienced with the methods described in this document, and/or demonstrate adequate training from an expert prior to conducting the survey. Survey leaders should assess all contributors and, where necessary, provide training and guidance to maximise the effectiveness of all observers (for example, Saffer 2002). The identity of observers should always be recorded to allow for the detection and possible statistical correction of differences between observers if necessary (Resources Inventory Committee 1998). Some indication of the previous experience of observers with the target taxa, and the identification challenges inherent in surveying for these taxa, should also be provided to help assess the competency of observers and reliability of observations.

STEP 6: Document survey methods and results

Survey methods and level of search effort vary widely between studies. For this reason it is essential that survey reports include detailed information on the methods used and the level of search effort adopted. This should include who was involved, what work was carried out and where, when (both date and time of day) and how the survey was conducted, as well as the climatic conditions at the time. The survey report should follow the standard aims, methods, results, and discussion format common to all scientific research. Without this information it is difficult to interpret the survey results, and impossible to replicate the study for comparative purposes (Resources Inventory Committee 1998). It is useful to record the GPS location of all sampling units and provide maps of the study area. Detailed descriptions of the habitat should be recorded. Information on the condition of the habitat at the time of the survey should also be included, as this may be useful in later analysis (for example determining whether species presence/absence is due to temporary factors such as drought). Documenting the habitat occupied by target taxa during the survey process, and a site description, will add value to the survey at minimal extra expense (NSW DEC 2004). Documentation of observers and their skills is also important (see above). Presentation of all mammal taxa recorded is essential as it can provide a measure of survey effort and effectiveness.

It is important that reports contain suitable information to demonstrate the survey was sufficient to draw the conclusions. Documenting the survey effort will be particularly important for species that might be present at very low abundance in the project area. Findings should be supported wherever possible by information such as:

- site photos showing equipment placement and habitat structure,
- photos/records of scat or other trace material,
- summary tables with measurements and diagnostic observations from captures, and
- photos of mammals if no tissue samples can be taken.

Tabulated GPS coordinates of sites and equipment placement will allow precise determinations of occurrence within a project area.

Maps should be included that show the location of planned infrastructure over the top of aerial photographs (ideal) or other geographical layers that represent the habitats present in the area. Indicating the location of equipment placement such as trapping equipment, as well as GPS tracks of the transect path taken during active acoustic monitoring or searches will allow a better understanding and interpretation of survey effort.



Reports should carry some justification of the survey design, whether it be opportunistic, systematic or focused on certain likely habitats. This would include information on the habitat types present and the survey effort given to each. The design should also distinguish between known or potential foraging, breeding and commuting habitats. For species that might be present at very low abundance, it is important to describe the likelihood of presence based on habitat descriptions made as part of the survey. Explanations on the timing of the survey, suitability of the weather, the speed and duration of transect travel and observations recorded should also be given.

Survey data should be made available to state and territory environment departments to be included in fauna databases where appropriate.

2.2 Grouping mammals according to body size and survey methods

The methods used to detect non-flying mammals during field surveys can be grouped according to the target species' body size and the nature of their ecology. In general, direct evidence (such as an animal in the hand or visual observation by an experienced investigator) provides the most unequivocal evidence of species presence, and most survey methods are designed around these approaches. Survey methods designed to detect mammalian fauna by direct evidence include capture techniques, diurnal observation, and spotlight survey. Signs of fauna activity, such as diggings in the ground, scratches on tree trunks, burrows, nests, dens, scats and tracks can provide indirect evidence of a species' presence, especially if the sign is species-specific. Where signs are detected, but are not sufficient to distinguish between species, then direct survey methods targeting the locations where signs of fauna activity were detected are required to provide a definite species identification.

There are a large number of biological and ecological factors that influence how visible a species is in the field and in turn how easily it is detected, including:

- body size and other morphological characteristics (for example, fur colour, distinctive markings, brightness of eye shine)
- behaviour (for example, vocalisations, displays, flight, home range size, diet and foraging activity, ease of capture, use of nests, dens or burrows)
- sociality (for example, whether individuals are solitary or gregarious)
- activity patterns (diurnal, nocturnal, crepuscular, seasonal, climatic or longer term environmental effects such as rainfall, which relate to breeding and hibernation)
- habit (ground-dwelling, arboreal or scansorial)
- habitat (for example, structure and density of vegetation, or physical attributes of the topography such as steepness of slope, rocky outcrops or boulders, gullies or caves)
- abundance (common or rare within an area).

Taking into account the above factors, species that are likely to be the most visible in the field are those that are large and conspicuous, possibly gregarious, active during the day, ground-dwelling, inhabit an open terrain (for example, grasslands) and relatively common. Examples of this type of species in Australia are found within the large kangaroo species (*Macropus* genus). In contrast, the majority of the non-flying mammal species

listed under the EPBC Act are small or medium in body size, nocturnal, inhabit rugged, remote or densely vegetated habitats, and by the nature of their limited abundance and restricted distributions are considered rare. Of the large-sized species listed, which includes the Barrow Island euro, *Macropus robustus isabellinus*, the rock wallabies *Petrogale* spp., the wombats and the quolls, detection is limited by the rugged habitats in which the species live or (in the case of the quolls and the wombats) their nocturnal activity patterns.

All of the non-flying mammals listed on the EPBC Act have been grouped into one of four classes (Table 1) according to body size and habit, which directly relate to appropriate survey methods for detection. Three body weight classes (small, medium and large) are defined. Arboreal species are grouped as a distinct class, because although this group includes both small and medium-sized species, the appropriate survey methods for detecting arboreal mammals are similar. The average adult body weights are taken or calculated from male and female averages provided in published literature that is referenced in the species profiles. The body weight classes are not exclusive and have been used as a guide to group species according to appropriate survey methods, hence some species fall outside the defined weight range. For example, the chuditch or western quoll, *Dasyurus geoffroyi*, and northern quoll, *D. hallucatus*, weigh on average less than the large-sized species minimum weight of 3000 grams, yet have been included with the other quolls in the large-sized class because of similarity in appropriate survey methods (Table 1).

The four non-flying mammal classes used in this report are:

- large-sized ground-dwelling mammals – includes species with an average adult body weight greater than 3000 grams
- medium-sized ground-dwelling mammals – includes species with an average adult body weight between 300–3000 grams
- arboreal mammals with an average adult body weight between 50–500 grams
- small-sized ground-dwelling mammals – includes species with an average adult body weight between 10–300 grams.

Large-sized ground-dwelling mammals include two wombat species, one kangaroo, ten wallabies, the quokka, Tasmanian devil and four species of quoll (Table 1). These species are almost entirely ground-dwelling, however, quolls can climb trees and rock wallabies inhabit very rugged terrain that differs from most of the other listed ground-dwelling species. All of the species are primarily nocturnal. However, they generally become active at dusk and all can exhibit activity during daylight hours to some degree, particularly during the winter months (see species profiles for details).

The medium-sized ground-dwelling mammals include the numbat, greater bilby, boodie, woylie, seven bandicoot species, three potoroos, three bettongs and five species of hare-wallabies (Table 1). With the exception of the numbat, these species are all nocturnal and shelter during the day in nests, burrows, hollow logs or dense vegetation on the ground.

The small and medium-sized arboreal species are a diverse assemblage of seven primarily arboreal mammals (Table 1). They include the red-tailed phascogale, two possum species, two gliders and two rats, the brush-tailed rabbit rat (which is both tree and ground-dwelling) and the golden-backed tree rat, which, based on very limited information, appears to be primarily arboreal (see species profile).



The small-sized ground-dwelling mammal class contains a diverse range of species including a shrew, a pygmy possum, marsupial moles, 10 Dasyuridae species and 14 native rodents. This class includes species from a wide range of ecosystems (for example, the arid zone of central Australia and alpine regions of Victoria and New South Wales). Despite this diversity of habitat, survey methods typically used to detect these species are similar.

The classes have been used here to group species according to similar survey methods and differ from the classes used by Burbidge and McKenzie (1989) and Short and Smith (1994) to define mammal size classes in terms of a critical weight range for medium-sized, non-flying mammals between 35 and 5500 grams. Burbidge and McKenzie (1989) demonstrated that mammals within the critical weight range have disproportionately experienced a far greater rate of extinction in Australia since European settlement than other mammals. When the non-flying mammals listed under the EPBC Act are considered in terms of the critical weight range, 74 per cent fall within this range (note that species with male weights over 5500 grams were not included in the calculation).

Table 1. Threatened non-flying mammal species listed on the EPBC Act as at July 2010 classified according to body weight and habit.

Family	Scientific name	Common name	EPBC Act status
Large-sized ground-dwelling species (average body weight > 3000 g)			
Vombatidae	<i>Vombatus ursinus ursinus</i>	Common wombat (Bass Strait)	Vulnerable
	<i>Lasiornhinus krefftii</i>	Northern hairy-nosed wombat	Endangered
Macropodidae	<i>Macropus robustus isabellinus</i>	Barrow Island euro	Vulnerable
	<i>Setonix brachyurus</i>	Quokka	Vulnerable
	<i>Petrogale lateralis</i>	Black-footed rock wallaby (West Kimberley race)	Vulnerable
	<i>Petrogale lateralis</i>	Black-footed rock wallaby (MacDonnell Ranges race)	Vulnerable
	<i>Petrogale lateralis lateralis</i>	Black-flanked rock wallaby	Vulnerable
	<i>Petrogale lateralis hackettii</i>	Recherche rock wallaby	Vulnerable
	<i>Petrogale penicillata</i>	Brush-tailed rock wallaby	Vulnerable
	<i>Petrogale persephone</i>	Proserpine rock wallaby	Endangered
	<i>Petrogale xanthopus xanthopus</i>	Yellow-footed rock wallaby	Vulnerable
	<i>Onychogalea fraenata</i>	Bridled nailtail wallaby	Endangered
	<i>Macropus eugenii eugenii</i>	Tammar wallaby	Extinct
	<i>Dasyurus geoffroii*</i>	Chuditch or western quoll	Vulnerable
Dasyuridae	<i>Dasyurus maculatus gracilis</i>	Spotted-tailed quoll or yarri (north Queensland)	Endangered
	<i>Dasyurus maculatus maculatus</i>	Spotted-tailed quoll (SE mainland population)	Endangered
		Spotted-tailed quoll (Tasmanian population)	Vulnerable
	<i>Dasyurus hallucatus</i>	Northern quoll	Endangered
	<i>Sarcophilus harrisii</i>	Tasmanian devil	Endangered
Medium-sized Ground-dwelling Species (average body weight range approx. 300-3000 g)			
Dasyuridae	<i>Myrmecobius fasciatus</i>	Numbat	Vulnerable
Peramelidae	<i>Perameles bougainville bougainville</i>	Western barred bandicoot (Shark Bay)	Endangered
	<i>Isoodon auratus auratus</i>	Golden bandicoot (mainland)	Vulnerable
	<i>Isoodon auratus barrowensis</i>	Golden bandicoot (Barrow Island)	Vulnerable
	<i>Isoodon obesulus obesulus</i>	Southern brown bandicoot	Endangered
	<i>Isoodon obesulus nauticus</i>	Southern brown bandicoot (Nyuts Archipelago)	Vulnerable
	<i>Perameles gunnii gunnii</i>	Eastern barred bandicoot (Tasmania)	Vulnerable
	<i>Perameles gunnii</i> unnamed subsp.	Eastern barred bandicoot (mainland)	Endangered
Potoroidae	<i>Macrotis lagotis</i>	Greater bilby	Vulnerable
	<i>Bettongia tropica</i>	Northern bettong	Endangered



Family	Scientific name	Common name	EPBC Act status
	<i>Bettongia lesueur lesueur</i>	Boodie or burrowing bettong (Shark Bay)	Vulnerable
	<i>Bettongia lesueur</i> unnamed subsp.	Boodie or burrowing bettong (Barrow and Boodie Islands)	Vulnerable
	<i>Bettongia lesueur graii</i>	Boodie or burrowing bettong (inland subspecies)	Extinct
	<i>Bettongia penicillata ogilbyi</i>	Woylie	Endangered
	<i>Potorous gilbertii</i>	Gilbert's potoroo	Critically Endangered
	<i>Potorous longipes</i>	Long-footed potoroo	Endangered
	<i>Potorous tridactylus tridactylus</i>	Long-nosed potoroo (South-east mainland)	Vulnerable
Macropodidae	<i>Lagorchestes hirsutus bernieri</i>	Rufous hare wallaby (Bernier Island)	Vulnerable
	<i>Lagorchestes hirsutus dorreae</i>	Rufous hare wallaby (Dorre Island)	Vulnerable
	<i>Lagorchestes hirsutus</i> unnamed subsp.	Rufous hare wallaby (central mainland) or mala	Endangered
	<i>Lagorchestes conspicillatus conspicillatus</i> **	Spectacled hare wallaby (Barrow Island)	Vulnerable
	<i>Lagostrophus fasciatus fasciatus</i>	Banded hare wallaby (Marnine Munning)	Vulnerable
Small & Medium-sized Arboreal Species (average body weight range approx. 100-500 g)			
Petauridae	<i>Gymnobelideus leadbeateri</i>	Leadbeater's possum	Endangered
	<i>Petaurus australis</i> unnamed subsp.	Fluffy glider or yellow-bellied glider (wet tropics)	Vulnerable
	<i>Petaurus gracilis</i>	Mahogany glider	Endangered
Pseudocheiridae	<i>Pseudocheirus occidentalis</i>	Western ringtail possum	Vulnerable
Muridae	<i>Mesembriomys macrurus</i>	Golden-backed tree rat	Vulnerable
	<i>Conilurus penicillatus</i>	Brush-tailed rabbit rat	Vulnerable
Dasyuridae	<i>Phascogale calura</i>	Red-tailed phascogale	Endangered
Small-sized Ground-dwelling Species (average body weight range approx. 10-300 g)			
Croidurine	<i>Crocidura attenuata trichura</i>	Christmas Island shrew	Endangered
Notoryctidae	<i>Notoryctes caurinus</i>	Northern marsupial mole or Karkarratul	Endangered
	<i>Notoryctes typhlops</i>	Southern marsupial mole or Yitjarritjarri	Endangered
Burramyidae	<i>Burramys parvus</i>	Mountain pygmy possum	Endangered
Dasyuridae	<i>Sminthopsis butleri</i>	Carpentarian dunnart	Vulnerable
	<i>Sminthopsis griseoventer boullangerensis</i>	Boullanger Island dunnart	Vulnerable
	<i>Sminthopsis aitkeni</i>	Kangaroo Island dunnart	Endangered
	<i>Sminthopsis psammophila</i>	Sandhill dunnart	Endangered
	<i>Sminthopsis douglasi</i>	Julia Creek dunnart	Endangered
	<i>Pseudantechinus mimulus</i>	Carpentarian antechinus	Vulnerable

Family	Scientific name	Common name	EPBC Act status
	<i>Parantechinus apicalis</i>	Dibbler	Endangered
	<i>Dasycercus byrnei</i>	Kowari	Vulnerable
	<i>Dasycercus cristicauda</i>	Mulgara	Vulnerable

Family	Scientific name	Common name	EPBC Act status
	<i>Dasycercus hillieri</i>	Ampurta	Endangered
Muridae	<i>Pseudomys pilligaensis</i>	Pilliga mouse	Vulnerable
	<i>Pseudomys fieldi</i>	Shark Bay mouse or djoongari	Vulnerable
	<i>Pseudomys australis</i>	Plains rat	Vulnerable
	<i>Pseudomys fumeus</i>	Smoky mouse or konoom	Endangered
	<i>Pseudomys shortridgei</i>	Dayang or heath rat	Vulnerable
	<i>Pseudomys oralis</i>	Hastings River mouse	Endangered
	<i>Notomys aquilo</i>	Northern hopping mouse	Vulnerable
	<i>Notomys fuscus</i>	Dusky hopping mouse or wilkiniti	Vulnerable
	<i>Xeromys myoides</i>	False water rat	Vulnerable
	<i>Zyomys pedunculatus</i>	Central rock rat	Endangered
	<i>Zyomys palatalis</i>	Carpentarian rock rat	Endangered
	<i>Zyomys maini</i>	Arnhem Land rock rat	Vulnerable
	<i>Melomys rubicola</i>	Bramble Cay melomys	Endangered
	<i>Leporillus conditor</i> ***	Greater stick-nest rat or wopilkara	Vulnerable

* The chuditch *Dasyurus geoffroii* and the northern quoll *Dasyurus hallucatus* weigh on average less than 3000 grams.

** The spectacled hare wallaby (Barrow Island) *Lagorchestes conspicillatus conspicillatus* weighs on average more than 3000 grams.

*** The greater stick-nest rat *Leporillus conditor* weighs on average more than 300 grams.



3. OVERVIEW OF SURVEY METHODS AND EFFORT

3.1 Diurnal searches for potential habitat resources

Diurnal searches for potentially suitable habitat resources are an important component of all fauna surveys. A search for potential habitat resources or signs of fauna activity can increase the chances of detection, using survey techniques such as trapping or spotlighting by focusing the effort in the most appropriate location within a study area. Potential habitat resources vary between species, but may include shelter sites (such as tree-hollows, hollow logs, boulders or rocks, caves and crevices) and food sources (such as plant species, prey and water).

Potential resources targeted during the search will depend on what species are considered likely to occur on the subject site or in the locality. Where specific habitat resources for the non-flying mammals listed under the EPBC Act are known, they are outlined in the species profiles. Species of more than one body size group (see Table 1) can be targeted at the same time during a search if it is appropriate. Searches for signs of mammal activity (described in Section 3.2) can also be conducted at the same time if considered appropriate. For example, tracks or scats may be present in a cave.

To identify all potential habitat resources within a study area (or within representative sampling sites), searches need to be conducted across the area. Vegetation maps, aerial photographs, topographic maps and satellite imagery (for example Google Earth) can be useful in locating areas for targeted searches, depending on the location, accuracy and currency of the information.

Recommended method and effort

For small sites it may be best to conduct the diurnal search for potential fauna habitat resources along transects spaced at 50–100 metre intervals, or in quadrats in representative habitats to ensure that an area is systematically searched. The placement of transects or quadrats will depend on a number of factors including the size of the area, the distance within which fauna can be reliably detected and the amount of available time. The use of transects and a specified search effort ensures the effort can be repeated over time for comparisons, or replicated between sites if required. The placement of transects should be planned in advance using aerial photographs, topographic maps and vegetation maps (if available) and then ground-truthed to stratify the survey to represent all, or just relevant habitats within, the target area.

The time taken to effectively search a subject site will vary considerably according to the size and nature of the area. Consequently, it is not possible to provide strict guidelines in this regard. A suggested survey effort for a 5 hectare area is two hours for every one hectare stratified survey site within the area, with searches for potential habitat resources carried out in conjunction with the survey for signs of fauna activity. This is comparable to the duration recommended in the guidelines reviewed (see appendix), which usually combine the search for habitat resources with the search for signs.

For large sites and remote areas, constraints may require the identification of potential habitat resources through ground-truthing after reviewing vegetation maps, aerial photographs and imagery and discussions with local people, rangers and indigenous groups.

3.1.1 Caves and rock boulders

Shelter sites are sometimes easier to detect than the fauna that use them. For example, caves, rock crevices or rock overhangs that are used by a number of threatened species (for example, the Barrow Island euro, most of the listed rock wallabies and quolls) can be located using aerial photographs, topographic maps and diurnal searches, whereas detecting the actual fauna species requires far more effort. The location of caves or other similar potential habitat resources should be clearly recorded (that is, map reference or GPS) and marked physically in the field, and on a map, to ensure that they can be located again.

3.1.2 Tree species and tree hollows

Tree hollows or tree species used by listed arboreal mammal species for shelter and food are much easier to detect than the animals themselves, provided this information is known for each particular species. These habitat features are best detected during the day either during surveys conducted on foot, or for larger surveys over vast areas from a helicopter, in the case of searches for large distinct trees. For example, Bradford and Harrington (1999) used helicopter surveys and ground based surveys to identify food tree species of the fluffy glider (see species profile).

All hollow-bearing trees or species of food trees (tree species are indicated in species profiles where appropriate) within a subject site should be identified to concentrate direct detection survey methods and maximise the chance of target fauna species detection. It may be best to conduct the diurnal search along transects spaced at 50–100 metre intervals across the subject site (depending on the abundance of trees and the size of the area to be surveyed), in order to cover the entire area. The location of all target tree species or trees with hollows need to be clearly recorded (that is, map or GPS reference) and marked both in the field, and on a map, to ensure that they are easily identified again.

3.2 Indirect detection - diurnal searches for signs of mammal activity

Indirect evidence of a species presence at a location refers to finding signs of fauna activity. This includes conducting diurnal searches across the subject site for signs of non-flying mammal activity such as scats, scratches on trees, sap-feeding scars on tree trunks, diggings in the ground, nests, dreys, remains, tracks and burrows.

Signs of mammal activity and habitat resources are often detected more so than the species themselves (although indirect evidence can also be difficult to find and once found it is difficult to confirm a species from this, especially when species experts are not present). In addition, signs can be detected during the day, whereas for the majority of listed mammals, direct observations can only be made at night as the species are in general nocturnal. This is true of all mammal species regardless of body size, but the larger the species then the larger the signs and hence this method is most applicable for medium and large-sized mammals. Furthermore, by targeting areas within a subject site where previous sightings have been recorded, or where signs of mammal activity have been detected, the chances that target fauna will be detected during the direct survey methods will be increased.

The presence of signs of activity at potential habitat resources indicates that the resources may be in use. For example, scats observed at the base of a hollow-bearing tree, or fresh scratches in the tree bark leading up to the hollow indicate that the hollow may be currently in use. Similarly, signs at burrow entrances including tracks, scats or freshly excavated earth indicate if the burrow is in use. The tracks and scats of some species are difficult to distinguish, but they may be located on a runway or near a burrow entrance. Signs that a cave



may be in use include scats, tracks or the presence of remains littering the floor. In some cases, scats or remains may lie protected in a shelter or crevice after the species has become extinct from the locality (for example, greater stick-nest rat nests on the mainland; see species profile). Expert advice may need to be sought from a museum or another specialist to identify and age the bones.

Recommended method and effort

Daytime searches for signs are usually undertaken concurrently with daytime searches for habitat resources (see Section 3.1). The recommended survey effort is therefore the same for these survey techniques, that is, two hours search time for each one hectare survey site of a stratified sampling program undertaken in a subject site up to 5 hectares in size (that is, 50 000 square metres).

The time taken to conduct the community consultation process has not been included in the estimated search time, and will vary depending on the nature and location of the subject site. Some examples of this type of survey are provided below in Section 3.2.1. Examples of other types of signs used to indirectly detect the listed mammalian fauna are provided in the following paragraphs.

3.2.1 Community consultation

Community consultation can be effective in obtaining historical information and anecdotal observations, particularly for large and conspicuous mammals, which are often noted by the local community. For example, observations of the spotted-tailed quoll by the public have been used to indicate the species presence in published and unpublished reports (Ecovision Environmental Consultants 1996, Lunney & Matthews 2001, Belcher et al. 2001). Similarly, Aboriginal communities have aided many surveys for threatened species in remote locations from across Australia (for example, Burbidge et al. 1988). Records of species killed or injured on roads and taken to local wildlife carers can also provide valuable information.

Information can be sourced from local communities through interviews, publicity methods such as newspaper articles, pamphlets and interpretive programs, or mail surveys by contacting people within a local area and asking them to fill in a questionnaire or contact a number with information.

3.2.2 Scats

Scats (animal faecal droppings) provide indirect evidence that a species occurs at a location. Searches for scats are applicable for all species regardless of size; however, the scats produced by larger species are more easily detected than those of smaller species. Scats of some species are extremely hard to find (for example, bandicoots). An investigator must be experienced and familiar with the scats made by listed species for this technique to be effective in the field, as some scats are not easily identified to species level. However, some scats can be collected and identified later by appropriate experts or through genetic testing if required.

A limitation of using scat identification as a survey method is that the pellets are often indistinguishable between similar species and hence other direct survey methods (for example, spotlight surveys) may be required to confirm the actual species present. However, the location where scats are detected can be targeted to increase the chance of making a direct observation of fauna species.

DNA analysis is a technique currently being used to differentiate between the previously indistinguishable faecal pellets of sympatric species such as the quokka, the western grey kangaroo *Macropus fuliginosus*, and two wallaby species in south-west Western Australia (Alacs et al. 2003; Hayward et al. 2005) (see the species profile for the quokka). Scats that are less than a day old can be collected for DNA. If scat DNA analysis is a

planned survey method, advice and cooperation should be sought by an expert in the field for instructions on appropriate collection and preservation techniques. DNA sampling has recently been successful in detecting carnivorous predators where other conventional methods have proved difficult and, in one study, provided valuable insight into fox abundance in relation to lethal control, individual behaviour and movement, as well as sample design (Piggott et al. 2008). Another survey has found DNA analysis to be a reliable technique, allowing a higher rate of species identification in comparison to camera traps (Rosellini et al. 2008).

Where scats are detected, the location should be marked with flagging tape and recorded on a map or with a GPS device. In this way additional direct detection surveys can be conducted at the scat locations. Furthermore, the time since the scats were deposited (age) should be estimated from colour, moisture and content (if possible to determine in the field), although this can never be reliably predicted and will only give a very rough estimate. Aging scats in this way may vary according to environmental conditions, and so the time of year and weather conditions should be recorded concurrently.

Searching for scats during the day can often result in an animal being 'flushed' from its shelter, which is often the case with rock wallabies, the spectacled hare wallaby, and the northern nailtail wallaby (S Ingleby pers. comm.) (the same applies for searches for tracks, which are described in Section 3.2.4). This may need to be considered if potential predators are present, such as wedge tailed eagles, which may capture a flushed animal. Searches for signs of animal activity require far less effort and have less impact on animal welfare than trapping, and therefore they are the preferred survey method for many medium and large-sized mammals as long as they are conducted at times when predators are not in the immediate vicinity.

3.2.3 Predator scat and owl pellet analysis

Predator scats and the digestive pellets (casts) of owls should be collected if detected for the identification of prey species from indigested bone and hair material (particularly relevant for small-sized prey species). This survey technique has significantly contributed to the detection of small-sized threatened mammal species in many surveys, and has been important in helping to define the distributional ranges for a number of the small arid-zone species, particularly from the Northern Territory, Western Australia and South Australia. Furthermore, owl pellets are often preserved for many years and their contents can indicate what species may have once been present, but which may have since undergone local extinction. If predator scat analysis is a planned survey technique, advice and cooperation should be sought by an expert in the field for instructions on appropriate collection and preservation techniques.

3.2.4 Tracks

Tracks (marks in the ground left by an animal's feet, tail or a combination of both) are another sign of fauna activity that indirectly indicate a species presence. Searches for tracks can be conducted in conjunction with searches for scats, or they can be surveyed in a more targeted manner using soil plots, sand trays and/or predator pads (described in the direct detection methods – Section 3.3.2). Diurnal searches for tracks should be an integral part of any survey design.

Tracks made by similar species (for example those made by small wallabies and potoroos) are often indistinguishable (Catling et al. 1997, described in the species profiles for potoroos) and direct survey methods are therefore required to determine which species is present. Any tracks potentially made by listed mammals, such as potoroos, must be considered an important sign that the species may occur in an area. Areas where tracks are detected should be targeted by additional direct survey methods to confirm species presence.



The likelihood that tracks will be present and detected during a search is influenced by the nature of the substrate, the density of the vegetation and the amount of leaf litter or rock/pebbles covering the ground. Detection is most effective when the substrate comprises sandy soil (for example, coastal or arid habitats), wet clay soils, or the muddy edges of water courses and waterholes which provide the best medium for the short-term retention of animal tracks. Leaf-litter covered forest floors, gibber plains and rocks/boulders/cliffs are not amenable for the retention of animal tracks, and in these habitats field surveys for tracks are conducted by clearing an area of gibbers or laying sand trays or soil plots (techniques described in Section 3.3.2), although care needs to be taken when laying these to ensure pathogens such as *Phytophthora* are not introduced (Western Australia has strict guidelines to prevent this), or by targeting locations within the subject site where tracks may be identified. For example, the sandy floors of caves, cleared “scrapes” (shelter sites made by the macropodoidea under small trees or shrubs), dirt vehicle tracks, animal trails, pads and runways or around water sources where the ground is either wet or sandy provide excellent opportunities for detecting tracks.

The investigator should be familiar with the appearance of tracks of fauna considered likely to occur in the area, particularly the targeted listed mammals. If a positive identification cannot be made in the field the investigator should photograph or make plaster casts of tracks so that they can be identified by an appropriate expert. Investigators with previous experience in locating and identifying tracks are more likely to detect these subtle signs. Tracks are often found in association with habitat resources and, by targeting search effort at these locations, tracks are less likely to be overlooked.

3.2.5 Signs of foraging - diggings

A number of listed mammals dig into the ground for food such as underground fungi or invertebrates. The signs of this activity are collectively referred to as “diggings” or foraging pits, and searches for such signs should be incorporated into a survey design for relevant species. All of the listed medium-sized ground-dwelling species make diggings as they forage; specifically the listed bandicoot species (the western barred bandicoot, two subspecies of the golden bandicoot, two subspecies of the eastern barred bandicoot, and two subspecies of the southern brown bandicoot), potoroos (Gilbert’s potoroo, the long-footed potoroo and the long-nosed potoroo), the greater bilby, the numbat, the bettongs (the northern bettong and the two subspecies of burrowing bettong) and the woylie.

In areas where listed mammals (or other similar but non-listed species, including rabbits) overlap in distribution, it is often difficult to distinguish between the diggings to confidently confirm which species is present. To a degree, the diggings of all of the listed species are described as having a conical shape (Triggs 1998); however, size, location and the presence of other signs, such as the remains of food or scats, can help distinguish between diggings. For example, potoroo diggings can be distinguished from those made by bandicoots by their larger size and relatively flatter base; however, it is not possible to distinguish between the diggings of species of the same genus (Claridge & Barry 2000; Triggs 1998; Rees & Paull 2000). The presence of fungi fruiting bodies can be used to identify bettong and potoroo diggings and similarly, diggings made by numbats are often found in association with ant’s nests or termite runways (Triggs 1998). The diggings made by the southern brown bandicoot and rabbits are both produced by digging forward rather than downward, but the diggings are differentiated on the basis of tracks and scats that are often found in association with the diggings (Rees & Paull 2000).

All diggings should be documented as they can contribute to the ongoing investigation of these species. Sites where diggings are detected should also further be surveyed using direct detection methods (for example, spotlight surveys or trapping) to confirm species presence.

3.2.6 Signs of foraging - arboreal species

Arboreal species (in particular the yellow-bellied glider) are known to leave marks on the trunks of trees as they climb or feed on sap. Scratch marks made by claws leave long lasting signs on tree trunks that can easily be detected by an observer surveying trees for signs of fauna activity. Scratches are not always distinguishable between species, and are not specific to mammals (for example, goannas also climb trees), however, detecting the presence of these signs means that trees can be targeted by direct survey methods such as spotlight surveys or stagwatching.

Trees with hollows are often covered in scratches from fauna regularly climbing the trunk, and locating scratches can help to identify the presence of a hollow. While the presence of scratches doesn't always imply that the hollow is in use, it may indicate that a targeted species could possibly be present in the area on occasion. Searches for signs should not be restricted only to trees with obvious hollows or specific species of trees, because not all hollows are detectable from the ground and fauna may prefer different species of trees at different locations.

In addition to scratches, some species of glider use their incisor teeth to cut into the bark of trees to feed on sap (for example, the listed fluffy glider, *Petaurus australis* unnamed subsp.). Yellow-bellied gliders cut distinctive V-shaped sap-feeding notches into specific trees, which they regularly visit and recut to feed on the sap. The resulting scars on tree trunks are highly distinctive and their occurrence in an area indicates that an arboreal species is present at the site.

Trees with either scratches or feeding scars should be marked on a map and with flagging tape in the field and targeted with spotlighting (Section 3.3.3), stagwatching (Section 3.3.4) and possibly an arboreal hair sampling survey (Section 3.3.7) or an arboreal cage trapping survey if required (Section 3.3.9).

3.2.7 Shelter sites - burrows

Burrows provide indirect evidence of a species presence and undertaking searches for these features is an integral component of detection surveys for all known burrowing species. Among the listed species, there are approximately 18 that are known to dig and shelter in burrows. Species from all of the size classes are represented, including the northern hairy nosed wombat, the common wombat (Bass Strait), the greater bilby, the burrowing bettong, the western quoll, the numbat (digs a burrow in spring to hold nestling young), the kowari, the mulgara, the ampurta, and at least eight native rodents (*Pseudomys* and *Notomys* species). Burrows for these species can be detected during the day, and if required, trapping or spotlighting can be conducted at the burrow locations.

Burrows made by larger species are more obvious and hence more easily detected than those of smaller species. For example, wombat burrows are large and highly conspicuous and can even be detected to some degree from aerial surveys in open landscapes (St John & Saunders 1989). The burrows of the small-sized species are much less obvious; however, they still provide a means of surveying for species that are otherwise only detected through trapping programs. Active burrows of all species are distinguished by signs of activity such as footprints, scats or freshly moved earth. If trapping is required to confirm the species, traps can be set near the burrow entrance to increase the chance of capture (see species profiles).

Marsupial mole tunnels can be detected by digging. Recent investigations have found that marsupial moles tunnel, rather than 'swim' as previously thought, and back fill as they move along (Benshemesh 2004). A survey methodology has been developed involving the digging of a steep and smooth sided trench to view these tunnels. Trenches are normally dug at three levels on a dune: near the crest, mid slope, and base



(Benshemesh 2004; Benshemesh 2005). Northern and southern marsupial moles, *Notoryctes caurinus* and *N. typhlops*, leave very different tracks, making them easy to differentiate. The southern marsupial mole leaves a distinctive sinuous tail-mark in the sand, whereas the northern marsupial mole shows no obvious tail-marks and leaves marks resembling a miniature turtle hauling itself over the sand (Strahan & Van Dyck 2008). Survey techniques for these species are discussed in more detail in the species profiles.

3.2.8 Shelter sites - nests or scrapes on the ground

Species that construct nests or scrapes for shelter sites are included among all of the size classes of listed ground-dwelling mammals. For example, the large-sized Barrow Island euro and the bridled naitail wallaby make temporary scrapes or hip-holes in the ground (as do all other kangaroos and wallabies) under trees, shrubs or in drainage channels, which they lie in during the heat of the day. However, it should be noted that the Barrow Island euro, like other *M. robustus* subspecies, also shelter in caves or under rocky overhangs (Triggs 1998) (see Section 3.1.1).

Nests constructed from grass and leaf litter in association with grass tussocks, spinifex hummocks, shrubs and dense vegetation are constructed to some degree by all of the medium-sized ground-dwelling listed species (excluding the greater bilby, the burrowing bettong, and the numbat). The nests of bettongs are conical in shape and have a single entrance, while those made by bandicoots have two entrances. Potoroos do not make elaborate nests but rather dig scrapes under vegetation (Triggs 1998).

The size and nature of small-sized mammal nests differ greatly between species. The greater stick-nest rat and the false water rat build elaborate nests, while others build more simple nests constructed from habitat features such as rocks and boulders (for example, the rock rats), crevices in the soil (Julia Creek dunnart) or vegetation (for example, other dunnarts). Detecting and identifying these structures requires careful and thorough searches in suitable habitat. For many species nests may be difficult to find (for example, mountain pygmy possum), but their location will often be marked by other signs such as tracks or scats. Furthermore, as mentioned previously (Section 3.2.2), animals may be flushed out of the nests if an observer approaches, and care must be made to ensure that predators are not present to catch any flushed animals. While nests on their own may provide evidence of a species presence, where some doubt remains other signs (for example, scats or tracks) and direct survey methods can be targeted at nest locations to confidently confirm which species is present.

3.2.9 Shelter sites - nests in trees

Two listed arboreal mammals construct nests in trees: the western ringtail possum and the golden-backed tree rat (see species profiles for details). Nests constructed by ringtail possums are referred to as dreys and are generally spherical constructions made from leaves and lined with shredded bark or grass (Triggs 1998). Western ringtail possums use more than one nest across their home range (Jones 1995), as detailed in the species profile. The golden-backed tree rat roosts in tree hollows, or, less commonly, in loosely woven nests under the spiky crown of pandanus, and has been recorded in a broad range of vegetation types (Palmer et al 2003). Nests are constructed from *Pandanus* leaves (Triggs 1998). There are no published studies on the number of nests constructed and used by an individual golden-backed tree rat.

3.3 Direct detection survey methods

Direct detection survey methods include techniques where target fauna are identified from a direct observation. Direct observations include detecting fauna while they are resting or active (for example, diurnal surveys and spotlight surveys), surveying species-specific distinguishing characteristics (for example, hair, tracks or photographic images), recording species-specific calls, and capture methods (for example, pitfall traps, small mammal box traps, cage traps and nest boxes). Descriptions of recognised direct survey for mammals are provided in the following paragraphs. Where appropriate, the descriptions include a review of the benefits and shortcomings obtained from the published literature.

Based on the previously reported use of the techniques and survey effort sourced from published and unpublished sources, the fauna survey guidelines reviewed (see Appendix), and consultation with experts, a recommended survey method has been devised for each technique. The recommended methods comprise details of the technique (for example, equipment and bait) and the minimum survey effort required (for example, number of traps, arrangements of traps and duration of sampling period). The recommended survey effort has been formulated for a stratified sampling design consisting of one hectare survey sites within a subject site up to 5 hectares in size, which can be used as a guide from which survey effort can be calculated for areas of different size.

Importantly, the recommended survey methods are intended to be used as a guide to indicate a minimum survey effort considered appropriate for detecting the listed mammal fauna. They are not designed to guarantee detection, with more or less survey effort likely to be needed for different species at different locations. Variables such as vegetation density, topography and locality differ enormously between the known habitats of the listed mammals; hence one survey standard is unlikely to suit all species. To overcome this, modifications to the survey standards are written into the species profiles where an increased survey effort is considered necessary, or where there is currently not enough information about the biology of the species available to recommend a standard survey method or effort. The standards are devised based on the assumption they will be used by experienced investigators.

3.3.1 Diurnal or daytime searches for active fauna

Diurnal or daytime surveys are appropriate for species that are active during the day, or at dawn or dusk. Diurnal surveys are conducted to detect fauna when they are likely to be actively foraging, drinking, emerging from a shelter, resting or basking in the sun. The survey method involves searching for fauna, and may be carried out on foot, from a vehicle or from a hide, which can include the base of a tree as described for stagwatching (see Section 3.3.4).

The manner in which a diurnal survey is conducted will depend on the species and the nature of the subject site. For example, daytime surveys for the numbat are conducted from vehicles on tracks or from planes during aerial surveys (Friend & Thomas 2003). Similarly, rock wallabies, the bridled nailtail wallaby and the Barrow Island euro are sighted from vehicles, aerial surveys or from surveys conducted on foot along transects (for example, Lim et al. 1992, Wong 1994, and see species profiles). Diurnal surveys for rock wallabies are also conducted from observation points or hides. For example, an escarpment may be scanned for basking rock wallabies if the investigator's view is clear or from a hide at a water source where kangaroos come in to drink.



Recommended standard survey method

The design and effort required to conduct an effective diurnal survey varies so greatly between studies that an overall standard has not been outlined here that is appropriate for the listed mammals. The design of the diurnal survey will be dependent on the nature of the site and the target species. If diurnal surveys are considered appropriate, then investigators should plan in advance the manner in which the survey will optimise the success of detection.

Transects or observation points should be selected in advance, taking into account the distance that would reasonably allow for an accurate sighting. For example, large-sized kangaroos and wallabies are visible at relatively great distances (for example, around 250 metres or more), if the vegetation and other habitat features (such as steep terrain or rock boulders) do not obstruct an observer's view (CH McElroy pers. obs.). In this case, transects spaced 500 metres apart are appropriate; however, visibility is unlikely to be that good for most species at any given site. Sighting distance should therefore be tested during the habitat investigation stage of the study. Binoculars should always be used to examine the animals and distinguish between species that may be similar in appearance and overlapping in distribution.

As a guide, diurnal surveys conducted on foot should be conducted at a similar speed as that recommended for spotlight surveys (10 metres per minute; Section 3.3.3). The distance between transects can be greater than that recommended for spotlight surveys because the field of view is not limited by the beam of the spotlight. For each one hectare survey site used to representatively sample a subject site up to 5 hectares in size, one 100 metre transect (or two if the observer's view is obstructed) should be used, with at least four survey sites required.

3.3.2 Soil plots / sand trays / predator pads

Soil plots are a modified version of diurnal searches for signs of tracks (Section 3.2.4). This method facilitates the detection of footprints by preparing or laying out a soil/sand substrate on the ground (for example, a 3 metre x 1 metre plot) at locations where fauna are likely to occur. The footprints left in the substrate are then identified to species level by an experienced person (Catling et al. 1997). To maximise the success of recording fauna, it is best if plots are placed where animals are likely to be moving, such as along natural or vehicle tracks, walking tracks, underpasses, or along fauna trails/runways. Soil plots placed on vehicle tracks have been successfully used to survey large and medium-sized ground-dwelling mammals from forests across eastern New South Wales (Catling et al. 2001). The method is also appropriate for detecting small-sized species such as the listed northern hopping mouse which is rarely captured in traps (Woinarski et al. 1999). Care must be taken to ensure weeds or *Phytophthora* root rot are not introduced.

From their comparison of survey methods in the forests of south-east New South Wales, Catling and colleagues (1997) found that soil plots and hair tubes (Section 3.3.7) provided comparable results in terms of the number of species detected, but soil plots detected more individuals. The greater number of individuals detected in soil plots provided information about abundance and distribution of species that the hair tubes did not. A drawback of soil plot surveys is that tracks of related species cannot be distinguished (for example, small wallabies and potoroos). However, soil plots used in conjunction with hair sampling were more successful survey methods for detecting potoroos than cage traps or spotlighting, which respectively recorded no captures and only one sighting (Catling et al. 1997).

A specialised form of soil plot has been used to detect the presence of predators in an area by luring them to bait placed in the centre of a cleared sand pad (or plot). For example, researchers trying to detect the presence of the kowari in the gibber deserts of South Australia clear circular sized pads (3 metre diameter) of gibbers and rake the sand smooth (Brandle et al. 2002) (see species profiles). A stone covered in tuna oil is placed in the centre of the pad to attract predators to the scent. In this way, predators (for example, the kowari, wild dogs or foxes), are lured to the bait overnight, leaving their footprints in the sand, which are subsequently identified by experienced personnel in the morning.

Recommended survey method

The recommended survey method for soil plots has been based on that described by Catling and colleagues (2001). Using a stratified sampling design of one hectare survey sites within a subject site up to 5 hectares in size, at least three sites should include a soil plot survey as follows:

- establish at least two one metre wide soil plots (raked substrate with fine grain sand added if required) across vehicle tracks, animal pads or other suitable areas (for example, underpasses under roads) per survey site
- set soil plots for three consecutive nights
- rake plots smooth each morning after the tracks have been identified and recorded, taking plaster casts or photographs of prints that cannot be distinguished in the field (provide a scale for all photographs)
- ensure that the investigator is capable of accurately distinguishing species tracks (for example, demonstrated experience) and is familiar with the tracks of the target fauna, and
- consider having a cast of the target species tracks made from museum specimens in advance to help distinguish tracks in the field by comparing against the cast (S Ingleby pers. comm.).

3.3.3 Spotlighting

Spotlighting is a survey method used at night to detect nocturnal species while they are active. It is effective for both arboreal and ground-dwelling species of all size classes, although arboreal mammals are most easily detected by this method. Spotlighting is conducted in a similar manner as a diurnal survey (Section 3.3.1), in that an investigator searches for active fauna, but in this case the target species are nocturnal and the investigators search area is defined by a spotlight. The survey is conducted at night with the aid of a spotlight to detect the animals in the dark, usually as a result of their eye shine, but night-vision scopes can also be used for sightings from stationary or hidden observation points (not discussed further here as a survey method).

Spotlight surveys are of limited use in dense vegetation as the light cannot penetrate far enough from the observer. In habitats with dense understorey vegetation, spotlighting can be conducted along clearings or tracks either by an observer on foot, or from a vehicle. Investigators must consider, however, that species may avoid road verges or other habitat edges that are suited to spotlight surveys. Where surveys are carried out in these areas species may go undetected.

The distance that fauna can be detected from the observer will vary depending on the nature of the subject site and an investigator's experience. Lindenmayer and colleagues (2001) indicate that the probability of detecting arboreal mammals during spotlight surveys is similar for distances up to 50 metres from the transect line. Therefore, transects placed 100 metres apart are optimal for arboreal mammal spotlight surveys, as the area surveyed between adjacent transects does not overlap.



Weather conditions are also known to influence the success of spotlight surveys as extreme temperature, rainfall or wind can reduce animal activity and also make it more difficult for an observer to see fauna. Laurance (1990) found that arboreal mammals in a North Queensland tropical forest were significantly less active when the temperature became cooler, which indicates the importance of climatic conditions during surveys. Temperature has not quantitatively been related to activity for most species but investigators should take a cautious approach by avoiding conducting surveys during inclement conditions such as heavy rain, strong wind or extremely hot or cold temperatures. To reduce the potential that climatic conditions may influence the survey outcome, surveys should be repeated over two nights and across all seasons if it is possible. Goldingay and Kavanagh (1988) found the detectability of feathertail gliders using spotlighting changes with the visibility of the moon.

The equipment and methods used for spotlight surveys are as follows:

- use of a light hand-held spotlight (minimum of 30 watt for open forests and woodlands; minimum of 50–75 watt in tall or closed forests) that is easily carried and is powered by a suitable battery (for example, portable, sealed lead acid rechargeable batteries). Extra batteries and globes are advisable to overcome equipment failure
- the spotlight should be held near the observer's line of vision to maximise the chance of detecting eye shine (light reflected from animals' eyes). If the spotlight is held beyond the direct line between the observer's eye and the eye shine of the animal, then the eye shine reflection is difficult to detect
- the spotlight beam should be moved slowly at a consistent speed over the relevant habitat (for example, ground level for ground-dwelling species)
- binoculars should be used once an animal has been spotted to confirm the species identity and to record any distinguishing features
- the direction of travel should be decided in advance, either by locating a track or by marking out a transect with flagging tape. In this way the observer moves a known distance at a set speed (for example, 10 metres per minute walking [Van der Ree & Loyn 2002], or approximately 5 kilometres per hour in a vehicle along a forest track) to ensure that the planned survey effort is achieved
- spotlighting should be conducted as quietly as possible. This is so that animals are less likely to be disturbed and carry on with their normal activities rather than hiding or fleeing before they can be seen. It also means that the observer is more likely to hear any calls or other noises that may indicate the species presence and location.

Light type, such as a White V redfitter, and light strength are important when spotlighting. Most ecologists recommend 30 or 50 watt, as 100 watt is too bright and most animals will look away, making it difficult to detect species using eye shine.

Recommended survey method

Survey effort will vary according to factors such as size and shape of the subject site and density of understorey vegetation. However, as a general guide, the following recommendations are suggested for spotlight surveys conducted on foot (per person) for a 5 hectare subject site (that is, 50 000 square metres) (Note: transect distances are indicated as a guide only and are expected to vary according to the size and shape of the subject site):

- use a hand held spotlight (50 or 75 watt) and adhere to the method described above
- survey at least two 200 metre transects per 5 hectare site (or longer transects for larger sites)
- maintain an interval of at least 100 metres between the two transects in order to maximise the area surveyed, which is usually 1 kilometre
- the location of transects must be selected to sample appropriate habitats (see species profiles) occurring within the subject site. It is important to note, however, that transects will go through many habitats
- move at a speed of 10 metres per minute, hence a 1000 metre transect will take 100 minutes (1 hour and 40 minutes) (this is a conservative estimate that is expected to vary according to the observer's experience and the vegetation density at the site). It is also beneficial to spend time standing still or searching trees with binoculars
- spotlight surveys along transects should be repeated on two separate nights where possible
- avoid very windy or rainy nights as these conditions can reduce fauna activity and the observers' ability to detect fauna
- investigators must be adequately experienced with the technique, and be able to distinguish species using a combination of detection of eye shine and close-up examination using binoculars.

Vehicle based spotlighting is only recommended for some macropods and considered a poor alternative for most other species.

Animal care and ethics considerations for spotlight surveys

Spotlight surveys must also be conducted according to the relevant animal care and ethics requirements, with as little interference inflicted on the animal's wellbeing as possible. This includes minimising the amount of time that a spotlight is shone directly on fauna, using a light with a narrow beam to reduce the blinding effect that the light may have on the animal's vision and, when practical, using a red or preferably a dimmer switch to reduce light intensity for prolonged observations once the animal has been spotted.

3.3.4 Stagwatching

Stagwatching is primarily used to detect some arboreal mammals, owls and microchiropteran bat species emerging from tree hollows to forage at night. The technique is called stagwatching in reference to the stags in which Leadbeater's possum prefers to nest, and this technique is the recommended way of detecting this species' presence (Smith et al. 1989) (see species profile). However, the principal is also applicable for detecting fauna emerging from dens (for example, quolls), burrows (for example, the greater bilby) or fauna (for example, kangaroos and wallabies) that come in to drink at water bodies in the arid zone (for example, dams, water holes or water troughs) at dusk, particularly when it is hot.

Observations are usually conducted either just before dusk or for a short time afterwards (time is species-specific) and involves stationing observers near fauna shelter sites (for example, dead or living hollow-bearing trees for arboreal species) so that they can identify and count the nocturnal species that emerge (Smith et al. 1989). Night vision goggles are also useful (Schulz pers. comm.).

This detection technique is relatively straightforward and involves a daytime habitat search to locate suitable shelter sites, followed by a period of observation at dusk. Survey duration varies in the literature but an observer should be stationed approximately half an hour before dusk and watch until early nightfall (approximately 40 minutes is generally recommended) (Harley et al 2005).



Trees: arboreal mammals

It is important that trees with hollows are identified on the subject site in advance and marked with a GPS and/or flagging tape. During the diurnal habitat search (Section 3.1), trees with scratches or sap-feeding scars (either fresh or old) should be noted and targeted for subsequent stagwatching and spotlight surveys. Experience in detecting tree hollows may be necessary as people not familiar with this kind of observation may underestimate the number of hollows in an area.

For the method to be most effective, multiple observers need to be available to simultaneously watch all the appropriate trees within the subject site. If multiple observers are not available, the survey effort should be conducted across the subject area using an appropriate stratified sampling design.

Burrows, dens and nests and habitat resources: ground-dwelling mammals

Observing ground-dwelling fauna emerge from their den, burrow or nest site after dusk is a modified version of stagwatching for arboreal fauna, and is applicable for many of the small and medium-sized listed mammals. It should be conducted at suitable shelter sites or habitat resources (for example, water sources) located within a site, and may require more than one observer per shelter site (for example, an observer at each burrow entrance). Observations should only be made at dens or burrows, or resources such as watering points that have signs of activity around them. If more than one such resource occurs on a site, then direct survey effort should be applied to the resource most likely to be used by the target fauna. Observers are placed near an active den or burrow (as far as possible from the site while still maintaining sight of the shelter site) at least 25 minutes before dusk, and watch for as long as is necessary before an animal emerges. Observers need to be sufficiently experienced to ensure they can distinguish target species from other fauna known to occur in the area. Binoculars and a spotlight should be used to confirm markings on animals.

Recommended survey method

Stagwatching survey effort will vary according to the target species and the number of potential shelter or resource sites present in the subject site. As a guide, a survey method for stagwatching should include the following:

- conduct a search for potential habitat resources, including shelter sites (see Section 3.1) and locate, mark with flagging tape and record the position of all potential shelter sites or relevant habitat resources present within a subject site
- station an observer at each potential shelter site or habitat resource at least 30 minutes before dusk and continue until 60 minutes after sunset for nocturnal species
 - ensure that the observer remains quiet so as not to disturb any fauna present, which may require the use of a hide if considered appropriate
 - watch the potential shelter site or habitat resource for at least an hour, or more if considered appropriate
- use a hand-held spotlight (50 or 75 watt) or night scope to distinguish fauna after dark (adhere to methods in Section 3.3.3)
- use binoculars to view distinguishing features of fauna to confirm a species' identity.

3.3.5 Call detection and call playback surveys

It is possible to detect species that make loud and distinctive vocalisations by call identification. Call detection surveys are carried out by passively listening for calls in suitable habitat, or alternatively eliciting calls by conducting call playback surveys.

Of the listed mammals, call detection surveys or call playback surveys are suitable for the fluffy glider (yellow-bellied glider), *Petaurus australis* unnamed subspecies, but not the mahogany glider, which does not make loud vocalisations. The fluffy glider from north-east Queensland has a loud and distinctive call, which it regularly uses as a form of intraspecific communication (Goldingay et al. 2001). The call playback survey comprises broadcasting a pre-recorded tape of the species call through a megaphone at regular intervals. Gliders will often call in response, and their location can be then identified by using a spotlight (Section 3.3.3). Yellow-bellied gliders are also known to respond to calls made by predatory owls such as the powerful owl, *Ninox strenua*, and hence can also be detected through call playback of the pre-recorded calls of this species.

Recommended survey method

Call detection and call playback surveys should be conducted in conjunction with stagwatching (Section 3.3.4) and spotlight surveys (Section 3.3.3), which are to be carried out on two nights per sampling location (for example, transect) within a subject site. NSW DEC (2004) specifies the following procedure:

- initial listening period of 10–15 minutes
- spotlight search of 10 minutes
- broadcast pre-recorded calls intermittently for five minutes
- listen for a response for 10 minutes
- inspect the immediate vicinity with a spotlight to see if non-vocalising fauna have been attracted to the call (10 minutes)
- two sites per stratification unit up to 200 hectares
- each site surveyed twice on separate nights.

For call detection and call playback surveys conducted to detect the presence of the fluffy glider, a recommended standard survey method and minimum survey effort is as follows:

- conduct a stagwatching survey (Section 3.3.4), and if the target species is not detected commence a call detection survey by having the observer remain at their station and quietly listen for the presence of calling gliders
- the call detection survey should be conducted for approximately 20 minutes
- if calls are not heard, then commence a call playback survey comprising a two minute call broadcast, followed by three minutes of listening
- at the end of the call playback survey, shine a spotlight in the surrounding trees to see if individuals were attracted to the sound but did not call
- then commence a spotlight survey on foot of the immediate surrounding habitat to see if any fauna has been attracted to the calls, or conduct a spotlight survey along a transect if part of the planned survey design



- conduct a second call playback survey at the end or during the spotlight survey
- replicate the survey on two separate nights if the target species is not detected during the first night.

Animal care and ethics considerations for call playback surveys

Investigators should check with the relevant animal care and ethics regulator to ensure surveys are consistent with current guidelines. The NSW Department of Primary Industries (NHMRC 2004) recommends that only two 15 minute call playback surveys should be played per night for the detection of nocturnal birds to avoid prolonged exposure and that call playback during the bird species' breeding season should be done with care so as not to disrupt the breeding of the resident pair. These considerations are also applicable to mammal surveys.

3.3.6 Nest boxes and camera traps

Use of nest boxes is a technique that requires more research, but preliminary findings suggest that it can be an excellent technique for detecting arboreal mammals, with several species being detected more readily in nest boxes in comparison to other 'conventional' survey techniques (for example, squirrel glider *Petaurus norfolcensis*). The most appropriate size of nest boxes will vary according to the species (Beyer & Goldingay 2006). Generally, larger species require larger boxes, although smaller species are not necessarily restricted to small boxes (Beyer & Goldingay 2006). Certain species have also been recorded chewing and widening the entrance of nest boxes (for example, the sugar glider *Petaurus breviceps* and brush-tailed phascogale *Phascogale tapoatafa* [Goldingay et al. 2007]). Species from 10–270 grams appear to be able to utilise nest boxes with an entrance diameter from less than 3 cm to greater than 8 cm, whereas mammals larger than 1000 grams will not use nest boxes with an entrance of less than 3 cm, and prefer them being greater than 8 cm (Beyer & Goldingay 2006). Nest box volume does not appear to greatly influence use except for mammals larger than 1000 grams which appear to prefer a size greater than 0.03 cubic metres (Beyer & Goldingay 2006).

Arboreal marsupials appear to prefer nest boxes with narrow entrances just big enough to enter (Menkhorst 1984a), and the height of the nest box can sometimes (but not always) influence the frequency of use by some species (Menkhorst 1984b; Beyer & Goldingay 2006). Large mammals (larger than 1000 grams) appear to require nest boxes higher than 6 metres above the ground, while medium-sized species (100–270 grams) require the nest box above 2 metres (Beyer & Goldingay 2006). Orientation of the nest box is unlikely to have major effect on usage, except for the potential for rain or excessive sunlight entering the box (Menkhorst 1984a).

Ward (2000) detected one feathertail glider, *Acrobates pygmaeus*, during 13.8 hours of spotlighting, while nest boxes captured 57 individuals within a 7 hectare area. Forty nest boxes were installed on a 5 by 8 metre grid, with 50 metres between points (5.7 nest boxes per hectare). Nest boxes had narrow entrances (15–25 millimetres wide slit) and were four to five metres above the ground. However, in surveys conducted by Goldingay and Sharpe (2004), 20 feathertail gliders were detected during spotlighting and only five detected in nest boxes.

Goldingay and colleagues (2007) trialled four different types of nest boxes to investigate which would be the most suitable for the feathertail glider. The species appeared to avoid medium-sized rear-entry boxes with a 45 millimetre diameter entrance, but no clear preference was shown for three designs with a narrow entrance of less than 25 millimetres. This study deployed four nest boxes per hectare.

Any survey targeting a threatened species which may utilise nest boxes should implement the technique in conjunction with other standard techniques, particularly for species in which the nest box technique has not been proven as successful. Similarly, standard survey efforts have yet to be determined for most threatened species in relation to detecting species presence, but it is considered that at least five nest boxes per hectare should be deployed. The volume, dimensions, entrance diameter and height above the ground of the nest box should take into consideration the target species and the information provided above.

It should be noted that nest boxes have a reduced occupation rate in forests with an abundance of natural hollows. They impose additional installation and construction costs and their use requires a minimum of two visits to a site (Ward 2000).

Camera trapping is becoming a more common method of surveying (Trolle & Kery 2005). Camera traps have the advantage of potentially obtaining a wide range of significant information. Automatic camera systems are triggered by an animal passing in front of a sensor that detects movement, changes in ambient light, or a thermal differential (Moen & Lindquist 2004). The two most common types of cameras are 'active' and 'passive' triggered. Active systems consist of a transmitting unit that sends an infrared beam, and a receiving unit which is set across the target area. A picture is taken when the infrared beam is broken. Passive systems are single units that use heat and motion detectors to trigger the camera (Kelly & Holub 2008). Infrared sensors work better at cooler ambient temperatures and are less consistent in warm environments (Swann et al. 2004). Camera trapping has been found to be the most effective method of detecting species at low or moderate densities (Vine et al. 2009).

Cameras allow for the detection of species that are difficult to study due to their elusive and nocturnal habits (Mace et al. 2004). They are less time consuming, less costly, and less invasive than long-term direct observation of animals. They are also beneficial in studying animals in inaccessible or difficult to access locations such as dens and nest cavities, or in rugged terrain (Mace et al. 1994). In addition, they enable the collection of valuable information about multiple species within any given community (Rosellini et al. 2008) and provide data that is more permanent and less disputable than data gathered by direct observation. However, there is concern that camera traps affect animal behaviour, with human activity, scent and the presence of camera equipment potentially attracting or repelling animals (Major & Gowing 1994, York et al 2001). Also, positive identification of a species from camera images alone can sometimes be difficult.

Thermal infrared imagery is often used in addition to other survey methods (for example, for the Christmas Island shrew), and can be used both on the ground and in the canopy (Schulz 2004).

Recommended survey method

Remote cameras allow for a relatively inexpensive tool to gather data on a broad range of species. The main limitation to camera systems is their sensitivity and false triggering, which often results in the memory card being filled with empty images and depletion of the battery. Another limitation is the failure to photograph a target animal (Swann et al. 2004). These false triggers are known to be more common for camera systems with wider detection zones (Swann et al 2004). Passive infrared-triggered camera systems have a number of set-up options for resolution, time delay between photos and day/night modes which if adjusted properly can minimise these false triggers.



The following guidelines can increase the success rate of cameras:

- choose a camera based on target species. Some systems are better at detecting smaller species than others, whilst all will detect larger species (for example, use white flash rather than infra-red to increase detail in images for identification of small species)
- choose a suitable camera for the size of the target area (for example, systems with a narrow detection zone are more appropriate for areas with a narrow entrance, whilst a wider detection zone is more suitable for recording activity within an larger area)
- use a very firm support to avoid false triggers
- for passive units set sensor height according to target species
- place the sensor in a position where there is no vegetation in the foreground
- set the camera 2–5 metres from the target area to avoid out of focus pictures
- ensure all cords are reinforced with duct tape or similar materials to help reduce cord loss due to animals chewing them (Swann et al 2004).

Some surveys use a food based attractant, although this is not always practical as an animal may stay in an area for a longer time, essentially modifying an animal's behaviour. This is acceptable for a detection type camera, but for a mark recapture camera survey project behaviour modification would not be acceptable (Moen & Lindquist 2004). Kelly and Holub (2008) found that different studies required different camera systems, depending on the species in question and the aims of the study. Camera traps are increasingly being used as they can reduce adverse effects that may be caused by more invasive methods such as physical capture (Kelly & Holub 2008; Silveira et al. 2003)

Baited remote cameras have been successfully used to detect small mammals (Nelson et al 2009). Ten cameras were deployed for 18 nights at sites where the smoky mouse was known to occur in Victoria, in conjunction with Elliot A traps and hair tubes (one hectare area). Each camera station consisted of a Sony 7.2 megapixel digital camera and a passive infrared sensor (using a white flash), attached to either a tree trunk or a wooden stake, with the sensor positioned approximately 25 centimetres above the ground. Five out of six cameras detected the species after 10 nights.

Despite the recent development of camera traps for use in wildlife surveys, the survey effort required for species detection has only been documented for a limited range of species groups. Further research is necessary to document the full range of threatened species described in this document. Based on known information the following survey design and effort is recommended:

- cameras should be deployed for at least 14 nights, and
- approximately 10 cameras should be deployed per hectare.

Camera traps should not be used as the only survey method and should always be used in conjunction with other standard survey techniques (for example, spotlighting, hair tubes, Elliot traps, cage traps etc). This is particularly important for species in which the technique has not been proven successful. Furthermore, as with other established survey techniques, the failure to detect a species following a survey using a camera trap does not mean the species is absent from the study area.

3.3.7 Hair sampling devices

Hair sampling devices are used as a survey technique to detect mammal species of all size classes by identifying species from a sample of hair (Suckling 1978, Scotts & Craig 1988). Barbara Triggs, a recognised expert in the identification of species from hair samples, has provided a list of the threatened non-flying mammals that could be reliably identified from hair samples, depending on the size and quality of the sample and the provision of accurate information about the location and habitat available from the sample site (Table 2). The listed species that can be identified from hair samples includes 59 per cent of the small-sized mammals, 70 per cent of the medium-sized ground dwelling mammals, 50 per cent of the arboreal mammals and 56 per cent of the large-sized mammals. The percentages calculated include subspecies that cannot be distinguished at the species level, such as the spotted-tailed quoll from north-east Queensland (*Dasyurus maculatus gracilis*) and the spotted-tailed quoll from south-east Australia (*Dasyurus maculatus maculatus*). This is a limitation of the technique; however, the listed subspecies should all be distinguishable based on the survey location given their discrete distributions.



Table 2. Listed threatened non-flying mammal species that can be positively identified by hair analysis.

Family	Scientific name	Common name	Identification from hair sample possible
Large-sized ground-dwelling mammals			
Vombatidae	<i>Vombatus ursinus ursinus</i>	Common wombat (Bass Strait)	Y
	<i>Lasiorhinus krefftii</i>	Northern hairy-nosed wombat	Y
Macropodidae	<i>Macropus robustus isabellinus</i>	Barrow Island euro	Y*
	<i>Setonix brachyurus</i>	Quokka	Y
	<i>Petrogale lateralis</i>	Black-footed rock wallaby (West Kimberley race)	Y
	<i>Petrogale lateralis</i>	Warru, black-footed rock wallaby (MacDonnell Ranges race)	-
	<i>Petrogale lateralis lateralis</i>	Black-flanked rock wallaby	-
	<i>Petrogale lateralis hackettii</i>	Recherche rock wallaby	-
	<i>Petrogale penicillata</i>	Brush-tailed rock wallaby	Y
	<i>Petrogale persephone</i>	Proserpine rock wallaby	Y
	<i>Petrogale xanthopus xanthopus</i>	Yellow-footed rock wallaby (SA and NSW)	Y*
	<i>Onychogalea fraenata</i>	Bridled naitail wallaby	Y
	<i>Macropus eugenii eugenii</i>	Tammar wallaby	Y
Dasyuridae	<i>Dasyurus geoffroii</i>	Chuditch, western quoll	Y
	<i>Dasyurus maculatus gracilis</i>	Spotted-tailed quoll or yarri (north Queensland)	Y*
	<i>Dasyurus maculatus maculatus</i>	Spotted-tailed quoll (mainland and Tasmania)	Y*
	<i>Dasyurus hallucatus</i>	Northern quoll	Y
	<i>Sarcophilus harrisii</i>	Tasmanian devil	Y
Medium-sized ground-dwelling mammals			
Dasyuridae	<i>Myrmecobius fasciatus</i>	Numbat	Y
Peramelidae	<i>Perameles bougainville bougainville</i>	Western barred bandicoot (Shark Bay)	Y
	<i>Isoodon auratus auratus</i>	Golden bandicoot (mainland)	Y*
	<i>Isoodon auratus barrowensis</i>	Golden bandicoot (Barrow Island)	Y*
	<i>Isoodon obesulus obesulus</i>	Southern brown bandicoot	Y*
	<i>Isoodon obesulus nauticus</i>	Southern brown bandicoot (Nyuts Archipelago)	Y*
	<i>Perameles gunnii gunnii</i>	Eastern barred bandicoot (Tasmania)	Y*
	<i>Perameles gunnii</i> unnamed subsp.	Eastern barred bandicoot (mainland)	Y*
	<i>Macrotis lagotis</i>	Greater bilby	Y
Potoroidae	<i>Bettongia tropica</i>	Northern bettong	Y*
	<i>Bettongia lesueur lesueur</i>	Boodie, burrowing bettong (Shark Bay)	-

Family	Scientific name	Common name	Identification from hair sample possible
	<i>Bettongia lesueur</i> unnamed subsp.	Boodie, burrowing bettong (Barrow and Boodie Islands)	-
	<i>Bettongia penicillata ogilbyi</i>	Woylie	-
	<i>Potorous gilbertii</i>	Gilbert's potoroo	-
	<i>Bettongia lesueur graii</i>	Boodie (inland subspecies)	-
	<i>Potorous longipes</i>	Long-footed potoroo	Y
	<i>Potorous tridactylus tridactylus</i>	Long-nosed potoroo (south-east mainland)	Y*
Macropodidae	<i>Lagorchestes hirsutus bernieri</i>	Rufous hare wallaby (Bernier Island)	Y*
	<i>Lagorchestes hirsutus dorrae</i>	Rufous hare wallaby (Dorre Island)	Y*
	<i>Lagorchestes hirsutus</i> unnamed subsp.	Mala, rufous hare wallaby (central mainland)	Y*
	<i>Lagorchestes conspicillatus conspicillatus</i>	Spectacled hare wallaby (Barrow Island)	Y
	<i>Lagostrophus fasciatus fasciatus</i>	Banded hare wallaby (Marnie Munning)	-
Arboreal mammals			
Petauridae	<i>Gymnobelideus leadbeateri</i>	Leadbeater's possum	Y
	<i>Petaurus australis</i> unnamed subsp.	Fluffy glider, yellow-bellied glider (wet tropics)	Y*
	<i>Petaurus gracilis</i>	Mahogany glider	-
Pseudocheiridae	<i>Pseudocheirus occidentalis</i>	Western ringtail possum	Y
Muridae	<i>Mesembriomys macrurus</i>	Golden-backed tree rat	-
Dasyuridae	<i>Phascogale calura</i>	Red-tailed phascogale	Y
Small-sized ground-dwelling mammals			
Croidurine	<i>Crocodyria attenuata trichura</i>	Christmas Island shrew	Y
Notoryctidae	<i>Notoryctes caurinus</i>	Karkarratul, northern marsupial mole	Y**
	<i>Notoryctes typhlops</i>	Yitjarritjarri, southern marsupial mole	Y**
Burramyidae	<i>Burramys parvus</i>	Mountain pygmy possum	Y
Dasyuridae	<i>Sminthopsis butleri</i>	Carpentarian dunnart	-
	<i>Sminthopsis griseoventer boullangerensis</i>	Boullanger Island dunnart	-
	<i>Sminthopsis aiteni</i>	Kangaroo Island dunnart	-
	<i>Sminthopsis psammophila</i>	Sandhill dunnart	Y
	<i>Sminthopsis douglasi</i>	Julia Creek dunnart	Y
	<i>Pseudantechinus mimulus</i>	Carpentarian antechinus	-
	<i>Parantechinus apicalis</i>	Dibbler	Y
	<i>Dasyercus byrnie</i>	Kowari	Y
	<i>Dasyercus cristicauda</i>	Mulgara	Y
	<i>Dasyercus hillier</i>	Ampurta	Y



Family	Scientific name	Common name	Identification from hair sample possible
Muridae	<i>Pseudomys pilligaensis</i>	Pilliga mouse	-
	<i>Pseudomys fieldi</i>	Djoongari, Shark Bay mouse	-
	<i>Pseudomys australis</i>	Plains rat	Y
	<i>Pseudomys fumeus</i>	Konoom, smoky mouse	Y
	<i>Pseudomys shortridgei</i>	Dayang, heath rat	Y
	<i>Pseudomys oralis</i>	Hastings River mouse	Y
	<i>Notomys aquilo</i>	Northern hopping mouse	-
	<i>Notomys fuscus</i>	Wilkinson, dusky hopping mouse	Y
	<i>Xeromys myoides</i>	False water rat	Y
	<i>Zyzomys pedunculatus</i>	Central rock rat	Y
	<i>Zyzomys palatalis</i>	Carpentarian rock rat	Y
	<i>Melomys rubicola</i>	Bramble Cay melomys	-
	<i>Leporillus conditor</i>	Greater stick-nest rat, wopilkara	-
	<i>Zyzomys maini</i>	Arnhem Land rock rat	-
	<i>Conilurus penicillatus</i>	Brush-tailed rabbit rat	-

* The table above assumes that a reasonable sample is available. Note that it is not generally possible to distinguish between subspecies – for example, *Dasyurus maculatus gracilis* and *D. maculatus maculatus*. These subspecies are marked with an asterisk*. Northern and southern marsupial moles can be identified to genus (denoted **).

Hair sampling devices operate by passively sampling the hair from mammals that are lured to the device by bait. The two standard structures are an open funnel or a tube, both of which have the bait enclosed in a chamber inaccessible to mammal species. While fauna attempt to get to the bait, some of their fur sticks to an adhesive insert that lines the upper inside surface of the tube or funnel. The inserts and the attached fur are removed at the end of a given sampling period (devices are usually set for several consecutive days) and analysed to determine the fauna species in question (see Brunner & Coman 1974). Inserts are usually sent to specialists for identification and consequently this technique does not require a specialist in hair identification in the field.

A number of different hair tubes exist. These include small tubes with an entrance diameter of 32 millimetres, larger tubes with an entrance diameter of 105 millimetres and a funnel made by Faunatech that is tapered with a closed bait chamber at its narrowest end. The contact area for collecting samples of mammal hair in the funnel is a thin wafer insert on its upper wall that is lined with an industrial adhesive. These are most often used to collect hair samples from bandicoots.

Hair-tubes were originally used in Australia to survey small-sized arboreal mammals that were otherwise surveyed by trapping because they were difficult to spotlight (Suckling 1978). The tubes were constructed from PVC pipe, were open at both ends (30 millimetre diameter x 100 millimetres long) and contained bait, wrapped in gauze, secured by a nail to the inside centre of the tube. Tubes were placed 2–6 metres above the ground in trees and left in place for two to three weeks. While Suckling (1978) did not detect the feathertail glider, *Acrobates pygmaeus*, or the eastern pygmy possum, *Cercartetus nanus*, with the tubes as intended, the sugar glider *Petaurus breviceps* and the brown antechinus *Antechinus stuartii* were detected.

Suckling's (1978) hair-tube design was modified by Scotts and Craig (1988) for the purposes of detecting the long-footed potoroo. The design was similar but used larger PVC pipe (90 millimetre diameter x 100 millimetres length) closed at one end with a stormwater adaptor (100 millimetres), with the bait enclosed in a central section by perforated aluminium screening. Both hair-tubes and cage traps were baited with a mixture of rolled oats, peanut butter, honey and essence of pistachio nut oil to lure and detect the potoroos (Scotts & Craig 1988). Hair-tubes were more successful than cage traps at detecting the long-footed potoroo, with a two per cent (four out of 201 hair tubes) versus 0.1 per cent success rate per 100 tubes or traps respectively, but both techniques had a relatively low success rate.

Hair tubes have now become a commonly used technique in many fauna surveys (Lindenmayer et al. 1999, Mills et al. 2002). Their structure has been modified and is commercially available as hair funnels (*Faunatech* Pty Ltd., Eltham, Vic.), but both hair tubes and hair funnels are often referred to as hair tubes. Hair funnels have a single entrance that tapers to a narrow end where the bait is enclosed in a chamber. Purpose-made adhesive PVC wafers are inserted in the inside upper surface of the funnels.

Recent studies suggest that the devices may not equally target common species, with the bush rat, *Rattus fuscipes*, more frequently detected in small tubes, the brown antechinus, *Antechinus stuartii*, and brush-tail possums more frequently detected in funnels, and the common wombat, *Vombatus ursinus*, and swamp wallaby, *Wallabia bicolor*, detected in large tubes (Lindenmayer et al. 1999, Mills et al. 2002). This difference may be due to a range of factors relating to the shapes of the devices, and the type of adhesive used. However, at this stage the causes are unknown.

Accurate identification of an animal is dependent on the quality of the hair sample. There is concern that hair collected in sampling devices is not always identified correctly (Lobert et al. 2001). However, errors in identification are less likely to occur if accurate details of the timing, location and habitat characteristics of the



survey are provided with the hair samples to the investigators who analyse the samples. Identification is also influenced by the type of hairs collected, the age of the animal and the animal's condition. As these variables are beyond the control of the technique, they are likely to influence all survey results.

Recommended survey method

The following recommendations have been devised to be comparable to the fauna survey guidelines reviewed (see appendix), but the survey effort tends to be greater in order to target the nationally listed mammals. Using a stratified sampling design of a subject site up to 5 hectares in size, at least three sites should include a hair sampling survey as follows:

- 20 hair sampling devices placed at each sampling site
- devices placed 20 metres apart in two parallel straight lines (transects) separated by 25 metres (this is dependent on species and those with a large home range will differ)
- one sampling site per representative habitat, with at least two sampling sites required per 5 hectares (replication across habitat types in areas greater than 5 hectares)
- set devices for 14 consecutive nights
- bait should target the species surveyed or (if surveying for a number of trophic types) alternate devices with a meat based bait (for example, cat food, singed chicken or tuna) and a standard bait (for example, a mixture of peanut butter, rolled oats and pistachio nut oil)
- re-bait the hair sampling devices if possible, unless targeting a “shy” species.

Arboreal hair sampling surveys are used for arboreal species that can be distinguished from hair samples (for example, Leadbeater's possum). In the case of subspecies, arboreal trapping is considered more appropriate for detecting the listed EPBC Act mammals because identification based on hair samples is not possible. An arboreal hair sampling program should be similar to that described above for a ground based survey; however, hair sampling devices need to be secured to tree trunks. The recommended effort is as follows:

- 20 hair sampling devices, attached to trees trunks approximately 3 metres above the ground at each sampling site (the number of devices set may vary according to the number of suitably sized trees in each site (see species profiles for details)
- devices placed 20 metres apart in two parallel straight lines (transects) separated by 25 metres
- one sampling site per representative habitat, with at least two sampling sites required per 5 hectares (replication across habitat types in areas greater than 5 hectares)
- set devices for 14 consecutive nights
- bait should target the species surveyed, or bait alternate devices with a meat bait suitable for target species (for example, cat food, singed chicken or tuna) and a standard bait (for example, a mixture of peanut butter, rolled oats and pistachio nut oil)
- re-bait the hair sampling devices if possible, unless targeting a shy species.

Investigators must accommodate the need for analysis (for example, either sub-contracted to recognised experts or else demonstrate their own experience and ability to distinguish species from samples) in their survey design. They must also be sure that the target fauna can be identified from hair samples, be aware of the possible limitations of this survey technique, and should demonstrate that they have weighed the limitations and benefits against other standard methods that may be appropriate.

Animal care and ethics considerations for hair sampling surveys

Investigators should check with the relevant animal care and ethics regulator to ensure surveys are consistent with current guidelines. The NSW Department of Primary Industries (www.animaethics.org.au/policies-and-guidelines/wildlife-research/wildlife-surveys) recommends that:

- the floor of the tube is free of adhesive tape to prevent small lizards and frogs becoming stuck
- hair tubes are angled with the entrance pointing slightly downwards for drainage
- if an animal does become stuck to the tape, do not try to pull it off, as this may seriously damage the skin. Either carefully trim the tape on the animal to as small a size as possible (the remaining tape will be shed during normal skin replacement) or gently ease with vegetable oil under the tape and slide it off.

3.3.9 Capture methods for small-sized species: pitfall traps

Many small mammals are virtually impossible to detect without the aid of a hair sampling (Section 3.3.7) or a live-trapping program. Pitfall traps specifically target small-sized ground-dwelling species, but can catch arboreal species such as small possums as they move along the ground. They are commonly used to detect small-sized mammal and reptile species in the arid and semi-arid zone. When used in conjunction with other trapping techniques, pitfall trapping often results in proportionately fewer captures, but it is considered an important method for capturing some species that are otherwise not detected by other survey methods (for example, *Sminthopsis* spp. and *Planigale* spp.; Laurance 1992, Catling et al. 1997, and see species profiles).

PVC pipes are increasingly used as an alternative to buckets as they are deeper and provide better protection, and are seen to be ethically more preferable in desert areas (Schulz pers. comm.). For example, in recent NSW natural resources monitoring, evaluation and reporting surveys, PVC pipes 70 centimetres deep were set in a line of 10 at various sites. Tight fitting steel hats have also been used as lids for the traps so they can be left in the ground.

Pitfall trapping involves catching small-sized animals in excavated holes in the ground (pits), which have been dug in a line at regular intervals within suitable habitat. The pits need to be lined with a material to prevent the walls from falling in and potentially burying any animals trapped, and to prevent animal escape. The two lining materials commonly used are:

- 20 litre plastic buckets (280–285 millimetre diameter rim by 400 millimetres depth); or
- PVC pipe with a cap or aluminium (preferably) flywire at the base (150 millimetre diameter rim by 600 millimetre or deeper depth).

The pit liner is placed vertically into the excavated hole so that the top is flush or just below ground level and any spaces between the lining and the hole are backfilled with soil. A drift fence aids in capture by intersecting the path of travel of fauna, re-directing them along the fence and subsequently into the pit. A drift fence (approximately 300 millimetres high with the lower 50 millimetres buried in the soil) is usually erected in conjunction with the pitfall traps, but the arrangement of the pits and drift fence varies (a review of the literature is provided in the following paragraphs). The drift fence should be supported by steel pegs where necessary, and consist of a material that is difficult for small mammals to climb (for example, plastic builder's dampcourse, shade-cloth or flywire). Shelter for trapped fauna is placed at the bottom of the pit to help prevent hypothermia or overheating and/or to provide refuge to escape from other fauna. This should include some leaf litter, a rock or piece of wood or a small piece of PVC pipe.



A number of Australian studies have compared the effects of pitfall survey designs by testing the capture success of fauna in the arid zone. For example, pit arrangement and the use of drift fences was investigated by Morton and colleagues (1988), Friend and colleagues (1989), Hobbs and colleagues (1994) and Moseby and Read (2001), who all found that drift fences between pits increased trapping rates. The results from Moseby and Read's (2001) study included data for small-sized mammals as well as reptiles. The number of mammals and reptiles captured in the first three nights of a pitfall survey was greater when drift fences were used (Moseby & Read 2001).

There is variation in opinion about how to arrange pitfall traps (number of pits, the distance between pits and configuration) to achieve optimal capture success. Moseby and Read (2001) arranged their pits in a cross configuration according to recommendations made by Morton and colleagues (1988); however, another study found that a more effective configuration for catching reptiles was to use a straight line of pits, connected with a drift fence (Hobbs et al. 1994). Furthermore, Hobbs and colleagues (1994) found that relatively longer trap lines (70 metres long comprising nine pits spaced at 7 metre intervals plus fence) captured more reptile individuals and species than shorter trap lines (60 metres in length comprising nine pits spaced 5 metres apart plus fence). Surveys conducted by Dickman (2001) within arid sites placed pitfalls in a grid formation. Each grid comprised six lines of six pitfall traps spaced 20 metres apart to cover one hectare, left open for two to four nights per grid (a minimum of 72 trap nights per hectare).

From another study into factors affecting capture rates of small-sized ground vertebrates in arid South Australia, Moseby and Read (2001) formulated a pitfall trapping survey effort to optimise capture success. The authors formulated their recommendations based on the trapping success of sites with the following pitfall trap arrangements:

- 20 sites of 13 pits spaced at 5 metre intervals in a cross configuration (PVC pipe 125 millimetre diameter and 500 millimetres deep)
- 20 sites of four pits spaced at 10 metre intervals in a cross arrangement (20 litre buckets, 285 millimetre diameter and 400 millimetres deep), with sites placed within 2 kilometres of each other.

They recommended trapping for between eight and 10 consecutive nights to optimise the detection of mammals, particularly rare species, from the assemblage of fauna in the chenopod shrubland habitat of their study area. To census the local mammalian fauna, they recommended a total of 25 trap-nights divided between three surveys conducted at different times of the year, using eight pits per site (size of site not defined). If the time available for survey is limited, they recommended increasing the number of sites, for example, approximately 40 per cent of the mammals present would be detected in a survey comprising 10 sites trapped for three consecutive nights (Moseby & Read 2001). However, if resources rather than time is limited, then trapping fewer sites (between three to five sites) for a longer period (10 nights) is recommended for detecting 60 per cent of the reptile fauna (data not available for mammals) (Moseby & Read 2001).

Pits for mammals need to be relatively deep to avoid escapes, with 400 millimetre deep pits recommended by Owens and Read (1999), and 600 millimetre pits recommended by Moseby and Read (2001) for more agile species. However, deep pits can be time consuming to dig depending on the terrain and aids may be needed to dig the holes. When the survey time is restricted, the number of survey sites or pits per site will be limited by the time it takes to excavate the pits (R Close pers. comm.).

Recommended survey method

Based on the above and other similar studies, a recommended survey method and minimum effort for pitfall trap surveys within an area up to 5 hectares in size is as follows:

- pits constructed from either PVC pipe (150 millimetre diameter and 600 millimetres deep) or plastic buckets (280 millimetre diameter and at least 400 millimetres deep), with preference given to deeper pitfalls for catching agile species
- at each sampling site, arrange 10 pitfall traps in a straight line (transect) at 10 metre intervals, either connected by a 120 metre drift fence (300 millimetres high flywire or garden shade-cloth, buried 50 millimetres into the ground, and secured with wire pegs), or give each pit its own drift fence that can be angled to terrain
- place a sampling site in all representative habitats, with a minimum of two sampling sites required per 5 hectares
- set traps for a minimum of four consecutive nights (preferably eight to 10 consecutive nights if ethical, or temporally replicate survey)
- check traps early in the morning and cover during the day if targeting only mammal species
- provide a small amount of nesting material for shelter (shade or warmth).

Animal care and ethics considerations for pitfall surveys

Investigators should check with the relevant animal care and ethics regulator to ensure surveys are consistent with current guidelines. It is essential that planning and management of surveys that involve pitfall trapping minimise the risk of animals being trapped too long. Recommendations include:

- minimise the possibility that more than one animal is trapped at one time by using a selective barrier over the entrance
- prevent hypothermia by providing leaf litter or other suitable bedding material
- prevent hyperthermia by shading the trap during the day or by placing shelter in the trap (for example, leaf litter, 35 millimetre PVC tube or folded cardboard)
- check trap twice a day or cover traps during the day
- prevent drowning by covering traps during rain, not setting them in low-lying areas or wetlands where they may fill with water, and/or provide a polystyrene float
- avoid deprivation of food and water (for example, provide a water saturated sponge)
- deactivate traps when they are not required (that is, cover or dig up)
- construct traps of an appropriate size
- consider the affects of catching non-target species
- protect trapped animals from ants or other insects by using an insecticide around the rim of the entrance (although the effects of insecticides on mammals, reptiles and amphibians are not always known and they should be used with caution).



3.3.9 Capture methods for small-sized species: box traps (Elliott traps)

A review of survey techniques by Garden and colleagues (2007) found Elliott traps to be the most successful technique for small-bodied mammal species such as dunnarts and antechinus. Recent surveys have lined the trap with cotton wool to prevent stress or death and provide insulation (Claridge et al. 2008). Minimising unnecessary recaptures and avoiding weather extremes also reduces the mortality of small mammals during trapping surveys (Clemann et al. 2005).

Traps are set with a generous amount of appropriate bait, usually a mixture of rolled oats, peanut butter, honey and raisins, known as 'universal bait'. However, the most appropriate bait varies considerably between species. For example, chuditches prefer a mixture of sardines, tuna oil and flour.

Small mammal box traps are designed to catch small and sometimes medium-sized mammals. The traps are used to catch both ground-dwelling and arboreal species, with traps set on the ground for the former and secured to platforms in trees for the latter. Elliott trapping is the most commonly employed and recommended small-sized mammal survey method in Australia. It is often used instead of or in conjunction with a pitfall trapping program, but usually with a comparatively greater trapping effort because of the ease with which the traps can be installed compared to pitfall traps.

Box traps operate by luring fauna into the traps to a bait placed inside, and as they step inside the trap their body weight offsets a treadle operated door behind them. In this way the traps are designed to capture only one animal at a time, which is a notable difference to the design of some small-mammal traps (such as the Ugglan trap or pitfall traps which are designed to potentially capture more than one animal at once). These traps rely upon the animal's weight to be activated, which can be a problem with small-sized, lightweight species (for example, the Pilliga mouse). A recent survey adjusted the sensitivity of the treadle (Tokushima et al. 2008) enabling the capture of such species.

The traps are collapsible and made of aluminium so that they are light weight and easily carried in the field. In Australia this trap is usually referred to as an Elliott trap, named after the manufacturers (*Elliott Scientific*, Upway, Victoria), but other brand names such as *Sherwin* and *Longworth* refer to similar single capture devices. For simplicity, Elliott trap is the term used to refer to these types of traps in this report.

There are a range of Elliott traps that vary according to size:

- Elliott B – large (460 millimetres x 1555 millimetres x 150 millimetres)
- Elliott A – medium (330 millimetres x 100 millimetres x 90 millimetres)
- Elliott E – small (230 millimetres x 90 millimetres x 80 millimetres)
- modified Elliott B traps with a door locking device to prevent escape by dexterous arboreal and scansorial mammal species such as the western quoll (Johnson 1996).

In general, Elliott A and E traps are used to catch small-sized ground-dwelling species (for example, the mountain pygmy possum and rodent species). Elliott B traps are used to catch the largest of the small-sized ground-dwelling and arboreal mammals, whose long tails can get caught and damaged in the door of an Elliott A trap as it snaps shut. This is particularly the case for the larger rodents, which lose the skin on their tails easily when handled incorrectly (for example, the rock rat species), and the arboreal species with long bushy tails (for example, the red-tailed phascogale). Cage traps (described in Section 3.3.10) are recommended for catching medium-sized arboreal species such as the mahogany glider.

Whether targeting ground-dwelling or arboreal species, traps are laid out in regular intervals along transects across a subject site. When targeting ground-dwelling species the traps are laid on the ground, usually near a log or under a bush. Traps are set above the ground for arboreal species, either on platforms attached to trees or in the branches of strong sturdy understorey plants of densely vegetated communities. Grid formations are often used by researchers as a means of measuring or monitoring a population size, habitat use or distribution within a given area. Transects laid out across an area at regular intervals also constitute a grid and the terms for arrangements are often used interchangeably in the literature.

It is critical that the location of each trap is clearly marked with flagging tape to ensure that a trap is not forgotten or lost, which may result in an animal's death if it is trapped inside and not released. Similarly, to reduce the risk of this occurring, the number of traps laid out in a line should always be the same, and a compass and tape measure (or counted footsteps) used when laying the traps so that they are in a straight line and will be easy to find again. At the end of a trapping program flagging tape should be removed so that it doesn't litter and will not be confused in a later survey that may be conducted on the same site.

A species-appropriate bait (usually a mixture of peanut butter, rolled oats and honey) is placed inside the trap to attract animals that may be in the vicinity. The amount of bait used should be generous so as to supplement the diet of an animal trapped overnight that has otherwise lost the opportunity to forage.

Trapping programs are generally conducted over a period of three to five consecutive nights. Traps are checked early in the morning, closed during the day and opened again during the late afternoon. In this way the capture of diurnal fauna (such as reptiles and birds) that may be lured into the trap by the bait is avoided and the effects of daylight/heat from the sun in the morning are reduced by releasing trapped fauna as early as possible (Monamy & Gott 2001). Similarly, cold or wet conditions can also impact upon trapped fauna by causing hypothermia if the traps get wet during rainfall, or if there is no insulating material (bedding) provided. Rain can be prevented from getting inside the traps by wrapping a plastic bag around the outside and securing it with a rubber band. Insulating material must be placed into traps set during cold conditions (for example, winter, spring or autumn), and at all times when trapping above the snow line. Tasker and Dickman (2002) recommended a handful of *Eucalyptus* leaves, but artificial materials such as Dacron, cotton wool, shredded paper towel and coconut fibre have also been used. Bedding material may also help to reduce stress. Animals captured in traps with bedding are found to urinate and defecate less and appear more calm when handled (Tasker & Dickman 2002).

Tasker and Dickman (2002), in their recent review of Elliott trapping methods, point out a number of ways to improve trapping success. These include:

- cleaning traps with detergent after they have been successfully used to catch an animal
- making sure the trap is set flush to the ground so that it is stable, by clearing away leaves and flattening the trap placement spot by 'scuffing' the ground with a boot
- placing traps in appropriate positions such as along runways, near a log, at the base of a tree with buttress roots or crevices, and in places where vegetation provides cover
- not placing traps or bait near predator scats
- spacing traps close enough to cover home range areas for small mammals (for example, 10 metres)
- selecting the duration of a trapping program to allow for the animals to become accustomed to the presence of a trap, while at the same time minimise the number of successive nights that an animal may be recaptured (for example, leave traps closed for the third night if trapping for more than three or four nights).



Catling and colleagues (1997) recommend Elliott traps to survey small mammals in eastern forests of NSW. However, other survey methods such as pitfall trapping, hair tubes and predator scat analysis should also be included in a survey design, as some species are less frequently detected in Elliott traps (for example, common dunnart, *Sminthopsis murina*). The Elliott trap survey effort used by Catling and colleagues (1997) is as follows:

- 20 Elliott A traps placed in two parallel transects 10 metres apart per site
- traps spaced at 7 metre intervals
- traps baited with peanut butter and rolled oats
- transects placed at right angles to forest tracks and commenced 20 metres from the track edge
- traps were set for three consecutive nights
- trapping sites selected according to habitat (vegetation types and climatic environments).

Using this survey design, Catling and colleagues (1997) conducted a total of 6780 trap-nights across 113 sites to record 1158 captures of 702 individual small mammals. The same methodology was employed in other similar studies by the authors (for example, Catling & Burt 1994).

Recommended survey method

Based on the study by Catling and colleagues (1997), the fauna survey guidelines reviewed, and other similar studies, a recommended survey method and minimum effort for Elliott trap surveys for an area up to 5 hectares in size has been outlined below for small-sized ground-dwelling species, and small and medium-sized arboreal species. Trapping for medium-sized ground-dwelling mammals is outlined in the following section (Section 3.3.10). Furthermore, the recommendations made by Tasker and Dickman (2002), which have been summarised above, should be followed to maximise the chances of capture.

Small-sized ground-dwelling mammals

The following survey method and minimum survey effort is recommended for small-sized ground-dwelling mammals:

- 20 Elliott A, B or E traps (see species profiles for details) placed at each sampling site
- traps placed 10 metres apart in two parallel straight lines (transects) separated by 25 metres (a greater distance between traps is recommended in some species profiles)
- one sampling site per representative habitat, with a minimum of two sampling sites required per 5 hectares (replication across habitat types in areas greater than 5 hectares)
- set traps for four consecutive nights
- check traps early in the morning and close during the day
- bait traps with a species-specific mixture (see species profiles)
- rebait and open traps in the late afternoon
- consider placing two traps at each trap station to saturate trapping effort if common species are likely to limit the detection of listed mammals
- provide a small amount of nesting material for shelter (for example, shade and warmth).

This survey effort represents a minimum of 160 trap nights per 5 hectare subject site (80 trap-nights per hectare survey site), which is comparable to the fauna survey guidelines reviewed (see appendix), which on average prescribe 83 trap nights per hectare.

The Christmas Island shrew is often surveyed by the use of pitfall traps, although standard techniques are difficult to use on the island due to the problem of crab interference (Meek 2000). Segments of PVC tubing placed at the bottom of pits to act as refuge sites, wire mesh capping and small diameter traps are all used in trapping as a means to exclude robber crabs and the majority of other crabs (Meek 2000; Schulz 2004). The species recovery plan encourages the following different techniques:

- pitfall trap lines (12 pits along a 25 metre line, diameter 250 millimetre and 80 millimetre) set at three sites in the Dales-Winifred Beach area, with underground powerline cable creating a drift fence (Meek 2000). Segments of PVC tubing (100 millimetre x 40 millimetre) placed at the bottom of pits to act as a refuge site for captured animals
- ten pitfall traps of PVC tubing (maximum diameter of 80 millimetres, minimum depth of 250 millimetres), each trap capped by heavy duty wire mesh at a distance of 5 metres apart with the upper rims flush with ground level. Drift fence similar to the one mentioned above, or utilise mobile crab fences developed by PAN (Jeffrey, pers. comm. in Schulz 2004). Wire mesh is hooked into place at the top of each pit and non-absorbent cotton wool or coconut fibre to be placed in the base for shelter.

Arboreal mammals

Trapping for arboreal species is in principal the same as trapping for ground-dwelling species, with the main difference being that traps set for arboreal species are set in trees or dense understorey vegetation above the ground. Elliott B traps or cage traps are the only traps recommended for catching the listed arboreal mammals, with specific details regarding the trap size outlined in the species profiles. Smaller Elliott A traps should not be used for arboreal trapping surveys because the tails of both listed (for example, the red-tailed phascogale) and unlisted mammal species (for example, the sugar glider and the squirrel glider) can get caught and injured in the trap doors (Soderquist et al. 1996; Rhind & Bradley 2002; and see species profile for the red-tailed phascogale). Cage traps are more suitable to catch the larger listed gliders and Leadbeater's possum, and both cage and Elliott B traps should be trialled for the golden-backed tree rat. The western ringtail possum is considered difficult to trap (see species profile) and, based on the current understanding of this species, trapping is not considered a standard method of detection.

To describe trap placement in trees, the methods used by Jackson (2000) during a live-trapping survey for the mahogany glider have been summarised. Cage traps were attached to tree trunks 4 metres above the ground on brackets made from two pieces of wood (920 millimetres x 100 millimetres) screwed together to form a T shape, and supported by a cross bracket of wood that connected to the T at a 45 degree angle.

Traps should be baited with a species-specific bait (for example, a mixture of creamed honey and rolled oats for mahogany gliders) as outlined in the species profiles. If using a honey and oat mixture for gliders, it may be beneficial to wrap the mixture in greaseproof paper to prevent it crumbling and falling out of a cage trap (Jackson 2000).

A cage trapping program should be designed to take into account two conflicting considerations. Firstly, enough traps need to be placed to cover the entire area of suitable habitat on the subject site (for example, forest and/or woodland). However, the number of traps that can be placed is limited by the time it takes to clear the traps in the morning, as traps must be checked and animals released before the animal's wellbeing (or that



of suckling nestling offspring) may be compromised. Jackson (2000) placed traps at 100 metre intervals, which means a larger area is sampled than if the traps were placed at closer intervals. However, this interval was designed to sample an area of up to 100 hectares in size and for smaller sites (for example, 5 hectares) it may be appropriate to set traps at a closer interval (for example, 50 metres).

The recommended survey method and minimum survey effort for trap surveys for listed arboreal mammals is:

- 10 Elliott B or cage traps (see species profiles for details) placed at each sampling site
- traps placed 2–4 metres above the ground (secured to platforms in trees, see above), approximately 50 metres apart in two parallel straight lines (transects) separated by 50 metres (a greater distance between traps is recommended in some species profiles)
- one sampling site per representative habitat, with a minimum of two sampling sites required per 5 hectares (replication across habitat types in areas greater than 5 hectares)
- set traps for four consecutive nights (this may vary for different species)
- check traps early in the morning and close during the day
- bait traps with a species specific mixture (see species profiles)
- rebait and open traps in the late afternoon
- spray a mixture of honey and water around tree trunk and trap to help lure target species
- consider placing two traps at each trap station to saturate trapping effort if common species are likely to limit the detection of listed mammals
- provide a small amount of nesting material for shelter (for example, shade and warmth).

This survey effort represents a total of 80 trap nights. For areas greater than 5 hectares in area, replication between representative sampling sites will be required and distance between traps increased, but specifications will be dependent on the project and the nature of the subject site.

Animal care and ethics considerations for Elliott trap surveys

Investigators should check with the relevant animal care and ethics regulator to ensure surveys are consistent with current guidelines. The NSW Department of Primary Industries (www.animaethics.org.au/policies-and-guidelines/wildlife-research/wildlife-surveys) has guidelines addressing animal care and welfare during Elliott trap surveys, which include:

- provide bedding material for shelter and to prevent hypothermia (for example, Dacron, dry leaf litter)
- place traps in locations where protected from climatic conditions (that is, in the shade under bushes)
- traps placed on slopes or rocky outcrops should be firmly secured to avoid the trap becoming dislodged when an animal is captured
- cover traps with a plastic bag to protect against rain but ensure adequate drainage
- use a species-specific bait (for example, mixture of peanut butter and rolled oats) but do not use meat or meat products
- place enough bait into the trap to supplement the animal's diet from loss of time foraging while trapped

- trapping of species which are known to leave their young in nests should be avoided at the relevant time of the year (if this information is known), because young may die in the event their mother cannot return to suckle them
- after traps are checked they should be left closed during the day and not set open again until immediately before the next survey night, to prevent hyperthermia
- trap for a maximum of between three and four consecutive nights to reduce potential recapture.

3.3.10 Capture methods for medium-sized species: cage traps

Cage traps are usually used to capture medium-sized species, but they do not exclude small-sized species and variations are used for large-sized species (for example, rock wallabies – see Section 3.3.11). Cage traps are sometimes referred to as a cat trap or a Mascot trap (constructed by *Mascot Wire Works Pty. Ltd.*). They are collapsible (usually) wire/netting mesh boxes, which have a treadle-operated closing mechanism. Like the Elliott traps, animals are lured into the traps by a bait placed inside, and as they step inside the trap their body weight offsets a treadle-operated door behind them. Cage traps range in size but are generally 200 millimetres high x 200 millimetres wide x 600 millimetres long (Catling et al. 1997). Other dimensions reported in the literature include:

- 200 x 200 x 560 millimetres (used for western quoll (Morris 1992))
- 370 x 130 x 130 millimetres (Bennett 1993)
- 370 x 180 x 150 millimetres (Bennett 1993)
- 360 x 220 x 170 millimetres (Carpararo & Beynon 1996)
- 450 x 450 x 900 millimetres (used for the quokka [Morris 1992]).

The type of bait used to lure a mammal into the trap will depend on the species. The appropriate baits for each of the listed mammals are provided, where relevant, in the individual species profiles.

A form of cage trap is also used to catch rock wallabies, but instead of aluminium, a soft material is used in the construction to prevent the animals injuring themselves. It is also necessary to secure rock wallaby traps to the ground to prevent dislodgment in the often steep and rugged habitats (see Section 3.3.11).

Cage traps are also recommended for some arboreal mammals. The technique and survey effort is described in Section 3.3.9.

Recommended survey method

Outlined below is the recommended survey method and minimum survey effort for cage trapping medium-sized ground-dwelling listed mammals:

- 10 cage traps (or Elliott B traps, see species profiles for details) placed at each sampling site
- traps placed on the ground approximately 50 metres apart in two parallel straight lines (transects) separated by 20–50 metres (a greater distance between traps is recommended in some species profiles)
- one sampling site per representative habitat, with a minimum of two sampling sites required per 5 hectares (replication across habitat types in areas greater than 5 hectares)
- set traps for four consecutive nights



- check traps early in the morning and close during the day
- bait traps with a species specific mixture (see species profiles)
- rebait and open traps in the late afternoon
- consider placing two traps at each trap station to saturate trapping effort if common species are likely to limit the detection of listed mammals
- provide a small amount of nesting material for shelter (for example, shade and warmth).

This survey effort represents a total of 80 trap nights. For areas greater than 5 hectares in area, replication between representative sampling sites will be required and distance between traps increased, but specifications will be dependent on the project and the nature of the subject site.

Animal care and ethics considerations for cage trap surveys

Investigators should check with the relevant animal care and ethics regulator to ensure surveys are consistent with current guidelines. The NSW Department of Primary Industries (www.animaethics.org.au/policies-and-guidelines/wildlife-research/wildlife-surveys) has guidelines addressing animal care and welfare during cage trap surveys, which include:

- provide bedding material for shelter and to prevent hypothermia (for example, Dacron, dry leaf litter)
- place traps in locations where protected from climatic conditions (that is, in the shade under bushes)
- traps placed on slopes or rocky outcrops should be firmly secured to avoid the trap becoming dislodged when an animal is captured
- cover traps with a plastic bag to protect against rain but ensure adequate drainage
- leave exposed traps shut during the day to prevent hyperthermia
- use a species-specific bait (for example, mixture of peanut butter and rolled oats) but do not use meat or meat products
- place enough bait into the trap to supplement the animal's diet from loss of time foraging while trapped
- trapping of species which are known to leave their young in nests should be avoided at the relevant time of the year (if this information is known), because young may die in the event their mother cannot return to suckle them
- after traps are checked they should be left closed during the day and not set open again until immediately before the next survey night
- trap for a maximum of between three and four consecutive nights to reduce potential recapture.

3.3.11 Review of survey techniques for rock wallabies

As the survey techniques employed to detect rock wallaby species are analogous, due to the similarity in habitat utilised by all of the species, a general review of previous studies is presented here which is intended to cover all species rather than providing individual accounts for particular species. The reason that this approach is taken is that whilst numerous studies have been conducted on some species, there is no published information for others and the survey techniques documented for particular species are generally considered applicable for all rock wallaby species.

Rock wallaby species inhabit areas associated with rock boulders, outcrops and escarpments regardless of what part of Australia the species' range occurs in. The habitats are rugged, often remote and are difficult to access, which limits the type of survey technique that can be effectively employed. For all species, the most commonly employed survey technique is searching for signs of activity in suitable habitat. Signs of activity include scats, tracks in sand on rock ledges or along cliff lines, and rock ledges that have been worn smooth from regular use by rock wallabies over time. Signs such as worn rock ledges and scats lying between rock crevices or at the back of caves can exist after a species has become locally extinct. Similarly, rock wallaby remains in caves, in predatory bird nests (for example, Sharp et al. 2002), or casts may also be detected after a species has disappeared from an area.

Surveys for rock wallabies therefore often consider past and present signs of activity. For example, a thorough survey to determine the past and present distribution of the black-flanked rock wallaby was undertaken in the Warburton Region of Western Australia by Pearson (1992). Historical records were obtained through a process of community consultation with local Aboriginal communities and other people who worked in the region since the 1930s, including geologists and dingo trappers. These locations were then visited, often with members of the local Aboriginal community to survey for signs of activity, such as tracks and scats.

A similar approach combining a desktop review and field survey for signs was undertaken for the brush-tailed rock wallaby in the Alpine National Park of New South Wales, the Australian Capital Territory and Victoria (Reside & Martin 1997). The authors emphasised the importance of a thorough desktop survey of previous records, community consultation and aerial photograph interpretation to identify potential brush-tailed rock wallaby habitat sites. They also stressed that ground surveys were essential to 'verify the site as an active or extinct rock wallaby location' (Reside & Martin 1997).

Observations of basking rock wallabies, conducted either from the ground or from the air (for example, in a helicopter or aeroplane), have been used to detect the yellow-footed rock wallaby, *Petrogale xanthopus* and the brush-tailed rock wallaby (Lim et al. 1992; Wong 1994). This technique is likely to be applicable to the other listed rock wallaby species, with the exception of the Proserpine rock wallaby (M Eldridge pers. comm.). Such surveys are best undertaken at dawn or dusk and not during summer or in hot weather (M. Eldridge, pers. comm.). Reside and Martin (1997) warn that whilst helicopters may enable access to remote areas, their use may also frighten wallabies, potentially causing them to fall or be injured. Reside and Martin (1997) suggest that helicopter surveys for suitable survey sites are an appropriate method but ground surveys are preferred for detecting animals.

Thorough daytime searches for signs and habitat resources are considered an adequate form of survey method for detecting the brush-tailed rock wallaby, as long as all suitable rocky habitat including mid-level ledges and holes are inspected for signs of activity (Reside 1988; Wong 1994). Standardised monitoring of the brush-tailed rock wallaby at a number of sites across New South Wales began in 2001 as part of the NSW Fox Threat Abatement Plan (NSW NPWS 2001). This monitoring uses scat plots placed along a transect through a colony to detect changes in the species' abundance over time. The plots are cleared of brush-tailed rock wallaby scats and then checked monthly throughout autumn each year, with the scats in each plot being counted and then cleared each visit. A total of 60 scat plots (1 by 2 metres) are monitored at each colony, and three colonies within each Fox Threat Abatement Plan priority site are monitored. Monitoring the plots takes an experienced investigator approximately five to six hours to complete.

Because of the rugged nature of the terrain, surveys should be conducted by a minimum of two investigators with previous experience with rock wallabies and their terrain. Experience with rock climbing and appropriate safety procedures and training may also be applicable, depending on the nature of the site.



Camera technology has recently been applied during surveys for rock wallabies. Infra-red Moultrie brand camera traps have been used to establish the presence of brush-tailed rock wallabies in an area (D Ashworth pers. comm.). Cameras are often located at a source of water or are baited with lucerne contained within an elevated net bag (to reveal the pouch of any photographed individuals as they reach up for the bait) (D Ashworth pers. comm.). Camera traps are also stationed near the exit points of refuges and known shelter sites (usually identified by the presence of scats). By targeting shelters and runs, the likelihood of detecting wallaby activity is greater than using grids of traps (D Ashworth pers. comm.).

4. SURVEY GUIDELINES FOR NON-FLYING MAMMALS

4.1 Other legislation and animal care and ethics

The welfare of target and other taxa should always be paramount.

Methods that have significant potential to cause disruption or harm to mammals include trapping surveys (which can require a permit under the EPBC Act and local or state government regulations) and broadcast surveys, which should be conducted in a manner that avoids exposing animals to prolonged playback calls. Methods should also be employed in a way that minimises damage to habitat (for example, trampling of vegetation).

Many of Australia's states and territories, as well as some councils and other government organisations, have legislation, guidelines and policies regarding threatened species that are independent of the Commonwealth. This includes lists of threatened mammal species that may differ to those of the Commonwealth. Further, it is important to note that many of the survey techniques described in this document may involve activities that are regulated by individual institutional animal care and ethics procedures, or may be subject to legislative constraints under particular state or Commonwealth laws and regulations.

Licences may be required from the relevant state or territory government authority to carry out surveys, and additional licences may be required to carry out surveys in National Parks, State Forests or other government-owned land. Animal care and ethics approval to conduct surveys may also be required, particularly for techniques that involve the trapping and handling of animals. Removal of indirect evidence such as pellets and feathers may also require a permit from the relevant authority.

Licences must be sought from the relevant state or territory government authority prior to the commencement of a survey, including appropriate animal care and ethics approval. Examples of animal care and ethics guidelines are discussed with the appropriate survey techniques; however, the requirements may vary depending upon the requirements of different legislation, committees or individual approvals. It is incumbent on the investigator to ensure that the animal care and ethics requirements specific to each investigation that involves the survey of non-flying mammals are identified, understood and followed.

Voucher specimens: These survey guidelines do not recommend that specimen collections are made for the purposes of identification, due to the threatened status of the species. Alternatives such as non-lethal tissue biopsies (such as a small plug of ear tissue) could be made after the appropriate state or territory permissions are given.



4.2 Effort

For the purposes of this document, survey effort has been prescribed based on a standard stratified survey design of areas up to 5 hectares in size.

Field surveys designed to detect threatened species require more rigorous design and effort than those used to detect common species. The probability that a species is detected during a survey is dependent on its abundance and distribution. All of the EPBC Act listed species are by the nature of their listing rare, and therefore it is unlikely that enough is known about their ecology, reproduction or habitat use to determine with confidence that any survey method or effort will guarantee a species' detection. This means that even when a threatened species is known to be present at a locality, detection of it may require greater survey effort than what is required to detect a common species.

Survey sites or project areas may range in size from a single to thousands of hectares, and be either relatively uniform or contain a variety of landforms and vegetation types. These guidelines should be used as a guide for modifying survey effort to accommodate different sites. Failing to detect a species at a particular location does not conclusively mean that it does not occur at that location. For this reason, this report is designed for an audience with an understanding of ecology, who will use the guidelines as a basis for devising an appropriate survey design to effectively survey a particular site (regardless of size or nature) or to assess if appropriate survey methods and sufficient survey effort have been undertaken to detect threatened non-flying mammals at a particular site.

For example, a project site of 500 hectares with uniform landform and vegetation composition might only require the same survey effort as a 50 hectare site, provided that sampling sites are chosen across the project site. If however the 500 hectare site contained several distinct vegetation types (rainforest, woodland, riparian) or significant landform types (gorge country, plains, caves) then sampling effort should be increased and stratified to give adequate coverage and representation. When undertaking a survey on a project site significantly larger than 50 hectares you should consider contacting Australian government and state/territory environment departments to discuss the appropriate level of effort.

Some justification of the sampling effort used, in reference to the survey guidelines, would be expected in the report.

4.3 Overview of methods for small sized ground-dwelling mammals

Table 3: Small-sized, ground-dwelling mammals listed on the EPBC Act.

Family	EPBC Act status	Species name	Common name	Average body weight (g)
Croidurine	Endangered	<i>Crocidura attenuata trichura</i>	Christmas Island shrew	5
Notoryctidae	Endangered	<i>Notoryctes caurinus</i>	Northern marsupial mole, karkarratul	~55
	Endangered	<i>Notoryctes typhlops</i>	Southern marsupial mole, yitjarritjarri	55
Burramyidae	Endangered	<i>Burramys parvus</i>	Mountain pygmy possum	56
Dasyuridae	Vulnerable	<i>Sminthopsis butleri</i>	Carpentarian dunnart	15
	Vulnerable	<i>Sminthopsis griseoventer boullangerensis</i>	Boullanger Island dunnart	13
	Endangered	<i>Sminthopsis aitkeni</i>	Kangaroo Island dunnart	23
	Endangered	<i>Sminthopsis psammophila</i>	Sandhill dunnart	35
	Endangered	<i>Sminthopsis douglasi</i>	Julia Creek dunnart	55
	Vulnerable	<i>Pseudantechinus mimulus</i>	Carpentarian antechinus	20
	Endangered	<i>Parantechinus apicalis</i>	Dibbler	70
	Vulnerable	<i>Dasycercus byrnei</i>	Kowari	105
	Vulnerable	<i>Dasycercus cristicauda</i>	Mulgara	115
	Endangered	<i>Dasycercus hillieri</i>	Ampurta	unknown
Muridae	Vulnerable	<i>Pseudomys pilligaensis</i>	Pilliga mouse	11
	Vulnerable	<i>Pseudomys fieldi</i>	Shark Bay mouse, djoongari	46
	Vulnerable	<i>Pseudomys australis</i>	Plains rat	65
	Endangered	<i>Pseudomys fumeus</i>	Smoky mouse, konoom	68
	Vulnerable	<i>Pseudomys shortridgei</i>	Dayang, heath rat	73
	Endangered	<i>Pseudomys oralis</i>	Hastings River mouse	95
	Vulnerable	<i>Notomys aquilo</i>	Northern hopping mouse	39
	Vulnerable	<i>Notomys fuscus</i>	Dusky hopping mouse, wilkiniti	46
	Vulnerable	<i>Xeromys myoides</i>	False water rat	41
	Endangered	<i>Zyzomys pedunculatus</i>	Central rock rat	85
	Endangered	<i>Zyzomys palatalis</i>	Carpentarian rock rat	130
	Endangered	<i>Melomys rubicola</i>	Bramble Cay melomys	~100
	Vulnerable	<i>Leporillus conditor*</i>	Greater stick-nest rat, wopilkara	350
	Vulnerable	<i>Zyzomys maini</i>	Arnhem Land rock rat	94

*The greater stick-nest rat weighs on average more than 300 grams.



The survey techniques used to detect small-sized ground-dwelling species are similar regardless of the habitat the species comes from. Following the desktop study and habitat investigation (see 'conducting surveys in six steps'), implementation of surveys should be according to a stratified sampling design. Where possible, survey effort should target habitat known to be suitable for listed species (if such information is available; see individual species profiles). The recommended survey effort is based on a study area of 5 hectares or less; for sites larger than this, surveys should be replicated within habitat types and/or plant communities.

The following survey techniques are currently used or appropriate to detect small-sized ground-dwelling mammals in the field:

- daytime searches for the presence of potentially suitable habitat resources for nests or burrows such as spinifex hummocks, boulders, crevices in the ground or between rocks (see species profiles for details). Description of the survey technique and recommended effort is outlined in Section 3.1
- daytime searches for signs of the species' presence such as tracks, nests, burrows or scats (description of the survey technique and recommended effort is described in Section 3.2.)
- collection of predator scats, owl casts or remains, targeting predatory bird or mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- pitfall trap surveys (description of the survey technique and recommended effort is outlined in Section 3.3.8)
- hair sampling device surveys (description of the survey technique and recommended effort is outlined in Section 3.3.7)
- Elliott A trapping surveys (small mammal box traps) (description of the survey technique and recommended effort is outlined in Section 3.3.9).

4.4 Overview of methods for arboreal mammals

Table 4: Arboreal mammals listed on the EPBC Act.

Family	EPBC Act	Species	Common name	Average body weight (g)
Petauridae	Endangered	<i>Gymnobelideus leadbeateri</i>	Leadbeater's possum	122–133
	Endangered	<i>Petaurus gracilis</i>	Mahogany glider	365–407
	Vulnerable	<i>Petaurus australis</i> unnamed subsp.	Fluffy glider	498
Pseudocheiridae	Vulnerable	<i>Pseudocheirus occidentalis</i>	Western ringtail possum	575
Muridae	Vulnerable	<i>Mesembriomys macrurus</i>	Golden-backed tree rat	267
Dasyuridae	Endangered	<i>Phascogale calura</i>	Red-tailed phascogale	52

The survey techniques used to detect small and medium-sized arboreal species are similar regardless of habitat. Following the desktop study and habitat investigation (see 'conducting surveys in six steps'), implementation of surveys should be according to a stratified sampling design. Where possible, survey effort should target habitat known to be suitable for listed species (if such information is available; see individual species profiles). The recommended survey effort is based on a study area of 5 hectares or less; for sites larger than this, surveys should be replicated within habitat types and/or plant communities.

The following survey techniques are currently used or appropriate to detect small and medium-sized arboreal mammals in the field:

- daytime searches for the presence of potentially suitable habitat resources for nest or den sites, such as tree hollows, dreys or tree species used exclusively as shelter sites by some species (see species profiles for details), and food trees, including characteristic feeding signs and/or favoured food trees (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of the species' presence, such as scratches on tree trunks and scats beneath trees (description of the survey technique and recommended effort is outlined in Section 3.2)
- stagwatching to distinguish arboreal species emerging from tree hollows or nests at dusk, with this being the primary detection technique for some species (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- spotlight surveys in suitable vegetation types for the presence of active or vocalising individuals at night (description of the survey technique and recommended effort is outlined in Section 3.3.3)
- call detection and/or call playback surveys for vocal species, in addition to playback of the calls of owl predators that are known to induce a call response (description of the survey technique and recommended effort is outlined in Section 3.3.3)



- arboreal Elliott B or cage trapping surveys to determine the presence, and to distinguish between similar arboreal species (description of the survey technique and recommended effort is outlined in Section 3.3.9)
- longer timeframe studies could consider using nest boxes, particularly for Leadbeater's possum.

These survey methods are widely prescribed in the state and territory guideline documents reviewed (see appendix) and have been developed and informed by the results of research. A description of these survey techniques and the recommended minimum effort for a subject site up to 5 hectares in size is outlined in the species profiles.

4.5 Overview of methods for medium-sized ground-dwelling species

Table 5: Medium-sized ground-dwelling mammals listed under the EPBC Act.

Family	EPBC Act status	Species name	Common name	Average body weight (g)
Peramelidae	Endangered	<i>Perameles bougainville bougainville</i>	Western barred bandicoot (Shark Bay)	226
	Vulnerable	<i>Isoodon auratus auratus</i>	Golden bandicoot (mainland)	310
	Vulnerable	<i>Isoodon auratus barrowensis</i>	Golden bandicoot (Barrow Island)	310
	Endangered	<i>Isoodon obesulus obesulus</i>	Southern brown bandicoot	775
	Vulnerable	<i>Isoodon obesulus nauticus</i>	Southern brown bandicoot (Nyuts Archipelago)	775
	Vulnerable	<i>Perameles gunnii gunnii</i>	Eastern barred bandicoot (Tas.)	800
	Endangered	<i>Perameles gunnii</i> unnamed subsp.	Eastern barred bandicoot (mainland)	975
	Vulnerable	<i>Macrotis lagotis</i>	Greater bilby	1350
Dasyuridae	Vulnerable	<i>Myrmecobius fasciatus</i>	Numbat	472
Potoroidae	Endangered	<i>Potorous gilbertii</i>	Gilbert's potoroo	875
	Endangered	<i>Potorous longipes</i>	Long-footed potoroo	1900
	Vulnerable	<i>Potorous tridactylus tridactylus</i>	Long-nosed potoroo (SE mainland)	1100
	Endangered	<i>Bettongia tropica</i>	Northern bettong	1200
	Vulnerable	<i>Bettongia lesueur lesueur</i>	Boodie, burrowing bettong (Shark Bay)	1500
	Vulnerable	<i>Bettongia lesueur</i> unnamed subsp.	Boodie, burrowing bettong (Barrow and Boodie Island)	~1500
	Extinct	<i>Bettongia lesueur graii</i>	Boodie (inland subspecies)	
	Endangered	<i>Bettongia penicillata ogilbyi</i>	Woylie	1300
Macropodidae	Endangered	<i>Lagorchestes hirsutus</i> unnamed subsp.	Rufous hare wallaby (central mainland), mala	1255
	Vulnerable	<i>Lagorchestes hirsutus bernieri</i>	Rufous hare wallaby (Bernier Island)	1620
	Vulnerable	<i>Lagorchestes hirsutus dorrae</i>	Rufous hare wallaby (Dorre Island)	1660
	Vulnerable	<i>Lagorchestes conspicillatus conspicillatus</i>	Spectacled hare wallaby (Barrow Island)	3050
	Vulnerable	<i>Lagostrophus fasciatus fasciatus</i>	Banded hare wallaby	1700



The survey techniques used to detect medium-sized ground-dwelling species are similar regardless of the habitat. Following the desktop study and habitat investigation (see 'conducting surveys in six steps'), implementation of surveys should be according to a stratified sampling design. Where possible, survey effort should target habitat known to be suitable for listed species (if such information is available; see individual species profiles). The recommended survey effort is based on a study area of 5 hectares or less; for sites larger than this, surveys should be replicated within habitat types and/or plant communities.

The following survey techniques are currently used or appropriate to detect medium-sized ground-dwelling mammals in the field:

- daytime searches for the presence of potentially suitable habitat resources for nests or burrows such as a dense understorey, hollow logs, grass hummocks and boulder or rock outcrops (see species profiles for details). Description of the survey technique and recommended effort is outlined in Section 3.1
- daytime searches for signs of the species' presence such as tracks, nests, burrows, scats or diggings (the survey technique is described in Section 3.2.)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted on foot through suitable habitat (description of the survey technique and recommended effort is provided in Section 3.3.3)
- hair sampling device surveys (description of the survey technique and recommended effort is outlined in Section 3.3.7)
- Elliott B or cage trapping surveys (description of the survey technique and recommended effort is outlined in Section 3.3.9 and 3.3.10)
- camera traps (description of the survey technique is outlined in Section 3.3.6)
- nest boxes (description of the survey technique is outlined in Section 3.3.6).

Other than camera traps and nest boxes, these survey methods are widely prescribed in the state and territory guideline documents reviewed (see appendix) and have been developed and informed by the results of research. A description of these survey techniques and the recommended minimum effort for a subject site up to 5 hectares is outlined in the species profiles.

4.6 Overview of methods for large-sized ground-dwelling mammals

Table 6: Large-sized ground-dwelling mammals listed on the EPBC Act.

Family	EPBC Act Status	Species name	Common name	Average body weight (kg)
Vombatidae	Vulnerable	<i>Vombatus ursinus ursinus</i>	Common wombat (Bass Strait)	19–32
	Endangered	<i>Lasiorhinus krefftii</i>	Northern hairy-nosed wombat	32.5 (females) 30.1 (males)
Macropodidae	Vulnerable	<i>Macropus robustus isabellinus</i>	Barrow Island euro	Up to 25 (females) 46 (males)
	Vulnerable	<i>Setonix brachyurus</i>	Quokka	2.9 (females) 3.6 (males)
	Vulnerable	<i>Petrogale lateralis lateralis</i>	Black-flanked rock wallaby	3.5 (females) 4.5 (males)
	Vulnerable	<i>Petrogale lateralis</i>	Black-footed rock wallaby (West Kimberley)	3.5
	Vulnerable	<i>Petrogale lateralis</i>	Black-footed rock wallaby (Macdonnell Ranges race), waru	4.1
	Vulnerable	<i>Petrogale lateralis hackettii</i>	Recherche rock wallaby	5
	Vulnerable	<i>Petrogale penicillata</i>	Brush-tailed rock wallaby	6.3 (females) 7.9 (males)
	Endangered	<i>Petrogale persephone</i>	Proserpine rock wallaby	5.2 (females) 7.2 (males)
	Vulnerable	<i>Petrogale xanthopus xanthopus</i>	Yellow-footed rock wallaby	6–11
	Endangered	<i>Onychogalea fraenata</i>	Bridled nailtail wallaby	4–5 (females) 5–8 (males)
	Extinct	<i>Macropus eugenii eugenii</i>	Tammar wallaby	7
Dasyuridae	Vulnerable	<i>Dasyurus geoffroyi</i> *	Chuditch, western quoll	0.89 females) 1.31 (males)
	Endangered	<i>Dasyurus maculatus gracilis</i>	Spotted-tailed quoll (north Queensland), yarri	Up to 4.0 (females) 7.0 (males)
	Vulnerable	<i>Dasyurus maculatus maculatus</i>	Spotted-tailed quoll (mainland and Tasmania)	Up to 4.0 (females) 7.0 (males)
	Endangered	<i>Dasyurus hallucatus</i> *	Northern quoll	Up to 0.69 (females) 1.12 (males)
	Endangered	<i>Sarcophilus harrisii</i>	Tasmanian devil	6.0 (females) 8.0 (males)



*The chuditch *Dasyurus geoffroii* and the northern quoll *Dasyurus hallucatus* are grouped here among the large-sized mammals; however, their average body weight is less than the 3 kilogram cut-off point otherwise used to class large-sized species.

The survey techniques used to detect large-sized ground-dwelling species are similar regardless of habitat. Following the desktop study and habitat investigation (see 'conducting surveys in six steps'), implementation of surveys should be according to a stratified sampling design. Where possible, survey effort should target habitat known to be suitable for listed species (if such information is available; see individual species profiles). The recommended survey effort is based on a study area of 5 hectares or less; for sites larger than this, surveys should be replicated within habitat types and/or plant communities.

The following survey techniques are currently used or appropriate to detect large-sized ground-dwelling mammals in the field:

- daytime searches for the presence of potentially suitable habitat resources for nests or burrows, such as a dense understorey, hollow logs, grass hummocks and boulder or rock outcrops (see species profiles for details). Description of the survey technique and recommended effort is outlined in Section 3.1
- daytime searches for signs of the species' presence such as tracks, scats, dens or scrapes (The survey technique is described in Section 3.2), collecting predator scats for species identification if required
- daytime searches for active fauna conducted either on foot or from a vehicle according to the effort recommended in Section 3.3.1
- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Sections 3.2.2 and 3.2.3)
- observations conducted at potential shelter sites, such as a burrow or a hollow log (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted on foot through suitable habitat (description of the survey technique and recommended effort is provided in Section 3.3.3)
- hair sampling device surveys (description of the survey technique and recommended effort is outlined in Section 3.3.7)
- depending on the species, cage trapping surveys are sometimes recommended (description of the survey technique and recommended effort is outlined in Section 3.3.10)
- camera traps (see Section 3.3.6).

These survey methods are widely prescribed in the state and territory guideline documents reviewed (see appendix) and have been developed and informed by the results of research. A description of these survey techniques and the recommended minimum effort for a subject site up to 5 hectares in size is outlined in the species profiles.

5. SPECIES SURVEY GUIDELINES

Ampurta

Dasycercus hillieri

Note that in a recent revision of the *Dasycercus* based on genetic and morphological grounds this species is indistinguishable from the crest-tailed mulgara *D. cristicauda* and has therefore been lumped with that species (Woolley 2005; Masters 2008). Under the EPBC Act this latest taxonomic change has not been formally recognised. Therefore, this species profile incorporates the former *D. hillieri* component of *D. cristicauda*.

States and territories: Queensland, Northern Territory and South Australia.

Regions: Eastern Simpson Desert.

Habitat: Hummock grass plains, sand ridges and mulga shrubland.

Habit: Ground-dwelling (burrows).

Avg. body weight: Unknown, but probably similar to Mulgara (~115 g) (Woolley 1995).

Activity pattern: Nocturnal.

Diet: Carnivorous: large invertebrates and small vertebrates.

Breeding: Unknown.

Description

Recent taxonomic work has suggested *Dasycercus hillieri* should not be recognised as a distinct form of *Dasycercus cristicauda* (Woolley 2005). However, for the purposes of this document we consider them as distinct species.

The species excavates burrows within which it shelters during the day. Burrows are found aggregated in complexes that can cover up to a kilometre of suitable habitat. The burrows are constructed under the raised mound of a dead spinifex hummock, and have a number of entrances, with between six to ten pop-holes located around the periphery of the raised mound (C Dickman pers. comm.). When the burrows are active, scoops of sand are seen at the pop-hole entrances and scats will also be scattered randomly around the area, including near the burrow entrances (C Dickman pers. comm.).

There is evidence that the ampurta breeds seasonally and may have other seasonal activity patterns. Females with pouch young have been captured between September and October, and lactating females without pouch-young have been captured in November (Dickman et al. 2001). If young become independent after November, then their recruitment into the population at that time may explain why capture rates have tended to be higher in summer in two studies (Masters 1998, Dickman et al. 2001).



The ampurta appears to be a sedentary species, with relatively small ranges compared to other Dasyurids. Individuals are capable of storing fat in their tails and of entering torpor, strategies that may enable them to survive within an environment of temporally unpredictable resources (Dickman et al. 2001). Another feature of their biology that demonstrates their flexibility to an unpredictable environment is their opportunistic breeding, with mulgara population increases recorded after rain, presumably in response to an increased availability of prey (Dickman et al. 2001).

Threatening processes are unclear, but are thought to include changes in fire regimes, introduced predators and grazing by introduced herbivores causing a reduction in available cover for prey items (Pavey and Cole 2002).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the ampurta in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs including burrows, pop-holes, particularly those with freshly excavated earth, tracks and scats (description of the survey technique and recommended effort is provided in Section 3.2). Note that identification of these indirect signs needs to be confirmed by an expert (for example, through the provision of digital photographs)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- possibly a hair sampling device survey as the mulgara are included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A trapping surveys using a mixture of rolled oats, peanut butter and tuna oil for bait, and conducted according to the technique and the recommended effort described in Section 3.3.9. However, this survey technique may not be effective in the Simpson Desert or at other sites yet identified, and should not be used on its own
- pitfall trapping surveys (with trap depth recommended to be 60 centimetres) conducted according to the technique and recommended effort described in Section 3.3.8., but with double the survey effort (that is, use four instead of two sampling sites within a five hectare area) if the survey is not conducted in conjunction with Elliott trapping
- spotlighting for active individuals on foot or from a moving vehicle, particularly at times when densities are higher following several consecutive good seasons
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- consider the placement of baited camera traps (same as for predator pads) in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric species (description of technique in Section 3.3.6).

While not previously reported to have been used to detect the ampurta, it may be worthwhile trialling the kowari predator pads (Brandle et al. 2002) (see kowari species profile), especially if the investigator believes the species is present but cannot confirm their presence through trapping techniques.

Similar species in range

The species is either sympatric or parapatric with the mulgara but this remains unclear (C Dickman pers. comm.). The two species are likely to be indistinguishable in the field and so hair or tissue samples should be considered for identification and/or molecular analysis, provided that the appropriate permission and licensing has been granted by the relevant state or territory government organisations. The only other similar species is the kowari, which can be distinguished from the ampurta by its lighter colour and the presence of black, denser tail fur on the tail tip and white fur at the base of the tail.

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Arnhem Land rock rat

Zyzomys maini

States and territories: Northern Territory.

Regions: Localised in Kakadu National Park and other locations in the sandstone massif of western Arnhem Land, Top End of the Northern Territory.

Habitat: The primary habitat is patches of floristically-rich monsoon rainforest with thick leaf litter often where there is seepage amongst boulders on steep slopes at the base of cliff lines and boulder beds of gorges within the Arnhem Land Plateau (Woinarski & Fleming 2008). Typically it occurs in terrain where there are many caves, crevices or boulders and may also be found in adjacent habitats such as sandstone heathlands and hummock grasslands (Woinarski et al. 1992). However, it is absent from many monsoon rainforest patches due various factors, including a lack of suitable food trees, absence of rocky habitat or possibly as a result of unknown interrelationships with adjoining habitats that may form important secondary habitat. The Arnhem Land rock rat also occurs in the wetter, more heavily vegetated parts of sandstone areas with scattered eucalypts (Woinarski & Fleming 2008).

Habit: Ground-dwelling (possibly shelters in rock crevices).

Avg. body weight: 94 g (Woinarski & Fleming 2008).

Activity pattern: Nocturnal.

Diet: Predominantly feeds on the seeds of various species of rainforest trees and perennial grasses (Begg & Dunlop 1980). Larger hard-shelled seeds are collected on the ground and carried to crevices in rocks where they are consumed (Begg & Dunlop 1980).

Breeding: Breeds throughout the year, with a peak of pregnant and lactating females between March and May (Begg 1981a). Litters comprise two or three young and most females only breed once per year (Begg 1981a). Reproductive output is reduced for at least a year following fire (Begg et al. 1981).

Description

The Arnhem Land rock rat was formerly considered to belong to the same species as the Kimberley rock rat *Zyzomys woodwardi* until a taxonomic revision recognised the Arnhem Land rock rat as a separate species (Kitchener 1989). It is one of three species of large rock rats that occur in the monsoonal tropics of northern Australia, with this species confined to the Arnhem Land Plateau of the Northern Territory. The extent of occurrence is unknown and within its range the species appears to be highly fragmented and very patchily distributed (Woinarski 2000). This distribution pattern is partly a result of its preferred monsoon rainforest habitat being patchy (Russell-Smith et al. 1993) and the topographic complexity of the deeply dissected western Arnhem Land Plateau. Even within patches of its preferred habitat this species may be absent. Within its patchy distribution, it occurs in sub-populations with very little genetic exchange between locations (Woinarski 2006). Long-term monitoring indicates that this species has significantly declined by as much as 83 per cent in some areas, which may be related to the increasing incidence of broad-scale 'hot' fires on the Arnhem Land Plateau (Woinarski et al. 2002; Watson & Woinarski 2003, 2004).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Arnhem Land rock rat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as rock overhangs, crevices and boulders with a floristically-diverse monsoon overstorey and dense leaf litter cover (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- daytime searches for signs, particularly of partially chewed seed husks under rock crevices, overhangs and boulders (description of the survey technique and recommended effort is provided in Section 3.2)
- Elliott A trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.8. However, *Zyomys* species are particularly susceptible to tail stripping when trapped, and should be handled with care. Such surveys could also be conducted with a combination of cage (description of the survey technique and recommended effort is provided in Section 3.2) and Elliott traps, and
- placement of baited camera traps (same as for predator pads) in suitable habitat, particularly in remote locations (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Similar species in range

The Arnhem Land rock rat overlaps in range with the common rock rat *Zyomys argurus* from which it can be distinguished by its larger size (the average weight of the common rock rat is 36 g [Fleming 2008]); the tail length, which is about the same as head body length rather than noticeably longer (average 146 millimetres in *Z. maini* compared to 108 millimetres in *Z. argurus*); denser fur; more extensive occurrence of long hairs on the tail; colour (more grey than brown); and, where the two species occur in sympatry, the Arnhem Land rock rat primarily occurs in the wetter, more heavily vegetated terrain (Woinarski & Fleming 2008).

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Banded hare wallaby

Lagostrophus fasciatus fasciatus

States and territories: Western Australia.

Regions: Bernier and Dorre Islands, Shark Bay.

Habitat: Dense *Acacia ligulata* scrub or other low and spreading shrubs (Prince 1995).

Habit: Ground-dwelling.

Avg. body weight: 1700 g (Prince 2008).

Activity pattern: Nocturnal.

Diet: Herbivore: grasses, shrubs and forbs (Prince 2008).

Breeding: Births have been recorded throughout the year, with a decline in frequency of births during the latter half of the year (Richards et al. 2001). Females produce between one and two young per year (Richards et al. 2001).

Description

The banded hare wallaby is the last species in the Sthenurinae subfamily, and has a range restricted to Bernier and Dorre Islands in Shark Bay (Prince 1995). It is a small macropod, with distinctive transverse bands marking the fur on its rump.

The banded hare wallaby overlaps in distribution with the rufous hare wallaby *Lagorchestes hirsutus* but the species tend to have spatially disjunct distributions, with the banded hare wallaby preferring dense *Acacia* species habitats, whereas the rufous hare wallaby is found in association with grasslands (Prince 2008). Within the acacia thickets, banded hare wallabies shelter within dense understorey vegetation during the day, but they forage in more open grassland habitats at night, making runways in the dense vegetation from regular movement patterns (Prince 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the banded hare wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes dense *Acacia* species habitats (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including runways, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2). Tracks may be indistinguishable from other wallaby species present on Bernier Island
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2).

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:



- observations conducted at dusk and early night at potential resource sites such as watering points according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- possibly cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10, using a mixture of fruit, peanut butter and rolled oats for bait.

The survey method recommended has been designed for surveys on Dorre and Bernier Islands where the banded hare wallaby is known to exist. Should surveys be required on the mainland then further expert advice should be sought from the relevant government authorities in Western Australia. Any signs of this species on the mainland should be reported immediately to the appropriate government authorities.

Similar species in range

On Dorre and Bernier Islands, there are a number of other macropodoidea species including the rufous hare wallaby and the burrowing bettong *Bettongia lesueur lesueur*, which may overlap in distribution with the banded hare wallaby.

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Barrow Island euro

Macropus robustus isabellinus

States and territories: Western Australia.

Regions: Barrow Island.

Habitat: Deeply dissected, rugged, terrain featuring caves, watercourses and rocky ledges (Poole 1995; Short & Turner 1991).

Habit: Ground-dwelling.

Avg. body weight: Between 6.25–25 kg (females) and 7.25–46.5 kg (males) (Poole 1995).

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: mainly grasses.

Breeding: Females are probably capable of breeding all year and give birth to one offspring at a time (Poole 1995).

Description

The Barrow Island euro is one of four *Macropus robustus* subspecies, which has a range restricted to Barrow Island off the western coast of Western Australia. Other *M. robustus* subspecies have a widespread distribution and occur across most of mainland Australia, excluding southern Australia and the Cape York Peninsula. On Barrow Island, the euro prefers recently burned patches of *Triodia* and the lack of free water on the island may constrain its population there (Short & Turner 1991). Euros are preferential grazers (over 90 per cent of their diet comprises grasses) (Clancy & Croft 2008) and on Barrow Island, floodout flats where grasses other than *Triodia* occur are an important resource (Short & Turner 1991).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Barrow Island euro in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas of open eucalypt forest, woodland and brigalow scrub (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats and scrapes in the shade of trees, under large shrubs or under rock overhangs (description of the survey technique and recommended effort is outlined in Section 3.2)
- diurnal surveys for resting wallabies, conducted according to the description of the survey technique and effort recommended in Section 3.3.1
- observations conducted at water points according to the technique and recommended effort provided in Section 3.3.4
- baited camera traps may be of use in confirming the presence and identity of wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)



- spotlight surveys conducted either on foot or from a vehicle according to the description of the survey technique and effort recommended in Section 3.3.3.

Capture techniques are not considered necessary to determine if the Barrow Island euro is present on a subject site.

Similar species in range

The Barrow Island euro occurs in sympatry with the smaller and distinctively marked black-footed rock wallaby *Petrogale lateralis*. Euros are distinguished by a naked rhinarium and, in this species, large rounded ears (Croft 1981). The scats of these two macropod species also differ in size and shape: Barrow Island euro scats are larger and squarer compared to the smaller and more elongated black-footed rock wallaby scats.

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Black-flanked rock wallaby

Petrogale lateralis lateralis

States and territories: Western Australia.

Regions: North-west Cape, Barrow Island, Salisbury Island, Calvert Ranges in the Little Sandy Desert and remnant and reintroduced populations in the wheatbelt (south-west Western Australia) (Eldridge & Pearson 2008).

Habitat: Rock boulders, escarpments and cliff-lines.

Habit: Ground-dwelling.

Avg. body weight: 4500 g (males) and 3500 g (females) (Eldridge & Pearson 2008).

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: grasses, shrubs and forbs.

Breeding: Unknown.

Description

Taxonomy within *Petrogale* has been investigated over the past decade through a number of morphological, chromosomal and molecular genetic studies (see Eldridge et al. 2001; Campeau-Peloquin et al. 2001 for summaries). It is believed that this genus has undergone recent and rapid radiation (Eldridge & Close 1997). These survey guidelines follow the taxonomy used in Eldridge and Pearson (2008), which recognises:

- *P. l. lateralis*;
- *P. l. hacketti*;
- *P. l. pearsoni*;
- the West Kimberley race; and
- the MacDonnell Ranges race.

Like all rock wallabies, the black-flanked rock wallaby inhabits areas associated with boulder outcrops and escarpments, and shelters in caves, on rock ledges and among boulders during the day. Shelter sites form an essential part of a rock wallaby's home range, but animals forage away from their shelter sites during the night (usually at only a short distance, but for many species the distance is unknown). All rock wallabies are herbivores that feed on grasses, forbs and shrubs (Eldridge & Pearson 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the black-flanked rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelter sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)



- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11). However, where the black-flanked rock wallaby occurs in sympatry with Rothschild's rock wallaby, *Petrogale rothschildi* (Hamersley range region of Western Australia), scats may need to be collected and analysed using either genetic techniques to distinguish between species. Scats should be collected from across the entire area from searches conducted during the day. For example, the technique used by Alacs and colleagues (2003) for analysis of quokka scats was collection of fresh pellets (less than one day old) which were then frozen at –20 degrees celsius until DNA extraction. However, further advice should be sought from an expert regarding the collection process, prior to the commencement of any field work
- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- use of baited camera traps (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat or possibly from a helicopter according to a suggested survey technique and effort provided in Section 3.3.11 (heeding caution to minimise disturbance to animals to ensure wallabies do not fall).

The taxonomy of *P. lateralis*, like some other rock wallaby species, is not completely resolved. However, the known distribution of *P. lateralis* (see Eldridge & Pearson 2008) does not overlap with other species, with the exception of a possible overlap between *P. l. lateralis* and *P. rothschildi* in the Hamersley Range region of Western Australia. As all *P. lateralis* subspecies are listed on the EPBC Act (1999), surveys designed to detect the presence of *P. lateralis* from a subject site need not conduct cage trapping surveys. Survey effort instead should focus on detecting signs in suitable habitat. Should confirmation of the species identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Section 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

The known distribution of *P. lateralis* (see Eldridge & Pearson 2008) does not overlap with other species, with the exception of possible overlap between *P. l. lateralis* and *P. rothschildi* in the Hamersley Range region of Western Australia. *Petrogale rothschildi* is distinguished from *P. l. lateralis* by its shorter and uniformly brown ears, absence of a side-stripe and occasional purple colouration around the shoulders (Pearson & Eldridge 2008).

References

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Black-footed rock wallaby (MacDonnell Ranges), warru

Petrogale lateralis

States and territories: Northern Territory, South Australia and Western Australia.

Regions: Central Australia.

Habitat: Rock boulders, escarpments and cliff-lines.

Habit: Ground-dwelling.

Avg. body weight: 4100 g (Eldridge & Pearson 2008).

Activity pattern: Diurnal/nocturnal.

Diet: Herbivore: grasses, shrubs and forbs.

Breeding: Unknown.

Description

Taxonomy within *Petrogale* has been investigated over the past decade through a number of morphological, chromosomal and molecular genetic studies (see Eldridge et al. 2001; Campeau-Peloquin et al. 2001 for summaries). It is believed that this genus has undergone recent and rapid radiation (Eldridge & Close 1997). We have followed the taxonomy used in Eldridge and Pearson (2008), which recognises:

- *P. l. lateralis*
- *P. l. hacketti*
- *P. l. pearsoni*
- the West Kimberley race, and
- the MacDonnell Ranges race.

The MacDonnell Ranges black-footed rock wallaby race, as its name implies, has a distribution restricted to the MacDonnell Ranges, which occur primarily in the Northern Territory but also Western Australia and South Australia (Eldridge & Pearson 2008). Like all rock wallabies, it inhabits areas associated with boulder outcrops and escarpments and shelters in caves, on rock ledges and among boulders during the day (Eldridge & Pearson 2008). Shelter sites form an essential part of a rock wallaby's home range, but animals forage away from their shelter sites during the night (usually at only a short distance but for many species the distance is unknown). All rock wallabies are herbivores that feed on grasses, forbs and shrubs (Eldridge & Pearson 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the MacDonnell Ranges black-footed rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelter sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)

- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- Baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat or possibly from a helicopter according to a suggested survey technique and effort provided in Section 3.3.11 (heeding caution to minimise disturbance to animals so as to ensure wallabies do not fall).

The known range of the MacDonnell Ranges black-footed rock wallaby is restricted to the MacDonnell Ranges (see Eldridge & Pearson 2008) and does not overlap in distribution with other rock wallaby species. Should confirmation of the species identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Section 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

No other rock wallaby species are known to occur in the restricted range of the MacDonnell Ranges black-footed rock wallaby.

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Black-footed rock wallaby (west Kimberley race)

Petrogale lateralis

States and territories: Western Australia.

Regions: Edgar Range, West Kimberley district, south of the Fitzroy River (Eldridge & Pearson 2008).

Habitat: Rock boulders, escarpments and cliff-lines.

Habit: Ground-dwelling.

Avg. body weight: 3500 g (Eldridge & Pearson 2008).

Activity pattern: Diurnal/nocturnal.

Diet: Herbivore: grasses, shrubs and forbs.

Breeding: Unknown.

Description

Taxonomy within *Petrogale* has been investigated over the past decade through a number of morphological, chromosomal and molecular genetic studies (see Eldridge et al. 2001; Campeau-Peloquin et al. 2001 for summaries). It is believed that this genus has undergone recent and rapid radiation (Eldridge & Close 1997). These survey guidelines follow the taxonomy used in Eldridge and Pearson (2008), which recognises:

- *P. l. lateralis*;
- *P. l. hacketti*
- *P. l. pearsoni*
- the West Kimberley race, and
- the MacDonnell Ranges race.

The west Kimberley race, as its name implies, has a distribution in the Kimberley region of Western Australia (Eldridge & Pearson 2008). The race is similar to the *P. l. hackettii* subspecies from the Recherche Archipelago in Western Australia, in that it only has ten pairs of chromosomes (Eldridge et al. 1991). However, the subspecies *P. l. lateralis* has a distribution that lies between the west Kimberley race and that of *P. l. hacketti*.

Like all rock wallabies, the west Kimberley black-footed rock wallaby inhabits areas associated with boulder outcrops and escarpments and shelters in caves, on rock ledges and among boulders during the day (Eldridge & Pearson 2008). Shelter sites form an essential part of a rock wallaby's home range, but animals forage away from their shelter sites during the night (usually at only a short distance but for many species the distance is unknown). All rock wallabies are herbivores that feed on grasses, forbs and shrubs (Eldridge & Pearson 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the west Kimberley black-footed rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelters sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- possibly the collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- Baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat or possibly from a helicopter according to a suggested survey technique and effort provided in Section 3.3.10 (heeding caution to minimise disturbance to animals to ensure wallabies do not fall).

The known range of the west Kimberley black-footed rock wallaby is restricted to the western Kimberley (see Eldridge & Pearson 2008) and does not overlap in distribution with other rock wallaby species. Should confirmation of the species identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Section 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

No other rock wallaby species are known to occur in the restricted range of the west Kimberley black-footed rock wallaby.

References

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Boodie, burrowing bettong (Barrow and Boodie Island)

Bettongia lesueur unnamed subsp.

States and territories: Western Australia.

Regions: Boodie and Barrow Islands, off the Pilbara coast.

Habitat: On Barrow Island, burrows are almost always associated with limestone cap-rock on slopes and the top of ridges; some are in the floor of caves (Burbidge & Short 2008).

Habit: Ground-dwelling (burrows).

Avg. body weight: 680 g (Burbidge 1995).

Activity pattern: Nocturnal.

Diet: Herbivore: tubers, seeds, nuts and plants.

Breeding: Undescribed for Boodie and Barrow Islands.

Description

The burrowing bettong's range previously covered much of arid western and central Australia, but it is now restricted to Dorre and Bernier Islands in Shark Bay and Boodie and Barrow Islands off the Western Australian coast (Short & Turner 1993). The Shark Bay subspecies of burrowing bettongs from Dorre Island were re-introduced to a fenced, predator-free mainland site, Heirisson Prong in Shark Bay (Sander et al. 1997). Pizzuto and colleagues (2007) found that a reintroduced population of burrowing bettong in western NSW selected microhabitats with up to 25 per cent canopy cover, one to two centimetres deep litter and open structure at ground level for nocturnal foraging and other activities.

The burrowing bettong is nocturnal and gregarious (Burbidge 1995). The only burrowing macropod to regularly shelter underground, they dig burrows that range from a simple structure with one or two entrances and short, shallow tunnels, to complex, interconnected warrens (Burbidge 1995). On Barrow Island, warrens with up to 90 entrances have been recorded (Sander et al. 1997). Local soil type constrains burrow complexity, and sandy soils usually support only simple burrows (Ride et al. 1962). The burrowing activities of this species created and maintained surface soil heterogeneity and influenced the composition of the plant communities in arid regions, and despite local extinction of this species across much of Australia, relict warrens still exert an impact on floral diversity and productivity (Noble et al. 2007).

Survey methods

A Wayne (Western Australian DEC, 2009) noted the importance of minimising disturbance to bettongs during trapping programs because of their tendency to reject pouch young when stressed. Passive means of detecting this species, like baited camera traps, are preferable in situations where trapping is not necessary. If trapping is necessary animal handling should be undertaken with caution.

The following survey techniques are recommended to detect the presence of the burrowing bettong in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes a wide range of habitat types within the islands of the species known range (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including burrows, diggings, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2).
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2.

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:

- observations conducted at dusk/early night at burrow entrances according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10, using a mixture of peanut butter, rolled oats, sardines or bacon for bait. A fence trapping system, similar to that devised for the bilby *Macrotis lagotis* by Southgate and colleagues (1995) and Gibson and Hume (2000) may also be appropriate (see the species profile for the bilby) for capturing the burrowing bettong as individuals emerge from their burrows
- camera traps baited with universal bait and added almond, walnut or truffle oil (see potoroo profiles for further information) are likely to prove useful for positively identifying and minimising impact on animals and are also cost-effective (description of the survey technique and recommended effort is outlined in Section 3.3.6).

The burrowing bettong is not distinguishable from hair samples (see Table 2, Section 3.3.6). Should this situation change, then hair sampling may provide an appropriate alternative detection technique, however this method should be used only as part of an integrative approach utilising other methods like baited camera traps.

The survey method recommended has been designed for surveys of areas within the burrowing bettong's known range. Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities. Any signs of the burrowing bettong on the mainland should be reported immediately to the Western Australian DEC or other relevant government authorities.

Similar species in range

There are no other bettongs on the islands; however, a number of other macropodoidea species occur on Barrow Island and their tracks may be indistinguishable from those made by the burrowing bettong, particularly if made by smaller-sized juveniles. The wallaby and kangaroo species include the spectacled hare wallaby *Lagorchestes conspicillatus conspicillatus*, the black-flanked rock wallaby *Petrogale lateralis lateralis* and the Barrow Island euro *Macropus robustus isabellensis*, all of which are listed on the EPBC Act. In addition, the



golden bandicoot *Isoodon auratus* also occurs on Barrow Island, but bandicoot tracks are distinguished from those of the burrowing bettong by the presence of three clawed toes on the forepaws rather than five. Baited camera traps will aid in the positive identification of species in this circumstance.

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Boodie, burrowing bettong (inland subspecies)

Bettongia lesueur graii

States and territories: South Australia (translocated population, but see comments below).

Regions: Extinct. Formerly this species was widespread in calcareous, lateritic and sandy country encompassing nearly half of the continent, including most of Western Australia and South Australia, western NSW and the Victorian mallee. It disappeared from Victoria in the 1860s and south-western Australia by the 1930s but persisted in the central and western deserts until the mid twentieth century, for example, 1950s in the Northern Territory after a widespread decline over the previous 50 years (Burbidge et al. 1988; Pavey 2006).

Habitat: The Boodie occurred in a broad range of habitats, excluding rocky ranges (Burbidge et al. 1988). It sheltered during the day in warren systems, with more than 50 individuals found in some complexes that it occasionally shared with the introduced rabbit.

Habit: Ground dwelling.

Avg. body weight: Up to 1.6 kg (Pavey 2006).

Activity pattern: Nocturnal.

Diet: Herbivore: tubers, seeds, nuts and plants.

Breeding: Breed continuously under suitable conditions giving birth to one and producing up to three young per year (Burbidge & Short 2008).

Description

As far as can be determined the subspecies *B. lesueur graii* is extinct. Individuals transferred to Roxby Downs Arid Recovery Project were 10 animals from Heirisson Prong, Shark Bay (for example, Burbidge & Short 2008). These individuals were a different subspecies: *B. lesueur lesueur*.

The burrowing bettong's range previously covered much of arid western and central Australia, but it is now restricted to Dorre and Bernier Islands in Shark Bay and Boodie and Barrow Islands off the Western Australian coast (Short & Turner 1993). The Shark Bay subspecies of burrowing bettongs from Dorre Island were re-introduced to a fenced, predator-free mainland site, Heirisson Prong in Shark Bay (Sander et al. 1997). Pizzuto and colleagues (2007) found that a reintroduced population of burrowing bettong in western NSW selected microhabitats with up to 25 per cent canopy cover, one to two centimetres deep litter and open structure at ground level for nocturnal foraging and other activities.

The burrowing bettong is nocturnal and gregarious (Burbidge 1995). The only burrowing macropod to regularly shelter underground, they dig burrows that range from a simple structure with one or two entrances and short, shallow tunnels, to complex, interconnected warrens (Burbidge 1995). On Barrow Island, warrens with up to 90 entrances have been recorded (Sander et al. 1997). Local soil type constrains burrow complexity, and sandy soils usually support only simple burrows (Ride et al. 1962). The burrowing activities of this species created



and maintained surface soil heterogeneity and influenced the composition of the plant communities in arid regions. Despite local extinction of this species across much of Australia, relict warrens still exert an impact on floral diversity and productivity (Noble et al. 2007).

Survey methods

Minimising disturbance to bettongs during trapping programs is important because of their tendency to reject pouch young when stressed (A. Wayne, Western Australian DEC, 2009, pers comm.). Passive means of detecting this species, like baited camera traps, are preferable in situations where trapping is not necessary. If trapping is necessary, animal handling should be undertaken with caution.

The survey methods recommended for the burrowing bettong (Shark Bay) and the burrowing bettong (Barrow and Boodie Island) have been designed for surveys of areas within the burrowing bettong's current known range. Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities. Any signs of the burrowing bettong on the mainland should be reported immediately to the Western Australian DEC or other relevant government authorities.

Similar species in range

There are no species similar in appearance to the inland subspecies of the Boodie within the species' known range.

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Boodie, burrowing bettong (Shark Bay)

Bettongia lesueur lesueur

States and territories: Western Australia.

Regions: Shark Bay: Dorre Island, Bernier Island and reintroduced into Heirisson Prong (mainland Shark Bay).

Habitat: Coastal dunes with heath, sandplain with heath, sandplain with hummock grassland, and travertine with heath (Short & Turner 1999).

Habit: Ground-dwelling (burrows).

Avg. body weight: 1280 g (Burbidge & Short 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: tubers, seeds, nuts, stems and leaves and some insects.

Breeding: Breeding recorded throughout the year but is concentrated during the wetter winter months (Short & Turner 1999).

Description

The burrowing bettong's range previously covered much of arid western and central Australia, but it is now restricted to Dorre and Bernier Islands in Shark Bay and Boodie and Barrow Islands off the Western Australian coast (Short & Turner 1993). The Shark Bay subspecies of burrowing bettongs from Dorre Island were re-introduced to a fenced, predator-free mainland site, Heirisson Prong in Shark Bay (Sander et al. 1997). Pizzuto and colleagues (2007) found that a reintroduced population of burrowing bettong in western NSW selected microhabitats with up to 25 per cent canopy cover, one to two centimetres deep litter and open structure at ground level for nocturnal foraging and other activities.

The burrowing bettong is nocturnal and gregarious (Burbidge 1995). The only burrowing macropod to regularly shelter underground, they dig burrows that range from a simple structure with one or two entrances and short, shallow tunnels, to complex, interconnected warrens (Burbidge 1995). On Barrow Island, warrens with up to 90 entrances have been recorded (Sander et al. 1997). Local soil type constrains burrow complexity, and sandy soils usually support only simple burrows (Ride et al. 1962). The burrowing activities of this species created and maintained surface soil heterogeneity and influenced the composition of the plant communities in arid regions. Despite local extinction of this species across much of Australia, relict warrens still exert an impact on floral diversity and productivity (Noble et al. 2007).

Survey methods

Minimising disturbance to bettongs during trapping programs is important because of their tendency to reject pouch young when stressed (A. Wayne, Western Australian DEC, 2009 pers comm.). Passive means of detecting this species, like baited camera traps, are preferable in situations where trapping is not necessary. If trapping is necessary, animal handling should be undertaken with caution.



The following survey techniques are recommended to detect the presence of the burrowing bettong in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes a wide range of habitat types within the islands of the species known range (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including burrows, diggings, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2). However, diggings should be distinguished between those made by the sympatric western barred bandicoot *Perameles bougainville* on Dorre and Bernier Islands
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys, which are detailed in Section 3.3.2.

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:

- observations conducted at dusk/early night at burrow entrances according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10, using a mixture of peanut butter, rolled oats, sardines or bacon for bait. A fence trapping system, similar to that devised for the bilby *Macrotis lagotis* by Southgate and colleagues (1995) and Gibson and Hume (2000) may also be appropriate (see the species profile for the bilby) for capturing the burrowing bettong as individuals emerge from their burrows
- camera traps baited with universal bait and added almond, walnut or truffle oil (see potoroo profiles for further information) are likely to prove useful for positively identifying and minimising the impact on animals and are also cost-effective (description of the survey technique and recommended effort is outlined in Section 3.3.6).

The burrowing bettong is not distinguishable from hair samples (see Table 2, Section 3.3.6). Should this situation change, then hair sampling may provide an appropriate alternative detection technique, however this method should be used only as part of an integrative approach utilising other methods like baited camera traps.

The survey method recommended has been designed for surveys of areas within the burrowing bettong's known range. Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities. Any signs of the burrowing bettong on the mainland should be reported immediately to the Western Australian DEC or other relevant government authorities.

Similar species in range

There are no species similar in appearance to the burrowing bettong within the species' known range.

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Boullanger Island dunnart

Sminthopsis griseoventer boullangerensis

States and territories: Western Australia.

Regions: Boullanger Island in Jurien Bay.

Habitat: Sandy substrates covered by a dense shrub layer of cushion fan-flower *Scaevola crassifolia*, *Acanthocarpus preissii*, boobialla *Myoporum insulare*, coastal daisybush *Olearia axillaris* and nitre bush *Nitraria billardieri* (Crowther et al. 1999).

Habit: Ground-dwelling.

Avg. body weight: 13 g (Crowther et al. 1999).

Activity pattern: Nocturnal.

Diet: Insectivorous, but also take young mice, lizards and soft fruits (Fuller & Burbidge 1987, Dickman 2008).

Breeding: Females have only one litter per year (in August), which comprises up to eight young. The young remain in the pouch for four to five weeks, after which time young are left in a leaf-lined nest just under the soil surface until first emergence in late October (Dickman 2008).

Description

The Boullanger Island dunnart has only recently been separated as a subspecies from the Western Australian mainland grey-bellied dunnart *Sminthopsis griseoventer* (Crowther et al. 1999). Compared to the grey-bellied dunnart, the Boullanger Island dunnart has a longer tail, is smaller in body size, has no entoconids on the second and third molars and differs genetically by having three fixed allozyme differences out of 18 examined (Crowther et al. 1999). The two subspecies otherwise appear very similar. The results from DNA analysis indicate that this subspecies may also exist on the mainland, as the DNA profile of a sample from Lesueur, near Jurien, matched that of the Boullanger Island form. Recent taxonomic research has suggested the species does not warrant differentiation from the mainland population (Start et al. 2006).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Boullanger Island dunnart in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, including but not limited to habitats with a sandy substrate and an associated dense shrub layer (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens
- pitfall trapping surveys (description of the survey technique and recommended effort is provided in Section 3.3.8).

Hair sampling device surveys are not recommended for the Boullanger Island dunnart because it is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change for this species, then hair sampling may provide an appropriate alternative detection technique.

Similar species in range

Along with the Boullanger Island dunnart, the EPBC Act listed dibbler and the introduced house mouse are present on Boullanger Island and have also been recorded in pitfalls (Fuller & Burbidge 1987). Consequently, investigators must be able to distinguish between these species. For surveys conducted on the mainland, a DNA sample may be required to distinguish between subspecies of *S. griseoventer*. This may require appropriate permission and licensing from the relevant government organisations.

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Bramble Cay melomys

Melomys rubicola

States and territories: Queensland.

Regions: Bramble Cay in the Great Barrier Reef.

Habitat: Herbfield and strandline vegetation.

Habit: Ground-dwelling.

Avg. body weight: 122 g (approximately) (Dennis 2008).

Activity pattern: Nocturnal.

Diet: Unknown, probably herbivorous, but may also feed on arthropods, intertidal fauna and flora, and dead seabirds, their chicks and eggs (Dennis 2008).

Breeding: Pregnant and lactating females have been recorded in July (Dennis 2008).

Description

The Bramble Cay melomys has the smallest distribution, is the most isolated and probably the most vulnerable of all Australian mammals. The species is known only from Bramble Cay in the Great Barrier Reef, which is approximately 340 metres long by 150 metres wide (Limpus et al. 1983). The species burrows amongst low-lying vegetation and forages at night among the grass and out onto the beach (Dennis 2008). Little is known about this species, other than it is closely related to the Cape York melomys *Melomys capensis* and the fawn-footed melomys *Melomys cervinipes* (Limpus et al. 1983). The main threat to the species is habitat loss through inundation or erosion of the coral cay (Dennis 2008). Its population was estimated at 94 in 1998 (Dennis & Storch 1998), and the Cay itself is only capable of supporting several hundred individuals (Limpus et al. 1983).

Survey methods

Individual Bramble Cay melomys have been observed at night with a spotlight, foraging and moving through the vegetation onto the beach (Limpus et al. 1983). No other rodents are known to inhabit the Cay but a dedicated survey should include a capture program so that a positive identification of the species can be made.

Given the extremely isolated and small size of the known distribution of the Bramble Cay melomys, it could be assumed that any impact to the Bramble Cay may affect the species. It is advised that any surveys for the species on Bramble Cay should be conducted in conjunction with relevant Queensland government authorities.

On the basis of what is known of the Bramble Cay melomys, the following survey techniques are recommended to detect the presence of the species in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, considering all available habitat on Bramble Cay (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs such as scats or tracks in sandy substrates (description of the survey technique and recommended effort is provided in Section 3.2)

- Elliott A trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9, using a mixture of peanut butter, rolled oats, honey and possibly sultanas as a bait
- spotlight surveys (conducted in a manner to avoid disturbance to nesting seabirds) conducted according to the technique description and recommended effort provided in Section 3.3.3, and
- consultation with scientists and other visitors to islands across the Great Barrier Reef region to aid in the detection of the potential presence of rodents such as this species on other islands in the region.

While the Bramble Cay melomys is not known from other islands or cays in the vicinity, the possibility that it occurs elsewhere should be considered. Fauna surveys on Great Barrier Reef islands should include a small mammal trapping program using Elliott traps and spotlighting techniques. The identity of any melomys captured on these islands must be confirmed by a rodent expert.

Similar species in range

The Bramble Cay melomys is similar in appearance to the Cape York melomys and the fawn-footed melomys (Limpus et al. 1983). The main morphological difference from these two species is the Bramble Cay melomys has a much rougher tail due to raised scales along its length, larger size, large feet and relatively small ears (Dennis 2008). Due to the isolation of the species, it is unlikely to be confused with any other species in terms of its known distribution.

As there are very few specimens of the Bramble Cay melomys, hair or tissue samples should be considered for future identification and/or molecular analysis, provided that the appropriate permission and licensing has been granted by the relevant Queensland government organisation. Similarly, any melomys caught elsewhere on the Great Barrier Reef should also be considered in terms of taking hair or tissue samples for confirmation of the species' identity.

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Bridled nailtail wallaby

Onychogalea fraenata

States and territories: Central Queensland - formerly occurred in north-western Victoria and central NSW.

Regions: Taunton Scientific Reserve near Dingo west of Rockhampton. Recently introduced to Idalia National Park, Central Queensland, and Scotia Sanctuary (western NSW).

Habitat: The surviving population occurs in areas where fertile soil supports open eucalypt forest, woodland and brigalow scrub.

Habit: Ground-dwelling in areas with habitat edges with sufficient shelter like shrubs, grass and fallen logs (Fisher 2000).

Avg. body weight: 4000–8000 kg (Lundie-Jenkins 2001).

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: grasses, forbs and chenopods, some browsing shrubs and possibly digs for tubers (Menkhorst & Knight 2001).

Breeding: Breeding occurs throughout the year, although pouch-young and young-at-foot are more often observed during late spring and summer (Evans & Gordon 2008).

Description

The bridled nailtail wallaby has white markings that run from the shoulders to its forearms and a black dorsal stripe that runs from shoulders to tail (Evans & Gordon 2008). The range of the bridled nailtail wallaby occurs west of the Great Dividing Range and previously extended across Queensland, NSW and Victoria, but it is now restricted to a small area in central Queensland near Dingo on Taunton Scientific Reserve (11 470 ha). The population size was estimated to be around 1500 individuals (Evans & Jarman, 1999); however, it declined recently in response to drought but is thought to be increasing again (Lundie-Jenkins 2001).

The wallabies feed on the leaves and stems of herbaceous plants, bushes and small shrubs (Dawson et al. 1992), which occur within the habitat of the transitional zone between dense acacia scrub and grassy eucalypt woodland (Lundie-Jenkins 2001). The wallabies are mostly solitary, feeding alone at night and resting during the day in the shade of bushes and shrubs (Evans & Gordon 2008).

At the Taunton site, female bridled nailtail wallabies had mean home range size of 25 hectares versus 60 hectares for males, although individual home ranges overlapped despite the tendency for individuals to shelter alone (Evans 1992, in Lundie-Jenkins 2001). Fisher (2000) found that preference for habitat edges may reflect the spatial arrangement of dense vegetation at wallaby height which was the preferred shelter habitat. In that study, shelter availability appeared to be a major factor constraining the movements of that population (Fisher 2000).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the bridled naittail wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas of open eucalypt forest, woodland and brigalow scrub (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats and scrapes (description of the survey technique and recommended effort is outlined in Section 3.2)
- diurnal surveys for wallabies resting, conducted according to the description of the survey technique and effort recommended in Section 3.3.1
- baited camera traps may be of use in confirming the presence and identity of wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- spotlight surveys conducted either on foot or from a vehicle according to the description of the survey technique and effort recommended in Section 3.3.3.

Similar species in range

The bridled naittail wallaby overlaps in distribution with the black-striped wallaby at Taunton Reserve. The species is distinguished by the larger body size of the black-striped wallaby, the solitary rather than gregarious nature of the bridled naittail wallaby and the white bridle markings on the bridled naittail wallaby. The scats of the bridled naittail wallaby are more cylindrical than those of the black-striped wallaby (Evans & Jarman 1999). Bridled naittail wallabies have a distinctive gait which also distinguishes them from black-striped wallabies.

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Brush-tailed rabbit rat

Conilurus penicillatus

States and territories: Western Australia, Northern Territory and Queensland.

Regions: Formerly monsoonal near-coastal northern Australia, from the northern Kimberleys, principally in the Mitchell Plateau area, east to around Burketown in the Gulf country of Queensland. Also some adjacent offshore islands with relatively high rainfall, including the Tiwi Islands, Inglis Island, Groote Eylandt, the Sir Edward Pellew Group off the Northern Territory and Bentinck Island in the Wellesley Group in the Gulf of Carpentaria off Queensland. Now it is highly localised and patchily distributed with only two sites known on the mainland of the Northern Territory: the Cobourg Peninsula and the Mardugal area of Kakadu National Park. The species also occurs in small areas of southern New Guinea.

Habitat: The primary habitat is mixed eucalypt tall open forest and woodland, or on the Cobourg Peninsula it occurs in coastal grasslands with scattered tall ironwood *Casuarina equisetifolia*, stunted eucalypts on stony slopes and on beaches (Woinarski 2007). Important factors in the landscape (excluding the Cobourg Peninsula) include open forest with taller trees, less frequent (or less intense) fires, sparse grass cover, distance from watercourses or moist areas, and the presence of tree hollows (Firth et al. 2005, 2006a). The brush-tailed rabbit rat shelters primarily in tree hollows and fallen logs; occasionally in the crowns of Pandanus and sand-palms (Firth et al. 2006b).

Habit: Ground and tree-dwelling.

Avg. body weight: 163 g (males) and 144 g (females) (Kemper & Firth 2008).

Activity pattern: Nocturnal, although often active at dusk.

Diet: Predominantly seeds (especially of grasses), with some fruits, leaves, grass and invertebrates also consumed (Firth et al. 2005).

Breeding: Breeds between March and October, during which time several litters comprising one to four (usually three) young are born (Kemper & Firth 2008).

Description

The brush-tailed rabbit rat is the only extant member of its genus, with its sole congener the white-footed rabbit rat *C. albipes* becoming extinct by the late 1860s (Dixon 2008). It is a large, partly arboreal rat that has a long brush-tipped tail and long ears. Although formerly reported as common (for example, Dahl 1897), it has declined across much of its range. Estimations suggest its distribution and population size has declined by over 50 per cent since European settlement in the Northern Territory (Woinarski 2000). Reasons for the decline of this species are unclear, but are possibly associated with a combination of factors, including disease, predation by feral cats and broad scale habitat changes through more frequent and extensive fires, weeds and changes in food availability as a result of grazing pressure from introduced grazers and domestic livestock (Firth et al. 2005, 2006a).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the brush-tailed rabbit rat in areas up to 5 hectares in size:

- daytime searches outside the Cobourg Peninsula for potentially suitable habitat resources such as open forest with taller trees, less frequent (or less intense) fires, sparse grass cover, and distance from watercourses or moist areas (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches on the Cobourg Peninsula for potentially suitable habitat resources such as coastal grasslands with scattered tall ironwood, stunted eucalypts on stony slopes and on beaches (description of the survey technique and recommended effort is provided in Section 3.1)
- trapping surveys using Elliott traps (conducted according to the technique description and recommended effort provided in Section 3.3.9) and cage traps (according to the technique description and recommended effort provided in Section 3.3.10) are the best techniques for targeted surveys of this species
- spotlight surveys conducted according to the technique description and recommended effort provided in Section 3.3.3.

Similar species in range

The brush-tailed rabbit rat occurs sympatrically with two other large rat species: the black-footed tree rat *Mesembriomys gouldii* and the golden-backed tree rat *M. macrurus*. It is distinguished from the black-footed tree rat by its smaller size (less than 600 grams in weight), short muzzle, and lack of black feet and ears. The golden-backed tree rat has an entirely whiteish coloured tail; the tail of the brush-tailed rabbit rat is black on the basal half with a dense tuft of either black or white fur on the end half to third. The golden-backed tree rat also has a distinct golden dorsal band.

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Brush-tailed rock wallaby

Petrogale penicillata

States and territories: Queensland, NSW and South Australia.

Regions: Great Dividing Range (Queensland, NSW and Victoria), Grampians (Victoria) and Warrumbungle National Park (NSW) (Menkhorst & Knight 2001).

Habitat: Rock boulders, escarpments (usually with a northerly aspect) and cliff lines (Eldridge & Pearson 2008), however, vegetation may also be used for shelter. A full description is provided in NSW NPWS (2002).

Habit: Ground-dwelling.

Avg. body weight: 7900 g (males) and 6300 g (females) (Eldridge & Pearson 2008).

Activity pattern: Diurnal/nocturnal.

Diet: Herbivore; grasses, shrubs and forbs (Short 1989).

Breeding: Breeding probably occurs throughout the year, but most births occur between August and November (Joblin 1983).

Description

The range of the brush-tailed rock wallaby occurs within three states (Queensland, NSW and Victoria) within south-eastern Australia. The species has declined throughout its range in response to a number of factors including persecution as pests, predation by introduced predators and competition with introduced herbivores (Eldridge & Pearson 2008; NSW NPWS 2002). The distribution is now highly fragmented, and Browning and colleagues (2001) describe the likelihood of migration between small remnant populations to be very low to non-existent. Small populations are thought to be possibly nomadic, with evidence from surveys of colonies disappearing and reappearing (Norris & Belcher 1986). Furthermore, individual wallabies are known to disperse in response to disturbance (see NSW NPWS 2002), which indicates that surveys conducted over a short time frame may fail to detect dispersing individuals near known populations of this species.

Extensive research has been conducted into the brush-tailed rock wallaby and only a very brief summary of that literature is provided here. Refer to the recovery plan for the species, or the NSW NPWS (2002) *Warrumbungle brush-tailed rock wallaby endangered population recovery plan* for a more thorough review of the available literature.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the brush-tailed rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelters sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)



- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- Baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat or possibly from a helicopter according to the suggested survey technique and effort provided in Section 3.3.11 (minimising disturbance to animals to ensure wallabies do not fall).

The known range of the brush-tailed rock wallaby overlaps with that of Herbert's rock wallaby in the north. Should confirmation of the species identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Section 3.3.10 and 3.3.11), camera trapping (see 3.3.6) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

The range of the brush-tailed rock wallaby overlaps with that of Herbert's rock wallaby *Petrogale herberti* in the north of the range.

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Carpentarian antechinus

Pseudantechinus mimulus

States and territories: Northern Territory and Queensland.

Regions:	Known from North, Vanderlin, Centre and South West Islands in the Sir Edward Pellew Islands in the Gulf of Carpentaria and the Mt Isa region, including the Selwyn Range approximately 140 km southeast of Mt Isa (Woinarski 2002; Woinarski 2004; Sanders and Slater 2004; Johnson et al. 2008). First recorded from the Alexandria Station area of the Barkly Tablelands (1905), with no subsequent records.
Habitat:	Inhabits rocky areas and shelters among pebbles, boulders and stony hillsides or outcrops with shrubby open woodland and hummock grass understorey (Johnson et al. 2008).
Habit:	Ground-dwelling.
Avg. body weight:	16 g (males), 18 g (females) (Johnson et al. 2008).
Activity pattern:	Nocturnal.
Diet:	Insectivorous.
Breeding:	Poorly known. None of the seven island females captured in July and August 1988 had pouch young, while four females captured in October 2003 had enlarged teats (Johnson et al. 2008). Individuals trapped in November 1997 near Mt Isa were recently weaned juveniles (Johnson et al. 2008).

Description

There is very little information available on the Carpentarian antechinus. It is the smallest of the *Pseudantechinus* species, but is otherwise similar to the sandstone antechinus *P. bilarni*, which is found in the surrounding mainland gulf country, and the fat-tailed antechinus *P. macdonnellensis*, with which it was once considered to be conspecific (Kitchener 1991).

The distribution of this species is poorly understood. The Carpentarian antechinus was first detected on mainland Northern Territory in 1905 but no specimens have been subsequently collected in this region. The species has since been collected from a number of islands in the Sir Edward Pellew Islands and from near Mt Isa (Woinarski 2004). However, recent fauna surveys in apparently suitable habitat to the north of these records have failed to detect the species (Woinarski 2004).

Survey methods

The small amount of information available for the Carpentarian antechinus suggests that an intensive survey effort, using pitfall and Elliott traps, consistent with the Northern Territory standard survey guidelines (NT DIPE 2005) is required for the detection of this species. The nature of the subject site is likely to dictate what survey method can be used, and given that the Carpentarian antechinus has previously been recorded in habitats characterised by boulders, rocks or rock crevices (Woinarski 2002), the habitat may not be suitable to dig pitfalls. An Elliott A trap successfully trapped one individual (Sanders & Slater 2004), and Elliott E traps have



previously been used to trap the closely related fat-tailed antechinus in similar rocky habitats (see Gilfillan 2001). It is likely that both of these trap types would be appropriate for the Carpentarian antechinus.

Note that given the poorly understood and highly disjunct distribution of this species, surveys in potentially suitable habitat throughout north-western Queensland and the Barkly Tablelands region of the Northern Territory should consider the possibility of this species potentially occurring and therefore incorporate a targeted survey strategy into any fauna surveys conducted.

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Carpentarian antechinus in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, including, but not limited to, habitats characterised by boulders, rocks or rock crevices (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs of activity, such as tracks or scats among rocks and rock ledges (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- pitfall trapping surveys conducted according to the technique and effort recommended in Section 3.3.8
- Elliott A/E trapping survey conducted according to the technique and effort recommended in Section 3.3.9
- consider the placement of camera traps in suitable habitat as this technique is ideal for cryptic species occurring at low densities.

Should the habitat of the subject site prove to be unsuitable for establishing pitfall traps, use twice the recommended survey effort for the Elliott trapping survey.

Hair sampling device surveys are not recommended because the Carpentarian antechinus is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change for this species, then hair sampling may provide an appropriate alternative detection technique.

Similar species in range

The distribution of the Carpentarian antechinus could potentially overlap with that of the sandstone antechinus *P. bilarni*, which is found in the surrounding mainland gulf country, and the fat-tailed antechinus *Pseudantechinus macdonnellensis*, which could potentially overlap in the southern limits of this species' range. The Carpentarian antechinus can be distinguished from these other species by its smaller size, relatively shorter tail and skull characteristics (Johnson et al. 2008). Identification should be confirmed by competent field investigators. Since there are very few specimens of the Carpentarian antechinus, taking of hair or tissue samples should be considered for future identification and/or molecular analysis, provided that the appropriate permission and licensing has been granted by the relevant state or territory government organisations.

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Carpentarian dunnart

Sminthopsis butleri

States and territories: Western Australia (northern) and Northern Territory

Regions: Kalumburu in the northern Kimberley (last observed 1966) and Tiwi Islands (Melville & Bathurst Islands); all records within 20 km of coast (Woinarski et al. 1996).

Habitat: Tiwi - Bathurst Island: Primary habitat is tall open eucalypt forest comprising Darwin woollybutt *Eucalyptus miniata*, Darwin stringybark *E. tetrodonta* and/or Melville Island bloodwood *Corymbia nesophila*; also in lower abundances in woodland with other eucalypt species, melaleuca woodland and low scrub areas (Ward 2009).

Kalumburu (Archer 1979): Eucalyptus and grassland habitat where black soil country abuts onto sandplains; and flood debris.

Habit: Ground-dwelling.

Avg. Body Mass: Body mass ranges between 15 g and 30 g (Woolley 2008).

Activity pattern: Nocturnal.

Diet: Unknown, but probably invertebrates and perhaps small vertebrates (Woinarski 2002).

Breeding: Poorly known, with pouch young recorded in December and a very young individual found in January at Kalumburu (Woolley 2008).

Description

The Carpentarian dunnart is a small, grey coloured dunnart that has a thin and sparsely furred tail, and has a faint strip of darker fur down the back of its head (Woolley 2008). Approximately nine wild-caught specimens, which have come from ten locations within an area of less than 20 000 square kilometres, represent the total number of records of this rare species (Woinarski et al. 1996, Woinarski 2002).

The species was first recorded at Kalumburu in the Kimberley region of Western Australia. However, it has not been recorded in that region since 1966, despite a targeted survey in 1991 (Woinarski et al. 1996). A number of individuals have since been collected in the Tiwi Islands (Melville and Bathurst Islands) (Woinarski et al. 2000, Woolley 2008, Ward 2009). Specimens collected on Cape York that were previously thought to be the Carpentarian dunnart have now been re-classified as a distinct species, the chestnut dunnart *Sminthopsis archeri*.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Carpentarian dunnart in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as logs or rocks that may act as suitable shelter sites (Archer 1979), including actively searching under debris (description of the survey technique and recommended effort is outlined in Section 3.1)

- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- spotlighting for active individuals
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- pitfall trapping surveys conducted according to the survey protocol of Ward (2009).

Hair sampling device surveys are not recommended because the Carpentarian dunnart is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change, then hair sampling may provide an appropriate alternative detection technique.

Similar species in range

The Carpentarian dunnart occurs sympatrically with the red-cheeked dunnart *Sminthopsis virginae*, but can be distinguished by the lack of rufous cheek fur. Specimens collected on Cape York previously thought to be the Carpentarian dunnart are now classified as a distinct species, the chestnut dunnart *Sminthopsis archeri*. As there are very few specimens of the Carpentarian dunnart, taking of hair or tissue samples should be considered for future identification and/or molecular analysis, providing that appropriate permission and licensing has been granted by the relevant state or territory government organisations.

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Carpentarian rock rat

Zyzomys palatalis

States and territories:	Northern Territory (may range into Queensland but currently there are no confirmed records [Puckey et al. 2003]).
Regions:	Known only from five sandstone gorges and escarpments in one pastoral lease (Wollongorang Station) near the Northern Territory-Queensland border, within 30 km of the original capture site (Puckey et al. 2008).
Habitat:	Dry rainforest thickets that fringe escarpments of deep gorges and scree slopes. Plant species characteristic of this habitat include pouteria <i>Pouteria sericea</i> , nutwood <i>Terminalia subacroptera</i> , rosewood <i>T. volucris</i> , common celtis <i>Celtis phillipensis</i> , rock fig <i>Ficus leucotricha</i> , white fig <i>F. virens</i> , the vine <i>Cissus reniformis</i> , gray nickabean <i>Caesalpinia bonduc</i> and the helicopter tree <i>Gyrocarpus americanus</i> (Trainor et al. 2000).
Habit:	Ground-dwelling (possibly shelters in rock crevices).
Avg. body weight:	115 g (Puckey et al. 2008).
Activity pattern:	Nocturnal.
Diet:	Fruits and seeds of fleshy-fruited plants.
Breeding:	Females generally give birth to between one and three young per litter and those living into their second year are capable of producing up to four litters, with breeding probably occurring in most months (Trainor 1996).

Description

The Carpentarian rock rat is one of five species of *Zyzomys* which inhabit rocky regions of Australia. It was first described in 1987 from a single female collected near Banyan Gorge on Wollongorang Station. Today there are only five known localities where the Carpentarian rock rat has been recorded, all within a 35 km radius of the original specimen (Trainor et al. 2000; Puckey et al. 2008). The preferred habitat is monsoon forest occurring on rocky slopes with sandy gorges (Churchill 1996). More recently radio-telemetry studies suggest the species prefers the valley and slope habitats rather than the plateau, with adults preferring slope habitats while juveniles prefer the valley habitat (Puckey et al. 2004). The majority of the species' diet is made up of rainforest fruits including native figs *Ficus* species, billygoat plum *Terminalia carpentariae*, emu apple *Owenia vernicosa* and river pandanus *Pandanus aquaticus* (Puckey et al. 2003).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Carpentarian rock rat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as rock and boulder outcrops, escarpments, gorges and cliffs with associated monsoon rainforest (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs such as scats or tracks in sandy substrates surrounding rocks or in caves and overhangs (description of the survey technique and recommended effort is provided in Section 3.2)



- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- hair sampling device surveys using a mixture of peanut butter, rolled oats and honey or sultanas conducted according to the technique and recommended effort outlined in Section 3.3.7
- Elliott A trapping surveys conducted according to the technique and recommended effort provided in Section 3.3.9. However, *Zyomys* species are particularly susceptible to tail stripping when trapped, and should be handled with care to avoid this occurring
- consultation with local people, including leaseholders, station hands, park rangers and field workers and investigating potential Indigenous knowledge of this species' presence in an area. Consultation is particularly important for this species as it may be present at very low densities for extended periods of time during dry conditions, making it virtually impossible to detect under such conditions
- placement of baited camera traps (same as for predator pads) in suitable habitat, which could be conducted in conjunction with hair tubes in remote locations accessed by helicopters (description of the technique is outlined in Section 3.3.6)
- searching for the remains of chewed fruit in crevices, under boulders and in overhangs
- possibly spotlight surveys conducted according to the technique description and recommended effort provided in Section 3.3.3.

Similar species in range

The Carpentarian rock rat is sympatric with the common rock rat *Zyomys argurus*. The two species can be distinguished by the smaller size of the common rock rat (average 45 grams) and its naked tail, compared to the furred tail of the Carpentarian rock rat, which is darker on the upper surface of the tail and has longer hair towards the tip (Menkhorst & Knight 2004).

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Central rock rat

Zyzomys pedunculatus

States and territories: Northern Territory.

Regions: Central Australia, with all recent records from the West MacDonnell Ranges (Nano 2008).

Habitat: The central rock rat occupies a range of habitats including tussock and hummock grasslands; low, open woodlands; cliffs; scree slopes; hills and valley floors. Sites are characterised by a high proportion of rock outcrop, stony soil surface and vegetation communities containing the northern cypress pine *Callitris glaucophylla* and the wattle *Acacia macdonnelliensis* (Cole & Woinarski 2000).

Habit: Ground-dwelling (possibly shelters in rock crevices).

Avg. body weight: 85 g (Cole 2000).

Activity pattern: Nocturnal.

Diet: Faecal analysis suggests the diet is predominantly plant material, dominated by seed (72 per cent of identifiable particles) and leaf (21 per cent), with slight seasonal variation (Nano et al. 2003). Stem and insects contributed 3 per cent and 4 per cent respectively (Nano et al. 2003).

Breeding: Based on observations of captive populations, litters comprise between one and four young every three months, and juveniles have been captured from wild populations in April, June, July and November (Cole 2000; Nano 2008).

Description

The central rock rat is one of five species of *Zyzomys*, all of which inhabit rocky regions of Australia. The central rock rat is confined to central Australia, while the other four species are found in restricted distributions across northern Australia. The central rock rat is extremely rare, and several trapping surveys have failed to detect its presence outside the West Macdonnell Ranges since it was last sighted in 1996 (the species was presumed extinct prior to this record). The range of the species is currently unknown (Cole 2000). Population monitoring following the rediscovery recorded a population boom in response to rainfall events, but the species declined dramatically as conditions became drier and a wildfire occurred in May 2002 (Nano 2008).

Very little research has been done on this species, and the biology is essentially unknown. Current threats are unclear, but suspected to be feral predators, altered fire regimes and the expansion of arid zone grazing (Cole 2000).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the central rock rat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as rock and boulder outcrops, escarpments, gorges and cliffs (description of the survey technique and recommended effort is provided in Section 3.1)



- daytime searches for signs such as scats or tracks in sandy substrates surrounding rocks or in caves/overhangs (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- hair sampling device surveys using a mixture of peanut butter, rolled oats and honey or sultanas conducted according to the description of the technique and the recommended effort outlined in Section 3.3.7, as the central rock rat is included among those species distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9. However, *Zyomys* species are particularly susceptible to tail stripping when trapped, and should be handled with care to avoid this occurring
- consultation with local people, including leaseholders, station hands, park rangers and field workers and investigating potential Indigenous knowledge of this species' presence in an area. Consultation is particularly important for this species as it may be present at very low densities for extended periods of time during dry conditions, making it virtually impossible to detect under such conditions
- placement of baited camera traps (same as for predator pads) in suitable habitat, which could be conducted in conjunction with hair tubes in remote locations accessed by helicopters (description of the technique is outlined in Section 3.3.6)
- possibly spotlight surveys conducted according to the technique description and recommended effort provided in Section 3.3.3.

Similar species in range

The central rock rat has an allopatric distribution with other rock rat species and is unlikely to be confused with other species within the area of its known range. However, it is possible that the species may be found at other locations. Hair or tissue samples should be considered for future identification and/or molecular analysis, provided that the appropriate permission and licensing has been granted by the relevant state or territory government organisations.

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Christmas Island shrew

Crocidura attenuata trichura

Regions:	Christmas Island, Indian Ocean.
Habit:	Unknown, probably mostly ground-dwelling, but may also be partially arboreal (Meek 2000).
Habitat:	Primary rainforest with dense leaf litter cover, extending from the plateau to the shoreline (Schulz 2004).
Avg. body weight:	5.3 g (from museum specimens) (Meek 2000).
Activity pattern:	Nocturnal.
Diet:	Insectivorous.
Breeding:	Unknown.

Description

The Christmas Island shrew is the only member of the shrew family (Soricidae) recorded in an Australian territory. The species was once common all over the island and its distinctive shrill squeaks could be heard throughout the rainforest (Lister 1888; Andrews 1900). By 1908 it was considered to probably be extinct, with no specimens either seen or heard during a visit by Andrews (1909). There have been two reports of the species since, once in 1958 and an accidental finding of two single individuals within a couple of weeks in 1985 (Meek 2000; Schulz 2004; Meek 2008). The species has not been recorded since these sightings despite targeted surveys using a range of techniques, or during extensive surveys of other fauna groups on the island. The cause of its decline is unknown and the species is regarded as probably extinct (Meek 2008). Habitat requirements critical for the species' survival, including the provision of foraging, shelter and breeding resources, are largely unknown.

Survey methods

Based on Meek's (2000) report, further research into trap design is required to enable surveys to be conducted without the interference by crabs. In the absence of crabs, detection methods as employed by Meek (2000) would be appropriate to detect the presence of the species. The recovery plan (Schulz 2004) offers some solutions to these problems, some of which are summarised below. The surveyor should consult Appendix 1 of the recovery plan prior to conducting any survey for the species.

Two possible strategies may be considered: firstly surveying in areas where crabs are excluded, or time surveys in the future to coincide with a reduction in the population density of crabs; or secondly, focus survey effort in the canopy in response to Meek's (2000) suggestion that the species may have been displaced into the canopy by the crabs. Under these conditions, the following survey techniques are recommended to detect the presence of the Christmas Island shrew in areas up to 5 hectares in size (it should be noted that the surveyor should consult the methods detailed in Appendix 1 of the recovery plan prior to conducting any surveys, particularly in relation to site selection):



- daytime searches for potentially suitable habitat resources such as rainforest habitats with dense leaf litter covered floors (description of the survey technique and recommended effort is outlined in Section 3.1). The recovery plan recommends spending one person hour actively searching under rocks, ground debris, at the base of trees, epiphyte clumps on trunks and in the canopy, and strips of loose bark on trunks and logs (Schulz 2004)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (if they occur on the island) (description of the survey technique and recommended effort is outlined in Section 3.2). The recovery plan also recommends locating nests of birds of prey that occur on the island for collection and analysis of regurgitated and discarded material (Schulz 2004)
- pitfall trapping surveys (description of the survey technique and recommended effort is outlined in Section 3.3.8). The recovery plan suggests establishing 10 pitfall traps at a distance of 5 metres apart (each trap 80 millimetres in diameter, minimum depth 250 millimetres). Wire mesh should be hooked into place at the top of each pit to exclude robber crabs (Schulz 2004)
- Elliott A/E arboreal trapping surveys (description of the survey technique and recommended effort is outlined in Section 3.3.9 but needs to be modified to include Elliott A traps, or even Elliott E traps rather than the larger Elliott A traps, due to the incredibly small size of the shrew). Lines of 25 Elliott traps should be established on the ground, with an additional 10 traps in the trees (including canopy) or rock faces, preferably in proximity to epiphytes (Schulz 2004). Traps should be surrounded by tied-down mesh to allow shrew passage but to prevent robber crab interference (Schulz 2004). Traps must be checked twice daily (early morning and late afternoon)
- at each site position 10 sheets of artificial habitat (for example, corrugated iron sheeting) and ten artificial nest burrows on the ground adjacent to the base of trees or amongst rocks, and regularly check (Schulz 2004).

Additional survey techniques that should be considered:

- hair sampling device surveys may be a suitable alternative technique (either ground-based or arboreal as described in Section 3.3.7), as the species is included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). However, the technique is not recommended since tests are needed to establish that a shrew is strong enough to escape from the adhesive tape and that the device is small enough to sample hair from a shrew's back. Should such tests demonstrate that the technique is safe and effective for sampling hair from the Christmas Island shrew (or a similarly sized species), then this may be an alternative detection technique.
- since the only recent sightings have been made by members of the public, consultation with local people and tourists, particularly park staff and field workers, is strongly recommended
- placement of unbaited camera traps of a design that can resist the high humidity, heavy downpours and tampering by the robber crab for extended periods of time in suitable habitat may be the best technique for locating this elusive species.

Similar species in range

The Christmas Island shrew is unlikely to be confused with any other small mammal species on the island.

As there are very few specimens of the Christmas Island shrew, taking of hair or tissue samples should be considered for future identification and/or molecular analysis, provided the appropriate permission and licensing has been granted by the relevant state or territory government organisations.

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Chuditch, western quoll

Dasyurus geoffroii

States and territories: Western Australia.

Regions: South-western Western Australia.

Habitat: Jarrah *Eucalyptus marginata* forest woodland or mallee shrubland (Serena & Soderquist 1995), specifically in moist, densely vegetated, steep-sloping forest and riparian vegetation (Orell & Morris 1994).

Habit: Ground and tree-dwelling, shelters in dens (earth burrows, hollow logs and hollows in termitaria).

Avg. body weight: 1300 g (males) and 900 g (females) (Orell & Morris 1994).

Activity pattern: Nocturnal/partly diurnal.

Diet: Carnivore: insects, other large invertebrates, small mammals, birds and lizards.

Breeding: Seasonally, with mating occurring late April to early July. Litters of between two and six suckle as pouch young for 61 days and then remain as den young until weaning (approx. September to November) (Orell & Morris 1994).

Description

Chuditch are medium-sized carnivorous marsupials distinguished from other species in their range by their brown fur with white spots and brush-like tail. Males are bigger than females and they also have larger home range areas (approximately 15 square kilometres) compared to females (3–4 kilometres squared) (Serena & Soderquist 1989). Females defend their home ranges, while males range over an area utilised by a number of different females.

Chuditch, like other quolls, shelter in dens during the day, and a female may use on average 66 logs and 110 burrows within her home range over the period of a year (Orell & Morris 1994). Logs that are used as dens must be at least 30 centimetres in diameter, and have a hollow diameter of 7–20 centimetres (Orell & Morris 1994). Burrows are constructed beneath habitat features such as stumps, logs, trees or rock outcrops (Orell & Morris 1994).

The species is an opportunistic feeder, foraging nocturnally for food sources located on the ground and in trees. Individuals will sometimes forage during the day during the breeding season, or if climatic conditions prevent nocturnal foraging (Orell & Morris 1994). Food items include insects, small mammals, birds, reptiles, fruit and flowers.

Survey methods

Recent studies conducted by Wayne and colleagues (2008) found bait to be a contributing factor in the trapping of chuditch with a bait consisting of meat meal, sardines, fish oil, chicken oil and rolled oats ('chuditch bait') increasing capture rates. The same study also recommends a relative low trap density and the use of free-swinging bait 'hooks' made of fencing wire as a way of reducing the problems associated with ants (Wayne et al. 2008). It is important to note that a completely closed loop rather than a hook should be used in order to avoid injury to trapped animals (Wayne et al 2008).

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the chuditch in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as jarrah *Eucalyptus marginata* forest woodland or mallee shrub land (Serena & Soderquist 1995), specifically in moist densely vegetated, steep sloping forest and riparian vegetation (Orell & Morris 1994) (see Ecovision Environmental Consultants 1996). Description of the survey technique and recommended effort is outlined in Section 3.1
- daytime searches for signs of activity, including tracks, scats and latrines (description of the survey technique and recommended effort is outlined in Section 3.2)
- hair sampling device (hair funnels) surveys, following the description of the technique and recommended effort provided in Section 3.3.7, and using a mixture of sardines, tuna oil and flour for bait. The chuditch is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- baited camera traps using 'chuditch bait' are a more cost effective survey method and also allow for concurrent data to be collected (M Schulz pers. obs.; Nelson 2008).

Cage trapping surveys are not considered necessary at the first stage of detection surveys as long as hair funnel or camera trap surveys are employed, as these are an appropriate and effective alternative. Should cage trapping surveys be required, it is recommended that they be conducted according to the description and recommended survey effort provided in Section 3.3.10, provided that permission and licensing has been granted from the relevant Western Australian government organisations. Cage trapping should not be conducted during between mid-August to mid-November when females may have large pouch young or den-young.

Surveys conducted between April and July may detect males in areas where they may not usually occur, either as they move in search of females to mate with or move away from other more competitive males. The locations of these records may indicate important supplementary habitats such as corridors within fragmented landscapes.

Similar species in range

There are no species similar in appearance to the chuditch within its known range.

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Common wombat (Bass Strait)

Vombatus ursinus ursinus

States and territories: Bass Strait, Tasmania.

Regions: Flinders Island.

Habitat: Open woodland.

Habit: Ground-dwelling (burrows).

Avg. body weight: Species average is 26 kg (McIlroy 1995), but the Flinders Island wombats are the smallest subspecies.

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: native grasses, sedges, rushes and the roots of trees and shrubs (McIlroy 1995).

Breeding: The species is reported to be capable of breeding at any time of the year (McIlroy 1995).

Description

Wombats are ground-dwelling herbivorous marsupials that forage mainly at night and rest in burrows during the day. A number of burrows (number varies) are constructed throughout an individual's home range area, with reports of up to 13 different burrows used over several weeks (McIlroy 1995). Signs of burrow entrances and piles of large distinctively square/rectangular shaped droppings are reliable signs of wombat activity within an area.

The Bass Strait wombat survives on Flinders Island in Bass Strait. The extinction of wombats on other Bass Strait Islands prior to 1910 has been attributed to hunting by sealers and settlers, and loss of habitat to agriculture (Bryant & Jackson 1999). Bass Strait wombats are slightly smaller than wombats from the mainland (Bryant & Jackson 1999), which are on average 26 kilograms and head-body length 98.5 centimetres (McIlroy 1995). No genetic studies have been published on this species (DEWHA 2009).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Bass Strait wombat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as open woodland (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including community records, burrows, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2)
- possibly spotlight surveys (description of the survey technique and recommended effort is outlined in Section 3.3.3), or observation surveys conducted at potentially active burrows to identify wombats emerging to forage (description of the survey technique and recommended effort is outlined in Section 3.3.4).

Trapping surveys are not considered necessary to determine the presence of the Bass Strait wombat from a subject site. If aerial surveys are undertaken, they should be conducted in association with ground-based daytime searches.

Similar species in range

There are no species similar in appearance to the Bass Strait wombat within the species' known range.

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Dayang, heath rat

Pseudomys shortridgei

States and territories: Victoria, South Australia and Western Australia.

Regions: South-western Victoria, adjacent parts of South Australia, possibly Kangaroo Island, the Fitzgerald River National Park and three sites in the southern wheatbelt of Western Australia (Menkhorst et al. 2008).

Habitat: Species-rich dry heathland that has been burnt within the last five to 15 years and stringybark open forests with a heathy understorey up to 25 years post fire; also heathland with the highest densities 30 years post fire, mixed scrub and mallee in Western Australia (Menkhorst et al. 2008). Microhabitat preferences include floristically diverse sites that are capable of supplying year-round food, especially grasses, sedges and underground fungi during autumn and winter.

Habit: Ground-dwelling (Menkhorst et al. 2008).

Avg. body weight: 70 g (Menkhorst et al. 2008).

Activity pattern: Nocturnal (partly diurnal).

Diet: Generalist herbivore: flowers, fruit, stems and leaves; also supplemented with insects and the fruiting bodies of underground fungi (Watts and Braithwaite 1978).

Breeding: Breeding occurs between September and February but varies with ephemeral habitat (Cockburn et al. 1981).

Description

The dayang is a relatively large native rodent, distinguished by its grey-brown colour, brown feet, blunt face, and hairy, non-annulated tail (Menkhorst et al. 2008).

The dayang primarily inhabits heathlands that have been patchily burnt to create a mosaic of age classes including areas of high productivity. In Victoria the optimum age post fire is between 10 and 20 years, while in Western Australia it is in long unburnt heath (that is, 30 year post fire) with no individuals recorded in recently burnt heath (that is, less than 10 years post fire) (Menkhorst et al. 2008). The dayang colonise relatively recently burnt areas, temporarily increasing in abundance. When the habitat returns to the previous unproductive state, dayang disperse again to colonise another newly burnt area (Menkhorst et al. 2008). In addition to dispersal, the population density decreases at sites as the time since burning increases, because juvenile survival decreases in mature heathlands (Cockburn et al. 1981). Changes in burning regimes may be related to the decline in this species distribution, particularly as a result of increased fire frequencies and large-scale fires resulting in uniform vegetation ages (Menkhorst et al. 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the dayang in areas up to 5 hectares in size:

- investigation of key habitat characteristics through vegetation mapping, habitat modelling and aerial photography. Additionally, daytime searches for potentially suitable habitat resources such as heathlands comprising a mosaic of fire affected habitats (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- hair sampling device surveys using a mixture of rolled oats, peanut butter, honey and pistachio nut oil (optional) for bait, conducted according to the description of the technique and the recommended effort outlined in Section 3.3.7, as the dayang is included among those species distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A/E trapping surveys as a primary survey technique conducted according to the technique description and recommended effort provided in Section 3.3.9
- possibly pitfall trapping surveys (with trap depth recommended to be 60 centimetres) conducted according to the description of the technique and the recommended effort outlined in Section 3.3.8, as long as the habitat is suitable for the establishment of pitfall traps
- it is likely that camera traps would be extremely useful (see Section 3.3.6). This technique has not been trialled, although this species has been recorded incidentally in the Grampians with camera traps set for the smoky mouse (Nelson et al. 2009).

It is recommended that surveys designed to detect the presence of the dayang consider any historical records of the species from the locality in terms of habitat connectivity. An investigator should target optimum post-fire ages for the various habitats indicated above that occur within, or are connected to a subject site, or which occur within a radius of, for example, 5 kilometres. The purpose of such an approach is to target prime post-fire age habitats where the dayang will be at higher densities, and therefore more easily detected. The large home range of the species and its dependence on dispersal between prime post fire habitat patches means that its presence at a site needs to be considered from a landscape perspective.

Similar species in range

The dayang is sympatric with a number of other rodent species and may be confused in the field. It can be distinguished from the bush rat *Rattus fuscipes* by the colouration of the tail: the dayang has a tail that is dark brown above and light below, whereas the bush rat has a pinkish-brown tail. The dayang can be distinguished from the swamp rat *Rattus lutreolus* and the broad-toothed rat *Mastacomys fuscus* by long grey hairs on the upper surface of its feet compared to the short brown fur on the feet of the other two species (Menkhorst & Knight 2004). The dayang can also be distinguished from the smoky mouse by its tail to body ratio: the dayang's tail length is less than its head and body length combined, whereas the smoky mouse is greater. Identification should be made by investigators familiar with the species' appearance, such as from previous experience with live or voucher specimens.



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Dibbler

Parantechinus apicalis

States and territories: Western Australia.

Regions: Currently in mainland south-western Western Australia this species is only known between Fitzgerald River National Park and Torndirrup National Park in south-western Western Australia, with the only known natural mainland population in Fitzgerald River National Park (Woolley 2008). It also occurs on Boullanger and Whitlock Islands (Jurien Bay) and has been recently successfully introduced to Escape Island (Woolley 2008). Formerly this species was more widespread, occurring from the Moore River region to King George Sound.

Habitat: Old-growth mallee heath on mainland Western Australia, and low heath on islands.

Habit: Ground-dwelling.

Avg. body weight: Body ranges from 60 to 125 g in males and 40 to 73 g in females, with island individuals being much smaller (Woolley 2008).

Activity pattern: Nocturnal.

Diet: Insectivore. Dietary generalist and opportunist (Miller et al. 2003).

Breeding: Mates in February to April, with up to eight young remaining dependent for between three and four months (Wolfe et al. 2000).

Description

The dibbler previously ranged from Shark Bay in Western Australia to Coffin Bay on the Eyre Peninsula in South Australia. The species' range gradually contracted to the southern coasts of Western Australia, and by 1904 the dibbler was assumed to be extinct. However, since 1967 a number of dibblers have been recorded on the mainland at south-western Western Australia (Muir 1985), and on Boullanger and Whitlock Islands (in Jurien Bay) in 1985 (Dickman 1986; Fuller & Burbidge 1987).

Dibblers have also been successfully reintroduced to Escape Island in Western Australia (D. Moro Australian Mammal Society presentation 2003) and to several areas on the mainland including Stirling Range National Park (Woolley 2008). Eighty-eight captive born individuals were released onto Escape Island between 1998 and 2000. Four years after the initial release, fourth generation wild-bred dibblers were captured from the population. Escape Island was selected for the translocation program because it comprises similar habitat characteristics as other islands where extant populations are found. Importantly, the island does not currently support the house mouse *Mus musculus* which is thought to compete with and transfer diseases to dibblers (D. Moro Australian Mammal Society presentation 2003). The successful translocation has added to the conservation of this species by increasing the distribution, and therefore reducing the likelihood that all populations may be wiped out by a catastrophic event.



Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the dibbler in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as densely vegetated habitats (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs of activity, such as tracks or scats in the sandy substrates available in the coastal habitats (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- possibly hair sampling device surveys (description of the survey technique and recommended effort is provided in Section 3.3.7), as the dibbler is included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- pitfall trap surveys conducted according to the technique and recommended effort described in Section 3.3.8
- Elliott A trapping survey using a mixture of peanut butter, sultanas and bacon for bait (description of the survey technique and recommended effort is provided in Section 3.3.9)
- consider the placement of camera traps in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric species such as the house mouse.

Where the house mouse and the Boullanger Island dunnart are present on the Jurien Bay islands, two Elliott traps may need to be placed at the same trap station to increase the trapping effort.

Similar species in range

There are no similar species within (or out) of the species range. It can be readily separated from other sympatric small mammal species by its tapering hairy tail, white eye ring and grizzled appearance of the fur (Woolley 2008).

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Dusky hopping mouse, wilkiniti

Notomys fuscus

States and territories: South Australia, Queensland, Northern Territory and NSW.

Regions: Patchily distributed; recorded from the Lake Eyre region, southern Strzelecki Desert and Cobbler Sandhills (South Australia), south-west Queensland and Sturt National Park (NSW) (Owens et al. 2008)

Habitat: Habitat generalist in sandy substrates (Moseby et al. 1999).

Habit: Ground-dwelling (burrows).

Avg. body weight: 32 g (Owens et al. 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: grains, seeds, green vegetation, insects and small lizards (Moseby et al. 1999).

Breeding: Breeds throughout the year in captivity (Owens et al. 2008).

Description

The dusky hopping mouse adaptations are characteristic of a species that has evolved to respond opportunistically to a climatically unpredictable environment, such as the arid habitats with sandy soils of north-west South Australia, far north-west NSW, south-west Queensland and south-east Northern Territory (Moseby et al. 1999). The species is capable of opportunistically breeding in response to environmental conditions.

Individuals live in burrows in small groups (approximately five individuals per burrow), and the burrows occur in loose aggregations in dune habitat (Owens et al. 2008). The burrow entrance (approximately 10 centimetres in diameter) leads to a main shaft that is connected to up to six pop-holes of vertical shafts with 2–3 centimetre diameter entrances (Owens et al. 2008).

The species' range has decreased in size and become fragmented during the last century. This observation of recent changes to the species distribution is supported by allozyme electrophoretic analysis, which indicates that the populations have only recently been separated (Moseby et al. 1999).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the dusky hopping mouse in areas up to 5 hectares in size:

- investigation of key habitat characteristics through vegetation mapping, habitat modelling and aerial photography. Additionally, daytime searches for potentially suitable habitat resources, including but not limited to sand dune habitats (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs such as tracks (these are the most obvious) and popholes (description of the survey technique and recommended effort is provided in Section 3.2)

- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- Elliott A trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9 using a mixture of rolled oats and peanut butter for bait (this technique can be difficult to use during summer)
- pitfall trap surveys conducted according to the technique description and recommended effort provided in Section 3.3.8, modifying the depth of the pitfall traps to at least 60 centimetres as per Moseby and colleagues (1999) and using narrow PVC piping (diameter 16 centimetres) rather than buckets to reduce the chance of escapes
- possibly a hair sampling device survey as the dusky hopping mouse is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- consultation with local people, including leaseholders and station hands and investigating potential Indigenous knowledge of this species' presence in an area. Consultation is particularly important for this species as it may be present at very low densities for extended periods of time during dry conditions, making it virtually impossible to detect under such conditions
- consider the placement of baited camera traps (same as for predator pads) in suitable habitat, concentrating on well-used runway areas (as told from the number of tracks), particularly as this species can be relatively easily separated from other sympatric species.

In addition, sand tray/soil plot surveys may provide a suitable survey method for detection in areas that do not have a sandy substrate. A description of the technique and recommended survey effort is provided in Section 3.3.2.

Similar species in range

The dusky hopping mouse overlaps in distribution with the fawn hopping mouse *Notomys cervinus* and the spinifex hopping mouse *Notomys alexis*. The dusky hopping mouse and the spinifex hopping mouse are found in association with sand dunes, while the fawn hopping mouse is associated with the gibber plains habitat (Owens et al. 2008). However, habitat separation should not be used exclusively to distinguish between species and morphological features should always be considered. The main morphological feature distinguishing the species is the presence of a well-developed throat pouch in both sexes of the dusky hopping mouse. The throat pouch has a fleshy lip that is covered in white inward pointing hairs, whereas it is less prominent and only occurs on males in fawn hopping mice. Similarly, only male spinifex hopping mice have a chest gland, but not a pouch like the other species (Owens et al. 2008).

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Eastern barred bandicoot (mainland)

Perameles gunnii unnamed subsp.

States and territories: Victoria.

Regions: Hamilton in north-western Victoria and reintroduced populations have been established at “Mooramong”, Gellibrand Hill Park and Hamilton Community Parklands (Vic DCNR 1996).

Habitat: Grassland areas, including suburban gardens (Seebeck & Menkhorst 2008).

Habit: Ground-dwelling.

Avg. body weight: 975 g (Seebeck & Menkhorst 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: invertebrates such as earthworms, insects and larvae, and bulbs and tubers (Seebeck & Menkhorst 2008).

Breeding: Breeding occurs throughout the year, with a peak between July and November, and litters comprising between one and five young (Seebeck & Menkhorst 2008).

Description

The mainland subspecies of the eastern barred bandicoot is known only from a few populations remaining around the Victorian town of Hamilton (Seebeck & Menkhorst 2008). The species had a former range that extended across much of Victoria and South Australia, but changes in land use, the introduction of feral predators, and possibly disease have caused the South Australian population to become extinct and the Victorian population to become functionally extinct (Todd et al. 2002).

The species' decline in western Victoria has been well documented (Vic DCNR 1996). The species was restricted to about 3000 hectares in Hamilton in the early 1970s and at that time comprised approximately 3000 individuals. Both the spatial extent and size of that population declined rapidly such that by the beginning of the annual population monitoring program in 1989, 52 individuals were captured and by 1991 only three were captured (Vic DCNR 1996).

In 1988 eastern barred bandicoots from the remaining Hamilton population were used to found a captive breeding colony, based on recommendations from the species management plan (Brown 1987, revised in 1988). Captive-bred offspring have been released into semi-wild populations at “Mooramong”, Gellibrand Hill Park and Hamilton Community Parklands, with extensive fox control management programs to reduce the effects of predation (Seebeck & Booth 1996; Vic DCNR 1996). By 1993 this reintroduced population, comprising up to 500 individuals, had provided a source for further reintroduction programs (Backhouse et al. 1995).

Survey methods

All known populations of the eastern barred bandicoot are currently managed and monitored in accordance with the requirements of the species' recovery plan (Vic DCNR 1996). Should targeted surveys for this species be required, advice should be sought from relevant local community groups and government organisations

including DCNR and the local council prior to the commencement of any field investigations. The survey techniques and recommended survey effort outlined for the eastern barred bandicoot in Tasmania provide a guide of suitable detection techniques.

Similar species in range

Within its currently restricted range on the mainland, the eastern barred bandicoot does not overlap in distribution with any other species of bandicoot.

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Eastern barred bandicoot (Tasmania)

Perameles gunnii gunnii

States and territories: Tasmania.

Regions: Northern and eastern Tasmania.

Habitat: Open grassland and areas of agriculturally improved pasture (Seebeck & Menkhorst 2008).

Habit: Ground-dwelling and cryptic in thick grasses.

Avg. body weight: 800 g (Seebeck & Menkhorst 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: invertebrates and tubers (Seebeck & Menkhorst 2008).

Breeding: Breeding occurs throughout the year but mostly between July to November, with litter size ranging from one to five (Seebeck & Menkhorst 2008).

Description

There are two subspecies of eastern barred bandicoot: *Perameles gunnii gunnii* from Tasmania and *Perameles gunnii* unnamed subspecies from the mainland (see previous species profile). The eastern barred bandicoot is distinctive, with three or four whitish bars across the rump. Whilst the Tasmanian subspecies has been separated from the mainland subspecies on the basis of morphological and genetic studies, the two may be indistinguishable in the field (Robinson 1995).

Breeding occurs throughout the year but the majority of births are recorded from July to November (Seebeck & Menkhorst 2008). One to five (usually two or three) young are born after 12 days' gestation and are weaned when between three to five months old. After her young are independent, a female can conceive and produce a second litter in quick succession (Seebeck & Menkhorst 2008).

In Tasmania the eastern barred bandicoot can occur in native grasslands, grassy woodlands and forests, and areas of pastoral development where there are patches of dense ground cover, often composed of weeds (Driessen et al. 1996, Seebeck and Menkhorst 2008). They also commonly occur in suburban areas and rural towns (M. Driessen pers. comm.). The distribution of the eastern barred bandicoot was originally associated with the native grasslands of the midlands and east coast, but the species is now locally extinct in these areas (Mallick et al. 1997). The species' range has probably been extended into the wetter south-eastern, north-eastern and north-western parts of the state as a result of land clearance of wet forests for agriculture in these areas (Driessen et al 1996). Clearing of forest for crops and pastures provides suitable ground cover and foraging habitat for the eastern barred bandicoot (Mallick et al. 1997, Seebeck et al. 1990). This ability to adapt to changes in the landscape has led to population densities of around eight animals per hectare being recorded in Tasmania, which indicates that this subspecies is relatively more secure than its Victorian counterpart (Seebeck & Menkhorst 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the eastern barred bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas with open grassland in proximity to refuge and shelter sites (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats, nests and conical foraging holes (description of the survey technique and recommended effort is outlined in Section 3.2), however, because the eastern barred bandicoot occurs in sympatry with the southern brown bandicoot *Isoodon obesulus* (another EPBC Act listed species), direct detection techniques should target sites with signs of foraging to distinguish between the bandicoot species
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- hair sampling device surveys conducted according to the description of the survey technique and recommended effort provided in Section 3.3.7, given that the eastern barred bandicoot is included among those species known to be distinguishable from hair samples (see Table 2)
- community liaison is a good technique for locating unknown populations. This been useful in detecting the mainland subspecies in the Hamilton area of Victoria
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10
- baited camera traps using universal bait (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Catling and colleagues (1997) note that both cage trapping and hair sampling surveys were disappointingly unsuccessful at detecting medium-sized mammals, especially in terms of the time and effort that they required. Given this result, it is recommended that cage trapping and/or hair sampling surveys be conducted to distinguish between bandicoot species in a staged detection process, with initial detection effort focussed on searches for signs and soil plot surveys. Baited camera traps may be worth investigating as a more time-effective means of detecting this species.

Similar species in range

The eastern barred bandicoot is distinguished from the sympatric southern brown bandicoot by its smaller size and white stripes on its rump.



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Fluffy glider, yellow-bellied glider (Wet Tropics)

Petaurus australis unnamed subsp.

States and territories: Queensland.

Regions: Western slopes of the wet tropics of north-eastern Queensland, north from the Lumholtz National Park to the Mt Windsor tableland at altitudes above 700 m (Van Dyck 2000; Goldingay 2008).

Habitat: Tall open wet eucalypt forest adjacent to rainforest, with red stringybark *Eucalyptus resinifera* a well represented canopy species (Van Dyck 2000; Bradford & Harrington 1999).

Habit: Arboreal.

Avg. body weight: 498 g (sexually dimorphic) (Goldingay et al. 2001).

Activity pattern: Nocturnal.

Diet: Sap of *E. resinifera* (80 per cent of feeding observations), nectar and pollen of eucalypts and banksias, arthropods and honeydew (Quin et al. 1996; Goldingay 2008).

Breeding: Seasonal breeding with 62 per cent of births (n=21) recorded between June and late August (Goldingay et al. 2001).

Description

The fluffy glider, *Petaurus australis* unnamed subspecies, is confined to the western slopes of the Wet Tropics region of north-eastern Queensland, separated by a distribution gap of over 300 kilometres from the south-eastern Australian subspecies of the yellow-bellied glider (Goldingay 2008). A recent phylogeographic study indicates that the northern subspecies is an evolutionarily distinct unit and is restricted from moving between other populations by unsuitable habitat, with a major biogeographic break at the Burdekin Gap (Brown et al. 2006). The two species are difficult to distinguish by appearance, with separation of the northern subspecies based on fur characteristics being contentious (Brown et al. 2006). In addition, Goldingay and colleagues (2001) reported a typical transition from white to yellow fur as juveniles matured to become adults among the northern subspecies.

The species is readily distinguished by a number of distinctive calls, including a loud high-pitch shriek followed by a low-pitch rattle audible over 500 metres away (Goldingay 2008). The species is the most vocal of all marsupials and calls are characteristic of the species across its range. Regular calling may facilitate communication between individuals which live in small social groups that occupy exclusive territories of approximately 50 hectares, or it may act as a form of territorial defence (Goldingay et al. 2001). The number of females and males per group is not uniform, but typically a group comprises three to six individuals, which may indicate that a range of mating systems (monogamy, polygyny and possibly polyandry) exist within the social system (Goldingay et al. 2001).



Yellow-bellied gliders use specially adapted incisor teeth to make distinctive V-shaped marks in the trunks and larger branches of suitable trees to access the sap on which they feed. In northern Australia, the yellow-bellied glider feeds exclusively on the red stringybark, *Eucalyptus resinifera* (Quin et al. 1996; Bradford & Harrington 1999) and uses only *E. grandis* trees for den sites (Russell 1984). Bradford and Harrington (1999) found that 99 per cent of sap-feeding scarred *E. resinifera* trees were within 500 metres of mature *E. grandis* trees.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the fluffy glider in areas up to 5 hectares in size:

- investigation of the presence of key eucalypt species, *E. resinifera* and *E. grandis* through examining fine-scale vegetation mapping (where available), aerial photography and ground truthing
- daytime searches for potential den sites in hollow-bearing trees, particularly *E. grandis* (description of the survey technique and recommended effort is outlined in Section 3.1);
- daytime searches for signs of activity, in particular the characteristic V-shaped sap-feeding scars on *E. resinifera* trees, (description of the survey technique and recommended effort is outlined in Section 3.2.6)
- stagwatching surveys at potential den sites (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- call playback surveys (Note: for best results use pre-recorded calls of the fluffy glider rather than those of the south-eastern Australian subspecies) conducted according to the method outlined in Section 3.3.5, including playback of the rufous owl call, which has had better results in call-playback surveys than fluffy glider calls in some cases (M Schulz pers. comm.) It is recommended that care should be taken conducting call playback surveys during the species' breeding season (NSW Agriculture 1998) so if possible avoid or limit the use of this survey technique between June and August (consult appropriate Queensland government organisations for advice)
- spotlight surveys (including listening for vocalisations) along transects, tracks or roads using the method described in Section 3.3.3. (Note: since this species is difficult to detect using spotlighting, listening for vocalisation is a primary technique for detection. It is therefore strongly recommended that spotlighting surveys are not conducted from a vehicle).

An arboreal cage trapping program consistent with the method outlined in Section 3.3.9 could also be employed if permission and licensing is approved by relevant Queensland government authorities; however, this technique is time-consuming, and the abovementioned techniques, if employed thoroughly, should normally be sufficient for detecting the species if present.

An important point to consider in the design of surveys to detect this species is that social groups are known to range over areas (possibly territories) approximately 50 hectares in size (Goldingay et al. 2001). Therefore, a 5 hectare site represents approximately one tenth of the total area that a group utilises in the course of their home-range movements, and therefore surveys may need to be either conducted on adjacent land or conducted at different times of the year to determine if the species is likely to potentially occur on the site.

Similar species in range

The fluffy glider can be distinguished from all other potentially sympatric glider species by its larger size, diagnostic vocalisations and characteristic feed marks on the trunks and larger branches of *E. resinifera*. Further, it can be distinguished from the sugar glider *P. breviceps* and the squirrel glider *P. norfolcensis* by the buff yellow belly colouration, larger size and lacking the distinctive white underbody.

Distinguishing between the northern subspecies of the yellow-bellied glider and southern populations should not be necessary as the north-eastern Queensland subspecies is geographically isolated by more than 300 kilometres from other populations in mid-eastern Queensland (Brown et al. 2006).

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Gilbert's potoroo

Potorous gilbertii

States and territories: Western Australia.

Regions: Two Peoples Bay Reserve (near Albany), Western Australia.

Habitat: Dense coastal heath habitat (Johnston 2008).

Habit: Ground-dwelling (nest in ferns or wire-grass).

Avg. body weight: 875 g (Menkhorst & Knight 2001).

Activity pattern: Nocturnal.

Diet: Mycophagous (primarily subterranean sporocarps but some epigeous fungi also eaten), and some invertebrates and fruits.

Breeding: Unknown.

Description

Gilbert's potoroo was believed extinct until it was rediscovered in very dense heathland at Two Peoples Bay in 1994 (Johnston 2008). The species has been separated from other *Potorous* species on the basis of genetic studies, which have shown that it is as different from the eastern long-nosed potoroo *Potorous tridactylus* and the long-footed potoroo *Potorous longipes* as they are from each other (Sinclair & Westerman 1997). Gilbert's potoroo is similar in appearance to the long-nosed potoroo, although more rufous in colour (Menkhorst & Knight 2001). This species is a specialist mycophagist and over 90 per cent of its faecal matter comprises fungal material (Nguyen et al. 2005).

Survey methods

DEC (2009) use hair-arch surveys to search for new populations. In a hair-arch survey, flexible plastic sheets are bent into an arc and held in shape by bent fence wire then placed in animal runways. Hair arches are sometimes baited with universal bait to encourage animal visitation. Hair is collected with double-sided sticky tape attached to the inside of the arch. The DEC (2009) reports that hair collection is labour intensive, although this method is less invasive than live trapping. Baited camera traps may be useful for locating unknown populations, and universal baits with added truffle or pistachio oil have been used successfully on this species (T. Friend pers. comm.).

The survey techniques recommended to detect the presence of Gilbert's potoroo in areas up to 5 hectares in size are the same as those recommended for the long-nosed potoroo, which are as follows:

- daytime searches for potentially suitable habitat resources, such as areas with a dense understorey (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including diggings, tracks and nests (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2)

- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- baited camera traps using universal bait (peanut butter and rolled oats) with truffle, pistachio or walnut oil (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- community liaison to identify new populations and increase awareness of this species may be of use.

It is recommended that one or more forms of direct detection surveys, such as spotlight surveys (Section 3.3.3), cage trapping surveys (3.3.10) or hair sampling surveys (3.3.7) should be conducted in association with the indirect survey techniques outlined above. Given the conservation status of this species, minimising handling and capture stress should be a priority. Therefore, non-trap methods of detecting this species (for example, camera traps and hair funnels) should be used wherever possible.

Similar species in range

Gilbert's potoroo is sympatric with the southern brown bandicoot *Isodon obesulus*. The tracks made by bandicoots are distinguishable from those of Gilbert's potoroo by the presence of three rather than five digits on the forepaws, and bandicoot diggings have a distinctive conical shape. The woylie *Bettongia pencillata* also occurs in south-western Western Australia, although it is not known to be sympatric with the Gilbert's potoroo in its limited range.

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Golden bandicoot

Isoodon auratus auratus

States and territories: Western Australia and Northern Territory.

Regions: Northern Kimberley region and Augustus Island, Western Australia, and Marchinbar Island, Northern Territory (McKenzie et al. 2008).

Habitat: Hummock grass on sandstone and deciduous vine thickets (McKenzie et al. 2008).

Habit: Ground-dwelling.

Avg. body weight: 310 g (McKenzie et al. 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: insects and tubers (McKenzie et al. 2008).

Breeding: Breeds throughout the year, with peaks in breeding activity at the height of the wet season (December to January) and the dry season (August) (McKenzie et al. 2008).

Description

The golden bandicoot had a former distribution that covered much of mainland Australia (McKenzie et al. 2008). Today, the species range is greatly restricted, with three subspecies occurring as follows:

- *I. a. auratus* on Marchinbar Island (Northern Territory), the northern Kimberley (mainland Western Australia) and Augustus Island (Western Australia)
- *I. a. barrowensis* on Barrow Island and Middle Island off the Pilbara coast (Western Australia) (Woinarski 2001), and
- *I. a. arnhemensis*, previously recorded in Arnhem Land (McKenzie et al. 2008), but which has not been recorded from definite observations on the Northern Territory mainland in recent years despite large-scale biodiversity surveys (Woinarski 2001).

The taxonomy of these subspecies is currently under review and relationships between this species and the southern brown bandicoot *I. obesulus* are being explored (Pope et al. 2001).

Southgate and colleagues (1996) found that on Marchinbar Island the species had a preference for low heath or shrubland vegetation types that are found on sand or sandstone. From an analysis of 23 scats, the species' diet comprised mainly invertebrates but also some plant matter (Southgate et al. 1996). Golden bandicoots dig conical foraging pits (Triggs 1998) and shelter during the day in rudimentary nests and shallow scrapes under vegetation or rocks (Southgate et al. 1996).

Threatening processes to the golden bandicoot are unknown, but anecdotal evidence suggests that predation by cats may be a factor (Southgate et al. 1996). Cats do not occur on Marchinbar Island and Barrow Island where populations are present; however, a population of golden bandicoots on Hermite Island became extinct when cats were introduced (McKenzie et al. 2008). Dogs are present on Marchinbar Island and golden bandicoot hair has been recovered from dog scat samples (Southgate et al. 1996). Changes to fire regimes are also believed to be driving the population trends of tropical mammals like the golden bandicoot.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the golden bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat, such as heath and open woodland habitats on sandy or sandstone substrates (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats, nests and conical foraging holes (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- baited camera traps using universal bait (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Southgate and colleagues (1996) reported that female bandicoots rejected pouch young after handling. Given that established non-invasive techniques like camera trapping are available, these options should be fully explored before using more invasive techniques. If animals are to be caught, high-sugar bait (containing honey or golden syrup) should be used in traps (see Southgate et al. 1996).

Hair sampling device surveys are not recommended because Southgate and colleagues (1996) did not successfully detect the golden bandicoot on Marchinbar Island with this technique. The geographic distribution of this species and its subspecies is still not well known and this should be considered when undertaking field surveys.

Similar species in range

The golden bandicoot is similar in appearance to the northern brown bandicoot *Isoodon macrourus*, which occurs throughout much of northern Australia. The two species can be distinguished easily by the larger size and duller colouration of the northern brown bandicoot.

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Golden bandicoot (Barrow Island)

Isoodon auratus barrowensis

States and territories: Western Australia.

Regions: Barrow Island, Middle Island and Augustus Island off Western Australia (DEWHA 2008).

Habitat: Hummock grass and limestone caves.

Habit: Ground-dwelling.

Avg. body weight: 310 g (McKenzie et al. 2008).

Activity pattern: Nocturnal.

Diet: Omnivore: insects and tubers.

Breeding: Breeding occurs throughout the year, usually after rain (McKenzie et al. 2008).

Description

The golden bandicoot had a former distribution that covered much of mainland Australia (McKenzie et al. 2008). Today, the species range is greatly restricted, with three subspecies occurring as follows:

- *I. a. auratus* on Marchinbar Island (Northern Territory), the northern Kimberley (mainland Western Australia) and Augustus Island (Western Australia)
- *I. a. barrowensis* on Barrow Island and Middle Island off the Pilbara coast (Western Australia) (Woinarski 2001), and
- *I. a. arnhemensis*, previously recorded in Arnhem Land (McKenzie et al. 2008), but which has not been recorded from definite observations on the Northern Territory mainland in recent years despite large-scale biodiversity surveys (Woinarski 2001).

The taxonomy of these subspecies is currently under review and relationships between this species and the southern brown bandicoot *I. obesulus* are being explored (Pope et al. 2001).

The Barrow Island golden bandicoot is a relatively small subspecies of the *Isoodon auratus* complex, confined to Barrow Island and Middle Island off the Pilbara coast in Western Australia (McKenzie et al. 2008). On those islands the species is relatively abundant (McKenzie et al. 2008). Golden bandicoots on Barrow Island have a similar diet to the ones on Marchinbar Island, feeding on ants, termites, turtle eggs, small reptiles and the common rock rat *Zyomys argurus* (McKenzie et al. 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the golden bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such heath and open woodland habitats on sandy or sandstone substrates (description of the survey technique and recommended effort is outlined in Section 3.1)



- daytime searches for signs of activity, including tracks, scats, nests and conical foraging holes (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- baited camera traps using universal bait (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Southgate and colleagues (1996) reported that female bandicoots rejected pouch young after handling. Given that established non-invasive techniques like camera trapping are available, these options should be fully explored before using more invasive techniques. If animals are to be caught, high-sugar bait (containing honey or golden syrup) should be used in traps (see Southgate et al. 1996).

Hair sampling device surveys are not recommended because Southgate and colleagues (1996) did not successfully detect the golden bandicoot on Marchinbar Island with this technique. The geographic distribution of this species and its subspecies is still not well known and this should be considered when undertaking field surveys.

Similar species in range

The golden bandicoot on Barrow Island and Middle Island does not overlap in distribution with other bandicoot species.

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Golden-backed tree rat

Mesembriomys macrurus

States and territories: Western Australia and possibly Northern Territory.

- Regions:** Currently confined to the North Kimberley region and islands in the Buccaneer Arch group where the average annual rainfall is above 600 mm (Palmer et al. 2003; McKenzie & Kerle 2008). Its current status in the Top End of the Northern Territory is poorly understood with unconfirmed sightings and possible hair samples from the Wessel Islands and Indigenous knowledge indicating the persistence of at least one population on the Arnhem Land plateau (Woinarski & Palmer 2006). The species formerly occurred in Western Australia as far south as Cape Range near Exmouth, including the Pilbara coastline and in the Top End of the Northern Territory; including Deaf Adder Creek in western Arnhem Land (Parker 1973; Watts & Aslin 1981).
- Habitat:** In the Kimberley the species occurs in a variety of habitats, including rainforest, eucalypt-dominated woodlands, lateritic uplands with *Livistonia* palms, blacksoil plains with *Pandanus* trees, sandstone screes, mangrove swamps and coastal beaches adjoining the above habitats (McKenzie & Kerle 2008). The last specimen collected in the Northern Territory (1969) came from *Pandanus* along a watercourse in sandstone habitat in Deaf Adder Creek. It has also been recorded in hollow trees of *Eucalyptus* scrubs in the Roebuck Bay area of the south-western Kimberley's (Dahl 1897).
- Habit:** Mostly arboreal.
- Avg. body weight:** 267 g (McKenzie & Kerle 2008).
- Activity pattern:** Nocturnal, possibly crepuscular.
- Diet:** Omnivorous, eating flowers, fruits, insects, plant shoots, grasses and leaves (McKenzie & Kerle 2008). Its diet in formerly occupied drier habitats is unknown, although it was recorded raiding dwellings for rice and flour in the Broome region (McKenzie & Kerle 2008).
- Breeding:** Litters of one to three, possibly breeds throughout the year (Menkhorst & Knight 2004).

Description

The golden-backed tree rat is a large rodent that has a distinctive long, slightly brush-tipped tail and a broad chestnut-gold stripe along the back. The species' former range encompassed much of the Pilbara and Kimberley regions of Western Australia and the northern part of the Northern Territory. The range has contracted, with the species now presumed locally extinct in the Pilbara and restricted to the higher rainfall areas of the northern Kimberleys, including five offshore islands in the Buccaneer Arch group (McKenzie & Kerle 2008). The species' status in the Northern Territory currently remains unclear, with no positive sightings recorded since 1969, although the species has been detected in hair samples collected from the Wessel Islands in 1993 (Woinarski 2000).



No single process has been identified as contributing to the decline of the species' range, although introduced predators and changed fire regimes resulting in broad-scale habitat alteration are likely to have been significant (Woinarski 2002).

Survey methods

There is currently not enough information available to formulate general survey methods required to detect the golden-backed tree rat. The survey methods suggested here conform to the Northern Territory DIPE (2005) standard biodiversity survey methods (see Appendix). The following survey techniques are recommended to detect the presence of the golden-backed tree rat in areas up to 5 hectares in size:

- daytime searches for potential habitat resources, such as *Pandanus* trees (habitat preferences are described in Section 3.2.9)
- daytime searches for signs of activity, such as nests in trees, particularly in *Pandanus*, scratches on tree trunks or scats (description of the survey technique and recommended effort is outlined in Section 3.2)
- stagwatching surveys at potential nest sites (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- spotlight surveys conducted according to Section 3.3.3 along transects, tracks or roads (additional surveys from a vehicle may also be made)
- combined arboreal and ground-based Elliott B and cage trapping surveys (divide the effort recommended for both surveys in half and carry them out simultaneously) across the subject site according to a stratified design as described in Section 3.3.9
- camera traps (including untimed systems) may be a useful technique using bait stations of peanut butter and rolled oats (M Schulz pers. obs.).

Similar species in range

The golden-backed tree rat is sympatric with the closely related black-footed tree rat, *Mesembriomys gouldii*. The latter species is larger, with a black tail and black feet. In contrast, the golden-backed tree rat has pink feet, a white tail, and a distinct golden-chestnut dorsal stripe that distinguishes it from all other tree rats.

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Greater bilby

Macrotis lagotis

States and territories:	Queensland, Northern Territory and Western Australia, and reintroduced to South Australia.
Regions:	Deserts of central Australia: Western Australia (from the Northern Territory border to Broome and south to Warburton) Northern Territory in the Tanami Desert South-western Queensland (Johnson 1995), and Reintroduced to areas within South Australia (Roxby Downs, Venus Bay Conservation Park, Thistle Island, and Yookamurra Sanctuary), Western Australia (Dryandra Woodland, Peron Peninsula), Queensland (Currawinya National Park), and NSW (Scotia Sanctuary) (Pavey 2006).
Habitat:	Acacia scrubland and hummock grasslands (Western Australia and Northern Territory), clay stony downs in channel country (Queensland).
Habit:	Ground-dwelling (burrowing).
Avg. body weight:	1750 g (males) and 950 g (females) (Johnson 1995).
Activity pattern:	Nocturnal.
Diet:	Omnivore: insects, larvae, seeds, bulbs, tubers and fungi (Gibson 2001). Opportunistic feeding strategy selecting dietary items in accordance with their abundance (Gibson & Hume 2004).
Breeding:	Capable of breeding throughout the year in captivity but is probably mediated by environmental conditions, with one to three offspring per litter (Southgate et al. 2000).

Description

The greater bilby is a distinctive Peramelid that had a former distribution which covered up to 70 per cent of the Australian mainland, mostly in arid and semi-arid environments (Southgate 1990a). This range has contracted and now the species' range is restricted to only the most arid parts of the former distribution, including parts of the Tanami Desert, a small area north-east of Alice Springs, the Gibson Desert, northern Great Sandy Desert, the inland Pilbara, the southern Kimberley, and a small area in the channel country in south-western Queensland (Southgate 1990b).

The greater bilby is found in hummock grassland habitats, predominantly comprising Spinifex, with an overstorey of Acacia and Melaleuca. The species feeds on a variety of food sources within their arid habitat, including insects, seeds, bulbs and fungi with preference related to availability (Gibson 2001). Signs of foraging and digging occur around the base of overstorey trees, where greater bilbies dig holes up to 250 millimetres in depth in search of food (Gibson 2001).

Greater bilbies emerge from burrows after dark to forage at night, and during the day they shelter in a relatively extensive burrow system that is up to 3 metres in length and 1.8 metres deep (Johnson 1995). A burrow can shelter one or more adults and newly weaned offspring have also been observed to remain for a short time in their maternal burrow (Johnson 1995).

The main reason for the decline of the greater bilby appears to be predation by feral cats and foxes, with predation by dingos possibly contributing (Southgate 1987). Competition with rabbits and livestock through grazing and modified fire regimes are also likely to have contributed to the decline (Johnson 1995).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the greater bilby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as hummock grassland in arid regions (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including burrows, tracks, scats and diggings (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2.

Should confirmation of the species' presence be required after detection of signs, then spotlight surveys conducted at the entrances of burrows after dusk would be a more time and cost efficient manner to directly observe the species rather than conducting a trapping survey. Such observational surveys are similar in principle to stagwatching surveys. The recommended survey effort for this technique has been outlined in Section 3.3.4.

Similar species in range

There are no similar species.

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Greater stick-nest rat, wopilkara

Leporillus conditor

States and territories: South Australia (reintroduced to Western Australia).

Regions: South Australia: East and West Franklin Islands and reintroduced to Reevesby, St. Peter Islands, Venus Bay and Roxby Downs (Breed & Ford 2007).

Western Australia: reintroduced to Salutation Island and Heirisson Prong (Robinson 2008a).

Habitat: Limestone country with dense, low shrub cover.

Habit: Ground-dwelling.

Avg. body weight: 350 g (Robinson 2008a).

Activity pattern: Mostly nocturnal.

Diet: Exclusively herbivorous, feeding on the leaves and fruit of mostly succulent plants (Robinson 2008a).

Breeding: Breeds throughout the year, but mostly March and April, when between one and three young are born (Robinson 2008a).

Description

The greater stick-nest rat is approximately the size of a small rabbit, has a compact body, large eyes and blunt nose. They are one of two *Leporillus* species known for their curious habit of building large, communal nests from twigs and branches. The other species, the lesser stick-nest rat, *Leporillus apicalis*, is considered extinct (Robinson 2008b). The large nest can be up to 1.5 metres in diameter and 1 metre high, and may house up to 20 animals. The nests are persistent (some up to 2000 years old), and may be found over the species' former range where they have been used to establish previous fauna and flora records (for example, Pearson et al. 2001). The greater stick-nest rat had a former range across much of arid and semi-arid southern Australia, until the introduction of feral predators and the expansion of arid zone grazing led to the decline of the species' range in the mid-nineteenth century (Copley 1999).

Both species of stick-nest rat became extinct on mainland Australia in the 1930s. In 1920, a small population of the greater stick-nest rat was found on the Franklin Islands off the South Australian coast (Jones 1922). This population remains extant today with an estimated population of 1000 to 1500 individuals (Robinson 2008a). It has been the source of animals bred in captivity and released to a number of other islands (Reevesby and St. Peter in South Australia and Salutation in Western Australia) and mainland sites (Heirisson Prong, Western Australia and Venus Bay, South Australia). The reintroduced island populations have expanded in size, while the mainland populations have had mixed success, mostly due to inadequate control of introduced predators (Copley 1999).



Survey methods

On the basis of previous studies, the following survey techniques are recommended to detect the presence of the species in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs such as stick-nests, tracks or scats (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- Elliott A/B trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9, using a mixture of peanut butter and rolled oats as bait
- camera traps at any unconfirmed locations such as overhangs (see Section 3.3.6)
- possibly spotlight surveys conducted according to the technique description and recommended effort provided in Section 3.3.3
- consultation with local people, including leaseholders, station hands, park rangers and field workers and investigating potential Indigenous knowledge of this species' presence in an area.

Care must be taken when handling these animals as the skin on their tail strips off easily if held by the tail.

Similar species in range

There are no similar species within the range of the greater stick-nest rat. The lesser stick-nest rat, although considered extinct, can be distinguished by its more slender build and bicoloured tail that is marked by a white tip. If possible, tissue samples (tail tip or ear punch) should be taken, provided that the appropriate permission and licensing has been granted by the relevant government organisations, and lodged with the South Australian Museum which maintains an extensive tissue collection of this species.

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Hastings River mouse

Pseudomys oralis

States and territories: NSW and Queensland.

Regions: Patchy distribution along the Great Dividing Range, from Barrington Tops NSW to Warwick Queensland (Townley 2008).

Habitat: Open woodlands ranging in altitude from 300 to 1250 m with grass, sedge and mat-rush *Lomandra* sp. dominated understorey (NSW NPWS 2003). Other habitat characteristics include a dense ground-cover, suitable shelter sites and an increased time since burning (> 10 years) (NSW NPWS 2003). The species utilises not only the sedge and mat-rush habitats on creek lines, but also ridge and mid-slope habitats with a dense ground cover and high species diversity (Meek et al. 2006; Townley 2008). They appear to be able to inhabit old-growth forests with no historical logging (Townley 2000) and areas that are subject to burn cycles of less than 5–8 years (Meek et al. 2003).

Habit: Ground-dwelling.

Avg. body weight: 85 g (females), 95 g (males) (Townley 2008).

Activity pattern: Nocturnal.

Diet: Herbivore: a large component of this species' diet comprises native legumes, especially *Glycine* spp., and seeds and leaves of *Carex* sp., *Juncus* spp. and *Poa* spp., especially new growth (Fox et al. 1994; Townley 2008). Additional dietary items include moss, hypogeal fungi and insects.

Breeding: Breeding has been recorded between August and March, with two to three young being raised. Between one and three litters may be born over a season (Townley 2008). Nest sites appear to vary depending on location. Sites include rock piles, crevices, tree butt hollows (Townley 2000) and fallen logs (Meek et al. 2006). The same nest site can be used by successive generations over several years (Townley 2008).

Description

The Hastings River mouse is one of the rarest extant *Pseudomys* species, with only about 620 captured since 1969 (NSW NPWS 2003). A thorough review of the ecology and conservation management strategy for the Hastings River mouse is provided in the recovery plan for the species (NSW NPWS 2003). Genetic studies indicate that there is little gene flow between populations (Jerry et al. 1998) suggesting that the distribution across its range is not continuous.

This species typically occurs in low densities, with frequently less than one individual per hectare (Townley 2008). As a result it can easily escape detection in fauna surveys where the trapping effort is comparatively low. Consequently, targeted trapping surveys are required in habitat that involves high trapping effort and is therefore labour intensive (see the reference to guidelines in the section below).



Survey methods

Surveys for the Hastings River mouse must conform to the survey guidelines provided in the species' recovery plan (NSW DECC 2005).

Similar species in range

The Hastings River mouse is sympatric with a number of other rodent species. It can be distinguished from these in the field using colouration, standard body measurements and external features, such as large protruding eyes, a rounded nose ('Roman nose'), distinctly white feet and the bicoloured tail (Townley 2008). The black rat *Rattus rattus* and the swamp rat *R. lutreolus* both have dark feet, small eyes and a unicoloured tail (Tweedie and York, 1993), whereas the Hastings River mouse has a slender bicoloured tail (dark above, light below) (Townley 2008). The Hastings River mouse also has four nipples in the groin region, in contrast to the bush rat *Rattus fuscipes* that has more than eight nipples located over the chest region. In addition, the Hastings River mouse lacks the strongly 'ringed' tail of the bush rat (NSW DECC 2005). The species is also similar to the eastern chestnut mouse *Pseudomys gracilicaudatus* but is distinguished by having bicoloured skin and hair, rather than just bicoloured hair, as with the eastern chestnut mouse (Townley 2008). Voucher specimens of this species are not allowed to be taken (NSW DECC 2005).

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Julia Creek dunnart

Sminthopsis douglasi

States and territories: Queensland.

Regions: Downs Country, north central Queensland, in an area of 8000 km² between Julia Creek and Richmond.

Habitat: Restricted to treeless or lightly timbered tussock grasslands on cracking clay soils associated with Mitchell Grass Downs, Gulf Plains and Desert Upland Bioregions (Kutt 2003). Favours habitat where there is a dense cover of flinders grass *Isielesma* spp. (Woolley 2008).

Habit: Ground-dwelling.

Avg. body weight: 55 g (Woolley 1995).

Activity pattern: Nocturnal. Probably shelters during the day in cracks in clay soils in the dry season, and in the wet season under or in vegetation (Woolley 2008).

Diet: An opportunistic feeder whose diet can range from invertebrates to small reptiles and mammals (Lundie-Jenkins & Payne 2000).

Breeding: The breeding season extends from September to February, with females having the potential to raise two litters of eight young in a season (Woolley 2008).

Description

The Julia Creek dunnart is restricted to the Mitchell grass downs country of north central Queensland and until 1992 was known only from museum records (Woolley 1992). As a result of targeted trapping surveys and the identification of remains in predator scats or pellets, it is now known to occupy a large area of Downs Country in central north Queensland (Woolley 1992; Kutt 2003).

It is the largest species of *Sminthopsis* with brown fur, speckled with grey above and buff white below, and with pinkish-white feet (Menkhorst & Knight 2004). It has a prominent facial stripe, rufous cheek hair and dark coloured rings around the eyes. Rufous hair may also be present at the base of the ears and towards the tip of its long, tapering tail, which is fattened at the base and slightly shorter than the length of the head and body combined (Woolley 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Julia Creek dunnart in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as Mitchell grass habitat with cracks in the soil that may provide shelter sites (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)

- hair sampling device surveys, as the Julia Creek dunnart is included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A and E trapping surveys conducted according to the description of the technique and recommended effort provided in Section 3.3.9, but to be consistent with previous surveys for the Julia Creek dunnart, increase the survey effort as follows:
- in areas of suitable habitat, use four rather than two survey sites per 5 hectare area (the minimum number of sites specified in Section 3.3.9)
- set 25 traps in each survey site, spaced at 20 metre intervals, and
- set traps for four to five consecutive nights (equating to 400 to 500 trap nights)
- consider the placement of camera traps in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric dunnart species
- community consultation may be critical for locating additional populations, particularly graziers and other people working in the Mitchell Downs grasslands.

Similar species in range

The Julia Creek dunnart can be distinguished from sympatric species, the fat-tailed (*S. crassicaudata*) and the striped-faced dunnart (*S. macroura*) by its larger size, length of the hindfeet (less than 20 millimetres), and the presence of a dark eye ring, dark upper outer edge of the ears and dark hairs on the tip of the tail (Woolley 2008).

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Kangaroo Island dunnart

Sminthopsis aitkeni

States and territories: South Australia.

Regions: Kangaroo Island (with all recent records from Flinders Chase National Park).

Habitat: Occurs in a variety of mallee heath vegetation types on both lateritic and sandy soils that had not been burnt in the last 11 years (Gates 2001; Robinson 2008).

Habit: Ground-dwelling.

Avg. body weight: 22.5 g (Robinson 1995).

Activity pattern: Nocturnal.

Diet: Invertebrates: spiders, ants, scorpions, grasshoppers and centipedes (Gates 2001).

Breeding: All juveniles captured by Gates (2001) were estimated to have been born between early October and early January (based on comparisons with growth curves for the related common dunnart *Sminthopsis murina*), which suggests a possible September to December breeding season for the Kangaroo Island dunnart (Gates 2001). No adult females have been captured and so litter size is unknown (Gates 2001).

Description

The Kangaroo Island dunnart was discovered in 1969 during land clearing, and at that time was classed as the common dunnart due to its similarity in appearance to that species. Electrophoretic analysis has since been used to separate the two species (Baverstock et al. 1984). The Kangaroo Island dunnart differs in appearance from the common dunnart by having dark sooty-coloured dorsal fur, and a slender pointier muzzle. The two species are considered allopatric (Robinson 2008). However, it is possible that the Kangaroo Island dunnart may occur on the adjacent mainland. If there is any doubt, a tissue sample should be taken for confirmation, provided that permission is granted from the relevant South Australian government authorities.

Survey methods

It is recommended that future surveys for detection of the Kangaroo Island dunnart should be consistent with the methods used by Gates (2001) and Owens (2000). Wherever possible, surveys should be designed to replicate sampling over time to provide an appropriate survey effort for this species, which has been shown to be difficult to detect.

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Kangaroo Island dunnart in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as habitat that has not been burnt for at least 11 years (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens using the technique and effort described in Section 3.2.3
- pitfall trapping surveys (with trap depth recommended to be 60 centimetres) as the primary detection technique, conducted to the technique and effort described in Section 3.3.8

- active searches under debris such as fallen logs, and potentially place artificial material on the ground and check periodically. This is a highly effective technique for the closely related common dunnart (M Schulz. pers. obs.)
- consider the placement of camera traps in suitable habitat, as this technique is ideal for cryptic species occurring at low densities, particularly where there are no sympatric species that could be readily confused
- community consultation may be critical for locating additional populations, particularly where people live in dwellings backing onto bush remnants.

Hair sampling device surveys are not recommended because the Kangaroo Island dunnart is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change for this species, then hair sampling may provide an appropriate alternative detection technique.

Similar species in range

No other dunnart species occurs on Kangaroo Island. On adjacent mainland areas this species can be separated from the common dunnart by blackish rather than brown dorsal fur colouration, grey rather than white belly fur and a longer tail (Robinson 2008). The Kangaroo Island dunnart may possibly occur on the mainland, and hence voucher or tissue/hair samples should be collected from mainland specimens in adjacent areas such as on the Fleurieu Peninsula, provided that the appropriate permission and licensing has been granted by the relevant South Australian government organisation.

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Kowari

Dasyuroides byrnei

States and territories: Queensland and South Australia.

Regions: Patchily distributed in the Channel Country of the Lake Eyre Basin between Boulia in Queensland and Cooper Creek in South Australia (Lim 2008, P Canty pers. comm.).

Habitat: Stony 'gibber' desert with less than 25 per cent vegetative cover between braided stream channels and sand dunes (Lim 2008).

Habit: Ground-dwelling.

Avg. body weight: 120 g (males) and 100 g (females) (Aslin & Lim 1995).

Activity pattern: Primarily nocturnal.

Diet: Carnivorous: primarily arthropods, also reptiles and mammals (Lim 2008).

Breeding: May to December, following rain, with between six and seven young born 30–35 days later (Aslin & Lim 1995).

Description

The kowari is a small, stocky dasyurid that can be readily identified by the dense black brush on the distal half of the tail. It is confined to scattered populations on gibber patches among grasslands, sand dunes and river channels in south-western Queensland and north-eastern South Australia. The kowari shelters in burrows during the day. Although patchily distributed, this species can undergo population eruptions as a result of good seasonal conditions.

The threatening processes for this species are unclear; however, the main threat is thought to be the reduction of ground-cover and soil erosion due to grazing by introduced herbivores, which in turn may reduce the available prey (Lim 1992, Canty & Brandle 2008). Road-killed individuals have been observed as a result of traffic on gibber plains (Lim 1992).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the kowari in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as sites for burrows (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs of activity including burrows, freshly excavated earth, tracks and scats (description of the survey technique and recommended effort is provided in Section 3.2). Note that identification of tracks requires confirmation by an expert
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- Elliott A trapping survey, using dog biscuits soaked in tuna oil for bait, conducted according to the description of technique and recommended effort provided in Section 3.3.9. However, increase the distance between traps from 10 metres to 100 metres

- potentially, predator pad surveys (follow the description of the survey technique and recommended effort provided in Section 3.3.2 and forthcoming publications from South Australia DEH, if available)
- spotlighting from a vehicle is effective when population numbers are high, particularly where the passenger has a hand net for catching individuals to confirm identification (M Schulz pers. comm.), provided animal welfare and occupational health and safety considerations are met
- community consultation, especially with landholders, farm hands and bore runners. This approach has resulted in a number of new localities on leasehold land (M Schulz pers. comm.) though care needs to be taken that it is not being confused with similar species (such as the ampurta, mulgara and sometimes kultarr)
- searching for road-killed individuals (especially on bitumen road surfaces) in suitable habitat
- possibly a hair sampling device survey as the kowari is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- consider the placement of baited camera traps in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric species (description of technique in Section 3.3.6).

Similar species in range

The kowari is similar in appearance to the mulgara *Dasycercus cristicauda* and ampurta *Dasycercus hilleri*. The extent of any overlap in distribution is unclear, due to the ambiguities in the identification of the latter two species (see ampurta species profile). However, the kowari can be distinguished from the other two species by the white colour of the fur at the base of its tail, the distinctive black brush at the end of its tail (Lim 2008) and having only four toes on the hind foot (mulgara and ampurta have five).

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Leadbeater's possum

Gymnobelideus leadbeateri

States and territories: Victoria.

- Regions:** Confined to the montane ash forests of the Central Highlands of Victoria. However, there is a small resident colony in a lowland swamp forest at Yellingbo State Nature Reserve (Smales 1994; Harley et al. 2005). Additionally, specimens were collected in the 1860s from the edge of the Koo-wee-rup Swamp on the western Gippsland Plain and from Mt Wills in the Eastern Highlands (Menkhorst & Lumsden 1995).
- Habitat:** Montane ash forests, dominated by mountain ash *Eucalyptus regnans*, alpine ash *E. delegatensis* or shining gum *E. nitens*. However, recent records include observations of animals sheltering in snow gum *E. pauciflora* stumps in the Victorian Alps (Jelinek et al. 1995). The population at Yellingbo occurs in forest dominated by mountain swamp gum *E. camphora* (Menkhorst & Lumsden 1995). Critical habitat requirements for this species include numerous dead stags or live hollow-bearing trees, a dense canopy or secondary tree layer, an understorey with *Acacia* spp. well-represented and an abundance of loose bark (Smith & Lindenmayer 1988; Lindenmayer et al. 1991).
- Habit:** Arboreal.
- Avg. body weight:** Varies between an average of 122 g in spring and an average of 133 g in autumn (Smith & Harley 2008).
- Activity pattern:** Nocturnal.
- Diet:** Acacia gum, sap of paperbarks and tea-tree, eucalypt nectar and manna, honeydew and a variety of arthropods (Smith & Harley 2008).
- Breeding:** May breed twice a year (winter and spring), with a maximum of two young per litter in the highlands and breed year-round in the lowlands (Smith & Harley 2008).

Description

Leadbeater's possum is one of the faunal emblems for Victoria. It is a small, fast-moving possum with grey to greyish-brown fur above and paler below, with a dark mid-dorsal stripe from the nose to the base of its club-shaped tail. A black stripe runs between the cheeks and the throat (Menkhorst & Knight 2004). Colonies have a matriarchal social structure and the species is polyoestrus, with breeding success related to food supply (Smith 1984).

Until 1961, Leadbeater's possum was only known from five specimens, with no records between 1909 and 1960. Since then, the species has been recorded at more than 300 sites, although some of these sites have subsequently been logged and no longer support this species (Menkhorst & Lumsden 1995). Its distribution is dependent on vegetation structure, food availability and nest-tree abundance. The possums prefer nesting in living or dead trees with short, thick trunks (2 metres diameter at breast height) and which contain numerous hollows (Lindenmayer et al. 1991). Trees which are estimated to be around 200 years in age, surrounded by young regenerating or mixed-aged mountain ash forest is considered optimal habitat in the Central Highlands as it provides nesting and foraging sites.

The occurrence of this species in lowland swamp forest is poorly understood, with only one remnant population remaining. It is unlikely that additional populations occur due to the extensive fauna surveys conducted in remnant vegetation on the Gippsland Plains. However, the possibility of rediscovery in additional localities cannot be ruled out given the cryptic nature of this possum. Similarly, targeted surveys have been undertaken in the Mt Wills area without relocating the species. However, any survey in this region of the Eastern Highlands should target this species and ensure that all sugar gliders detected are identified with certainty.

Management measures for conservation of Leadbeater's possum are outlined in the species' recovery plan (Macfarlane et al. 1997) in line with current understanding of the species' ecological needs and vulnerability to loss of habitat. Processes such as fire and selective logging help to maintain a mosaic of ecological successional states; however, high-intensity fire and clear felling in some areas can render them unsuitable for periods of up to 200 years (Macfarlane et al. 1997).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of Leadbeater's possum in areas up to 5 hectares in size:

- daytime searches for potential den sites in short and thick-set (minimum two metre diameter at breast height) mature hollow-bearing trees/stags (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, such as scratches on tree trunks, or scats on the ground below trees, particularly those considered potential den sites (description of the survey technique and recommended effort is outlined in Section 3.2.6 and 3.1.2)
- stagwatching surveys at potential den sites (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- spotlight surveys on foot along transects, tracks or roads (description of the survey technique and recommended effort is outlined in Section 3.3.3). Spotlighting surveys from a vehicle are considered less effective (M Schulz pers. comm.)
- arboreal hair sampling device survey, consistent with the methods described in Section 3.3.7
- if the species is not detected during the application of the aforementioned, then a cage trapping program (Section 3.3.10) or nest box survey (Section 3.3.6) is recommended.

Similar species in range

Leadbeater's possum is distinguishable from the sympatric sugar glider by the absence of a gliding membrane and its club-shaped tail, which is broader near the tip than at the base (Menkhorst & Knight 2004). This species can readily be confused with sugar gliders by inexperienced observers, a factor likely to be responsible for its only relatively recent discovery in the lowland forests at Yellingbo.

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Long-footed potoroo

Potorous longipes

States and territories: Victoria and NSW.

Regions: There are three known disjunct sub-populations of the long-footed potoroo, *Potorous longipes*, (Vic DNRE 2000):

east Gippsland (north-east of Orbost Victoria)

south-eastern NSW (South-East Forests National Park and Bondi, Nungutta and Yambulla State Forests), and

north-eastern Victoria (West Buffalo, East Riley and Tea Tree Range areas of the Barry Mountains).

There is possibly a fourth location in north-western Victoria (east of Mount Drummer) (Claridge 2002).

Habitat: Temperate rainforest, riparian forest and damp or wet sclerophyll forest, with a mixed species overstorey and a dense understorey (Victoria DNRE 2000). These areas are usually sheltered gullies with deep moist soils, with the dense groundcover providing protection from predators (Menkhorst & Seebeck 2008).

Habit: Ground-dwelling (nest in ferns or wire-grass).

Avg. body weight: 2100 g (males) and 1700 g (females) (Menkhorst & Seebeck 1995).

Activity pattern: Nocturnal.

Diet: Omnivorous but primarily mycophagous; over 90 per cent of diet comprises fungi (mostly mycorrhizal sporocarps), invertebrates and plant roots (Menkhorst & Seebeck 2008).

Breeding: Monogamous mating system (Menkhorst & Seebeck 1995).

Description

The long-footed potoroo was only described in 1980 (Seebeck & Johnson 1980) and since then extensive survey effort has been made to determine the species' range, abundance and aspects of its biology. Low density populations (Menkhorst & Seebeck 1995) in combination with difficulty in detecting the species means that there is still much to learn about the long-footed potoroo. For instance, in 1995 the remains of an individual were found 170 kilometres west of the closest known record from East Gippsland, in an area that previously had not been identified as potential habitat from climate modelling predictions (Claridge 2002).

Studies so far have shown that adult long-footed potoroo home ranges vary in size between populations (22–60 hectares East Gippsland and 14–23 hectares north-eastern Victoria), with males ranging over a greater area than females (Green et al. 1998; Vic DNRE 2000). Home range size probably relates to available resources of fungi and other habitat characteristics (Green et al. 1998; Green et al. 1999), which is similar to the long-nosed potoroo and, like that species, the long-footed potoroo is probably capable of breeding at any time of the year, particularly in response to resource availability (Vic DNRE 2000).

Survey methods

Survey techniques recommended to detect the presence of the long-footed potoroo in areas up to 5 hectares in size are the same as those recommended for the long-nosed potoroo, which are as follows:

- daytime searches for potentially suitable habitat resources, such as areas with a dense understorey (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including diggings, tracks and nests (description of the survey technique and recommended effort is outlined in Section 3.2). However, where the long-footed potoroo occurs in sympatry with the long-nosed potoroo, tracks and diggings cannot be distinguished between the species
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2. However, where the long-footed potoroo occurs in sympatry with the long-nosed potoroo or small wallaby species, tracks cannot be distinguished, or may be difficult to distinguish between species
- baited camera traps using universal bait (peanut butter and rolled oats) with truffle, pistachio or walnut oil (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- community liaison to identify new populations and increase awareness of this species.

An integrative approach is recommended for this species, whereby direct detection surveys like spotlighting (Section 3.3.3), cage trapping (3.3.10) or hair sampling surveys (3.3.7) should be conducted in conjunction with searches for traces like diggings, scats and tracks, baited camera traps and predator scat surveys etc. Also, given the mixed results of past trapping efforts, different techniques may work better in some locations than others and a variety of methods should be attempted for any given survey program.

To help distinguish the tracks of different species in the field, NSW State Forests have prepared foot casts of potoroos and bandicoots (S Ingleby pers. comm.) although, as indicated above, there are difficulties associated with identifying tracks of this species.

Given the paucity of information about the geographic distribution of this species, consultation and engagement with the community is likely to provide researchers with a starting point for further search efforts and may generate interest and awareness of this species in the community.

Similar species in range

The long-footed potoroo overlaps in distribution with the long-nosed potoroo, the long-nosed bandicoot *Perameles nasuta* and the southern brown bandicoot *Isodon obesulus*. The hindfoot of the long-footed potoroo is longer than the head and the species has 24 chromosomes, unlike the long-nosed potoroo with shorter hindfeet and 12 and 13 chromosomes for females and males respectively (Menkhorst & Seebeck 1995).

The long-nosed potoroo is sympatric with at least two species of bandicoot. However, tracks made by potoroos differ to those made by bandicoots by the presence of five clawed digits on the forepaws of long-nosed potoroos, compared with three clawed digits on the forepaws of bandicoots.



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Long-nosed potoroo (south east mainland)

Potorous tridactylus tridactylus

States and territories: Queensland, NSW, Victoria and South Australia.

Regions: Fragmented distribution along the east coast mainland, including south-eastern Queensland, north-eastern, central and south-eastern NSW, north-eastern Victoria, and three isolated regions in western Victoria, including a remnant population near the South Australian border.

Habitat: Coastal heath, and dry or wet sclerophyll forests with thick ground-cover and understorey habitats (Bennett 1993; Johnston 1995).

Habit: Ground-dwelling.

Avg. body weight: 1180 g (males) and 1020 g (females) (Johnston 1995).

Activity pattern: Nocturnal.

Diet: Omnivore: roots, tubers, fungi, insects and their larvae (Johnston 1995).

Breeding: Breeds throughout the year with peaks in late winter/early spring and late summer (Johnston 1995).

Description

The long-nosed potoroo consists of two subspecies: *P. t. tridactylus* from the south-eastern Australian mainland and *P. t. apicalis* from the Bass Strait islands and Tasmania (Johnston 1995). The mainland subspecies is listed as vulnerable under the EPBC Act.

Long-nosed potoroos are medium-sized nocturnal mammals that shelter in dense vegetation during the day and forage by digging for fungi, prey or tubers at night. The species' range has become fragmented and restricted by land use changes on the mainland. The extent and abundance of the long-nosed potoroo within its range is not well known because of the difficulties in trapping and detecting the species' presence.

Survey methods

The following survey techniques are recommended to detect the presence of the long-nosed potoroo in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas with a dense understorey (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, however observers should be aware that long-nosed potoroo diggings are usually indistinguishable in the field from those of sympatric species like bandicoots (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2)



- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2. However, where the long-nosed potoroo occurs in sympatry with the long-footed potoroo or small wallaby species, tracks cannot be distinguished, or may be difficult to distinguish between species
- baited camera traps using universal bait (peanut butter and rolled oats) with added truffle or walnut oil (description of the survey technique and recommended effort is outlined in Section 3.3.6).

An integrative approach is recommended for this species, whereby direct detection surveys like spotlighting (Section 3.3.3), cage trapping (3.3.10) or hair sampling surveys (3.3.7) should be conducted in concert with searches for traces like diggings, scats and tracks, baited camera traps and predator scat surveys etc. Also, given the mixed results of past trapping efforts, different techniques may work better in some locations than others and a variety of methods should be attempted for any given survey program.

To help distinguish the tracks of different species in the field, NSW State Forests have prepared foot casts of potoroos and bandicoots (S Ingleby pers. comm.) although as indicated above, there are difficulties associated with identifying tracks of this species.

Similar species in range

The long-nosed potoroo occurs in sympatry with the long-footed potoroo in parts of north-eastern Victoria and south-eastern NSW. If captured, the two species can be distinguished by the longer snout and the generally larger size of the long-nosed potoroo. These species also differ genetically, with long-footed potoroos having 24 chromosomes and the long-nosed potoroo 12 (females) or 13 (males) (Seebeck 1995).

The long-nosed potoroo is sympatric with several *Perameles* species. However, tracks made by potoroos differ to those made by bandicoots by the presence of five clawed digits on the forepaws of potoroos, compared with three clawed digits on the forepaws of bandicoots.

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Mahogany glider

Petaurus gracilis

States and territories: Queensland

Regions: North-eastern Queensland: distributed in a narrow and fragmented band generally below 120 m above sea level between Crystal Creek south of the Herbert River and the Hull River near Tully, covering an area of approximately 720 km² (QPWS 2001; Jackson 2008).

Habitat: Open woodland on Quaternary alluviums and low granite rises that supports species of bloodwoods (for example, *Corymbia clarksoniana*, *C. intermedia* or *C. tessellaris*), eucalypts (for example, *E. platyphylla* or *E. tereticornis*), melaleucas (for example, *Melaleuca dealbata*, *M. viridiflora* or *M. leucodendra*), and acacia species; often with a grass tree *Xanthorrhoea johnsonii* understorey (QPWS 2001).

Habit: Arboreal.

Avg. body weight: 407 g (males); 365 g (females) (Jackson 2008).

Activity pattern: Nocturnal.

Diet: Omnivorous, nectar, pollen, plant exudates, honeydew and arthropods. (Jackson 2008).

Breeding: Primarily give birth to one or two young between April and November; with a second litter raised in high quality habitat if the first litter is lost (Jackson 2008).

Description

The mahogany glider was first described in 1883 but was known only from a few specimens collected between 1886 and 1974 (Jackson & Claridge 1999). Over that time the species status was unclear and was often referred to as a squirrel glider, *Petaurus norfolcensis* because of its similarity in appearance. However, in 1986 three skins in the Queensland Museum were positively identified as *P. gracilis*, and in 1989 the species was recorded in the wild (Jackson 2008). Since then, the species has been found to have a fragmented and restricted distribution along the southern lowlands of the wet tropics region (Jackson & Claridge 1999).

Mahogany gliders are found in an open woodland habitat comprised of bloodwoods, eucalypts, melaleucas and acacias (Van Dyck 1993). The species is highly mobile and depends on continuous forest and woodland cover to range freely (Van Dyck 1995). The availability of suitable habitat has been reduced by approximately 80 per cent through land clearing practices, which is considered the primary threat to the species' survival (Jackson 2008).

The species is elusive and virtually silent (Van Dyck 1995) and therefore, unlike other glider species, cannot be detected by calls. Individuals nest in eucalypt hollows, with up to ten nests being used at any one time by the same individual or socially monogamous pair (Jackson 2008).

Management measures are outlined in the species' recovery plan (Parsons & Latch 2007), along with an evaluation of the previous recovery plan and threats currently facing the mahogany glider.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the mahogany glider in areas up to 5 hectares in size:

- daytime searches for potential den sites in hollow-bearing trees (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity (description of the survey technique and recommended effort is outlined in Section 3.2), such as gashes or scratches made in upper branches of bloodwoods and large-fruited red mahoganies, chunks of grass tree *Xanthorrhoea johnsoni* flower stalks lying on the ground, or scats on the ground below trees, particular those considered potential den sites
- stagwatching surveys at potential den sites (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- spotlighting surveys along transects, tracks or roads, depending on the nature of the site according to the method outlined in Section 3.3.3, however, additional surveys from a vehicle may also be made
- an arboreal cage trapping program conducted according to the method outlined in Section 3.3.9 may be required if the species is not detected through the aforementioned surveys, or to distinguish the species from other sympatric glider species, for example, by morphological characteristics or DNA analysis from a tissue sample (note that appropriate licences are likely to be required from Queensland government authorities).

A possible alternative survey method may be the use of hair sampling devices. However, at this stage this method cannot be considered as a standard because the species is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Identification of the species from guard hairs may be possible in the future on the advice of appropriate experts in this field.

Similar species in range

The mahogany glider is sympatric with the sugar glider *P. breviceps*. The sugar glider is separated by its small size (that is, half the length of the mahogany glider), distinctive white underbody, a longer, pointed muzzle, and a distinctive call. Mahogany and squirrel gliders are geographically isolated, with the closest known populations being approximately 25 kilometres apart (Jackson & Claridge 1999). The mahogany glider can be distinguished from the squirrel glider by its larger size, the presence of brown and honey tones and the longer, less bushy tail which is narrow at its base. The fluffy glider, *Petaurus australis* subsp., can readily be separated as it is larger, has a predominantly pale yellow underside, frequently utters a diagnostic call and produces diagnostic feeding marks in the trunks and boughs of trees. Due to the difficulty in separating the mahogany glider from squirrel and sugar gliders, all identifications should be confirmed by experienced field staff.

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Mountain pygmy possum

Burramys parvus

States and territories: Victoria and NSW.

Regions: Alpine regions.

Habitat: Rock scree or boulder fields supporting characteristic communities of subalpine heath dominated by the mountain plum pine *Podocarpus lawrencei* and adjacent habitats such as Poa-Carex sedgeland above 1400 m (Mansergh & Broome 1994). Dispersing juveniles may range into peripheral habitats generally at lower altitudes, such as the snow gum *Eucalyptus pauciflora* zone (Mansergh 1995). The total extent of primary habitat is less than 6 square kilometres (Broome 2008).

Habit: Ground-dwelling, utilises rock crevices in boulder fields.

Avg. body weight: 41 g (males), 42 g (females) (Broome 2008).

Activity pattern: Nocturnal and seasonal (hibernates during winter).

Diet: Omnivorous: arthropods (particularly the bogong moth *Agrotis infusa*); seeds and fruits, particularly of the mountain plum pine and snow-beard heath *Leucopogon montanus* (Mansergh et al. 1990).

Breeding: A single litter, usually of four young, is born in late spring to early summer following snow melt (Broome 2008). Young are carried in the pouch for about one month and then deposited in a nest with first individuals leaving the nest in early January (Mansergh 1995).

Description

The mountain pygmy possum is a small possum with mid-grey coloured fur that is lighter ventrally and slightly brown on its back (Menkhorst and Knight 2004). It is the only mammal that is restricted in distribution to the Australian alpine and sub-alpine regions and is confined to one of the smallest ranges (less than 6 square kilometres) of any Australian mammal. Within these regions, the species occurs only in small patches of rock scree in periglacial blockfields and blockstreams, above altitudes of 1400 metres where there is continuous snow cover for at least six months of the year (Broome 2008).

The mountain pygmy possum is a highly seasonal species, which breeds in summer and hibernates in winter when its habitat is covered in snow (April to October) (Broome 2008). During the summer months, the species eats mostly arthropods and fruits, particularly exploiting the abundance of bogong moths during their summer migration to the highland regions (Broome 2001). After the end of the breeding period in March, the possums gain weight rapidly and begin to store food for the anticipated winter torpor.



Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the mountain pygmy possum in areas up to 5 hectares in size:

- location of primary habitat (that is, rock scree and boulder fields) with mountain plum pine dominated sub-alpine shrubland through examining fine-scale vegetation mapping (where available), aerial photography and ground-truthing (description of the survey technique and recommended effort is provided in Section 3.1)
- location of distinctively chewed mountain plum pine seeds that are cracked transversely (as opposed to lengthwise in the sympatric bush rat, *Rattus fuscipes*; Triggs 1996)
- collection of predator scats (particularly introduced predators) (note: this is limited: even if detected the prey may have originated anywhere within a large radius; for example, 30 kilometres for dogs) (description of the survey technique and recommended effort is provided in Section 3.2)
- hair sampling device surveys, following the description of the technique and recommended effort provided in Section 3.3.7, as the species is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7), and
- Elliott A or E trapping surveys are the recommended primary technique, conducted according to the description of the technique and recommended effort provided in Section 3.3.9 (baiting the traps with walnuts), but to be consistent with previous studies on the mountain pygmy possum, increase the survey effort as follows:
 - in areas of suitable alpine habitat, use four rather than two survey sites per five hectare area (the minimum number of sites specified in Section 3.3.9)
 - sample during the warmer months of the year
 - set 25 traps in each survey site, spaced at 5 metres intervals in boulder field and adjacent alpine heathland habitats
 - use of camera traps, such as in artificially constructed habitat connecting discontinuous primary habitat (such as road underpasses).

An additional consideration for survey design is that the mountain pygmy possum sexually segregates within the boulder field habitat, with the large adult females occupying the preferred breeding habitat closest to the boulder field, and adult males and juveniles found at lower elevations (Broome 2001). However, in some populations this scenario does not appear to occur, for example the habitat occupied by males at Timms Spur in the Victorian Alps remains problematic despite extensive trapping. The location of migrating individuals at lower elevations, particularly juveniles after February, needs to be taken into account when establishing survey sites. If the subject site includes both boulder scree and alpine heathland, then to ensure both habitat types are sampled a trapping gradient placed along an altitudinal gradient may be appropriate. Note that dispersing juveniles may also occur in atypical adjacent habitat, although the importance of such vegetation types is poorly understood.

Similar species in range

No other small possum species occur within the mountain pygmy possum's range. However, there is potential for the eastern pygmy possum *Cercartetus nanus* to occur in areas where dispersing mountain pygmy possum move into the snow gum zone. The mountain pygmy possum can be readily identified by the presence of enlarged premolars and from other sympatric small ground-dwelling mammals by the syndactyle hindfeet (that is, second and third toes are fused) (Mansergh & Broome 1994).

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Mulgara

Dasycercus cristicauda

Note that the EPBC Act (as at July 2010) lists the ampurta *Dasycercus hillieri* as endangered and the mulgara *D. cristicauda* as vulnerable. In a recent taxonomic revision *D. cristicauda* has been split into two species: the brush tailed mulgara *D. blythi* occurring from Queensland to Western Australia, and the crest-tailed mulgara *D. cristicauda* which is currently confined to the Simpson, Tirari and Strzelecki Deserts (Woolley 2005). Further, the ampurta is no longer recognised as a distinct species and has been grouped with *D. cristicauda*, from which it is indistinguishable. Under the EPBC Act this latest taxonomic change has not been formally recognised (as at July 2010). Therefore, this species profile incorporates both *D. blythi* and *D. cristicauda* (excluding the *D. cristicauda* population that was previously referred to as *D. hillieri*; refer to the species profile for ampurta).

States and territories: Western Australia, Northern Territory and South Australia.

Regions: Widespread but patchy in central arid sandy regions.

Habitat: Hummock grass plains, sand ridges and mulga shrubland.

Habit: Ground-dwelling (burrows).

Avg. body weight: 115 g (Woolley 1995).

Activity pattern: Nocturnal.

Diet: Carnivorous: large invertebrates and small vertebrates. Rodents make up a greater proportion of their diet in winter and spring (Chen et al. 1998).

Breeding: May–June, five to eight young weaned in October–November (Masters 1998).

Description

This species profile combines two separate taxa: the brush-tailed mulgara *D. blythi* and crest-tailed mulgara *D. cristicauda* (see Woolley 2005). The two species are readily distinguished in the field by tail morphology: the former species lacks a tail crest while the black hairs of the tail in the latter species form a distinctive dorsal fin-like crest (Masters 2008, Woolley 2008).

Both species excavate burrows within which they shelter in during the day. Burrows are found aggregated in complexes that can cover up to a kilometre of suitable habitat. The burrows are constructed under the raised mound of a dead spinifex hummock, and have a number of entrances, with between six to ten pop-holes located around the periphery of the raised mound (C Dickman pers. comm.). When the burrows are active, scoops of sand are seen at the pop-hole entrances and scats will also be scattered randomly around the area, including near the burrow entrances (C Dickman pers. comm.).

There is evidence that the mulgara breeds seasonally and may have other seasonal activity patterns. Females with pouch young have been captured in September–October and lactating females without pouch-young have been captured in November (Dickman et al. 2001). If young become independent after November, then their recruitment into the population at that time may explain why capture rates have tended to be higher in summer in two studies (Masters 1998, Dickman et al. 2001).

The mulgara appears to be a sedentary species, with relatively small ranges compared to other Dasyurids. Individuals are capable of storing fat in their tails and of entering torpor, strategies that may enable them to survive within an environment of temporally unpredictable resources (Dickman et al. 2001). Another feature of their biology that demonstrates their flexibility to an unpredictable environment is their opportunistic breeding, with mulgara population increases recorded after rain, presumably in response to an increased availability of prey (Dickman et al. 2001).

Threatening processes are unclear, but are thought to include changes in fire regimes, introduced predators and grazing by introduced herbivores causing a reduction in available cover for prey items (Pavey and Cole 2002).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the mulgara in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs including burrows, pop-holes, particularly those with freshly excavated earth, tracks and scats (description of the survey technique and recommended effort is provided in Section 3.2). Note that identification of these indirect signs needs to be confirmed by an expert (for example, through the provision of digital photographs)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- possibly a hair sampling device survey as the mulgara are included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A trapping surveys using a mixture of rolled oats, peanut butter and tuna oil for bait, and conducted according to the technique and the recommended effort described in Section 3.3.9. However, this survey technique may not be effective in the Simpson Desert or at other sites yet identified, and should not be used on its own
- pitfall trapping surveys (with trap depth recommended to be 60 centimetres) conducted according to the technique and recommended effort described in Section 3.3.8, but with double the survey effort (that is, use four instead of two sampling sites within a 5 hectare area) if the survey is not conducted in conjunction with Elliott trapping
- spotlighting for active individuals on foot or from a moving vehicle, particularly at times when densities are higher following several consecutive good seasons
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- consider the placement of baited camera traps (same as for predator pads) in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric species (description of technique in Section 3.3.6).

While not previously reported to have been used to detect the mulgara, it may be worthwhile trialling the kowari predator pads (Brandle et al. 2002) (see kowari species profile), especially if the investigator believes the species is present but cannot confirm their presence through trapping techniques.



Similar species in range

The only other similar species is the kowari, which can be distinguished from the mulgara by its lighter colour and the presence of black, denser tail fur on the tail tip and white fur at the base of the tail.

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Northern bettong

Bettongia tropica

States and territories: Queensland.

Regions: Restricted to four locations:

Lamb Range east of Mareeba

Mount Windsor Tableland west of Mossman

Carbine Tableland

Coane Range near Paluma.

Habitat: Wet and mesic sclerophyll forests with a grassy ground-cover (Vernes et al. 2001) located on metamorphic and granitic soil substrates (Laurance 1997).

Habit: Ground-dwelling.

Avg. body weight: 1200 g (Winter & Johnson 1995).

Activity pattern: Nocturnal.

Diet: Primarily mycophagous, preferring the underground fruiting bodies of mycorrhizal fungi (Vernes et al. 2001). Grasses are important when fungi are unavailable (Abell et al. 2006).

Breeding: Breeding occurs throughout the year with one young produced per breeding event (Winter & Johnson 1995).

Description

The northern bettong is a small potoroid mammal restricted to fire-prone sclerophyll forests and woodland on the western edge of the wet tropics region of north-eastern Queensland (Winter & Johnson 1995; Vernes & Pope 2001). The taxonomic species status of the northern bettong is subject to debate, with some authorities considering it to be a subspecies of the brush-tailed bettong *Bettongia penicillata tropica* (Winter & Johnson 1995).

The northern bettong is estimated to have disappeared from over 90 per cent of its former range (Maxwell et al. 1996) and its occurrence is now within a restricted and fragmented range (Winter & Johnson 1995). Northern bettongs are solitary and nocturnal, sheltering during the day in a grass nest built under a tussock or a grass tree (Winter & Johnson 1995). Individuals have several nests within close proximity to each other and like other potoroids they have a relatively large home range area (59 hectares) with high rates of nightly movement (Vernes & Pope 2001).

In one study, truffles (underground fungi) comprised 23–67 per cent of the northern bettong's diet (Johnson & McIlwee 1997). Fire is thought to mediate truffle abundance in sclerophyll forests (Taylor 1992), and is likely to impact the northern bettong as well. Vernes and Pope (2001) investigated the effects of fire on a population of the northern bettong and found that a moderate-intensity fire did not significantly affect the home range size, location or rates of nightly movements of radio-tracked northern bettongs. These results suggest that the



bettong's behaviour was not disrupted by the moderately low-intensity fire, which may indicate that the species is adapted to frequent fires. Abell and colleagues (2006) found that northern bettongs used grasses as an alternative food source when seasonality of rainfall reduced the availability of fungi and that previous studies on this species' dietary habits probably underestimated the importance of food resources other than fungi.

Survey methods

The following survey techniques are recommended to detect the presence of the northern bettong in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas with wet and mesic sclerophyll forests and a grassy ground-cover (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including diggings, tracks, scats and nests (description of the survey technique and recommended effort is outlined in Section 3.2). However, because the rufous bettong may be sympatric in some areas with the northern bettong *Bettongia tropica*, direct detection survey techniques are required to distinguish between the species
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2 are considered appropriate to determine if bettongs occur on the subject site. However, direct detection techniques are required to distinguish between the species
- camera traps baited with universal bait and added almond, walnut or truffle oil (see potoroo profiles for further information) are likely to prove useful for positively identifying and minimising impact on animals and are also cost-effective (description of the survey technique and recommended effort is outlined in Section 3.3.6).

One or more of the following survey techniques is required to distinguish between the northern and rufous bettongs where signs of activity have been detected:

- possibly spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3, if the habitat understorey is open enough to allow for an effective beam of light to search with
- cage trapping surveys with universal bait and added almond, walnut or truffle oil (see potoroo profiles for further information) conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10
- hair collection (northern bettongs are identifiable from hair samples) (see Table 2, Section 3.3.7)

baited camera traps using universal bait (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Similar species in range

Northern bettongs appear to overlap in range with rufous bettong, but the latter occurs in drier habitat (Winter & Johnson 1995). The two species are distinguished by the smaller size of the northern bettong and the red colour of the rufous bettong's fur.

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Northern hairy-nosed wombat

Lasiorhinus krefftii

States and territories: Queensland.

Regions: Epping Forest National Park, north-west of Clermont.

Habitat: Grassland and eucalypt woodland on deep, sandy soil. Shelters in burrows in sandy soil.

Habit: Ground-dwelling (burrows).

Avg. body weight: Between 26–35 kg (Menkhorst & Knight, 2001).

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: perennial native grasses. Predominantly three native species (*Aristida* spp., *Enneapogon* spp. and *Fimbristylis dichotoma*) and the introduced buffel grass *Cenchrus ciliaris* (DEWHA 2009).

Breeding: Offspring are born in spring and summer and then spend between 10–11 months in the pouch. Females can breed once every two years provided there is sufficient rainfall (Van Dyck & Strahan 2008).

Description

The distribution of the northern hairy-nosed wombat formerly included the Riverina district of NSW and an area near St George in southern Queensland. However, its range is now restricted to only one location: a 300 hectare area of sandy grassy woodland in Epping Forest National Park in Queensland. The reasons for the species' decline in distribution and abundance are attributed to land use changes, with numbers increasing at Epping Forest since the exclusion of cattle in 1982 (Johnson & Gordon 1995). Dingo predation in 2000 saw another decrease in the population; dingo fences have since been erected and now protect the entire population (Van Dyck & Strahan 2008).

Burrows are occupied by up to ten individuals and are distributed in loose clusters (up to 20 within a few hectares) with multiple entrances (Johnson & Gordon 1995). The entrances of active burrows are marked with piles of dung and splashes of urine, with dung piles located at intervals along connecting trails between burrows. Smaller, single-entrance burrows are often scattered around the major burrows. These are not occupied permanently and provide a short-term refuge for animals. Burrows are constructed under trees along the 'shoulder' of a shallow gully filled with deep sand (Van Dyck & Strahan 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the northern hairy-nosed wombat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as open woodland (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including community records, burrows, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2)

- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- possibly spotlight surveys (description of the survey technique and recommended effort is outlined in Section 3.3.3), or observation surveys conducted at potentially active burrows to identify wombats emerging to forage (description of the survey technique and recommended effort is outlined in Section 3.3.4)
- hair trapping for animals by suspending double-sided adhesive tape between two star pickets at gates in trapping fences around burrows or between metal stakes set outside burrow entrances (Banks et al 2003).

Trapping surveys are not considered necessary to determine the presence of the northern hairy-nosed wombat on a subject site.

Similar species in range

There are no species similar in appearance to the northern hairy-nosed wombat within the species' known range.

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Northern hopping mouse

Notomys aquilo

States and territories: Northern Territory (and possibly Queensland).

Regions: Poorly understood.

Northern Territory: Western shores of the Gulf of Carpentaria, and Groote Eylandt and adjacent parts of Arnhem Land.

Queensland: Cape York Peninsula.

Habitat: Sand dunes, coastal habitats and inland areas (30—60 km from coast) associated with sandstone ranges all with sandy substrates (Note: may be an artefact of detection method) (Woinarski et al. 1999). Also recorded from the margins of coastal rainforest patches and eucalypt open forest (Woinarski & Flannery 2008). Most common in coastal grasslands, wet heaths and *Acacia* or *Hakea* dominated shrublands, particularly in habitats associated with hummock grass (Woinarski et al. 1999). Key microhabitat requirements are the diversity of bush-peas (Fabaceae) present and/or a 10 to 50 per cent cover of hummock grasses (Woinarski et al. 1999).

Habit: Ground-dwelling (burrows).

Avg. body weight: 38.5 g (Woinarski & Flannery 2008).

Activity pattern: Nocturnal.

Diet: Herbivore: grains, seeds and some green vegetation.

Breeding: Poorly known. Captive animals gave birth predominantly between mid-March and Mid-May and pregnant females have been collected in June (Woinarski & Flannery 2008).

Description

The northern hopping mouse is unique in that it is the only *Notomys* to occur in monsoonal environments, rather than arid or semi-arid parts of Australia. It is a small sandy-coloured mouse with a relatively long tail that has a tuft of darker hairs at the tip (Woinarski & Flannery 2008). It is similar in appearance to the spinifex hopping mouse *Notomys alexis*, although the two species' distributions do not overlap (Woinarski et al. 1999).

The species was first recorded from the Cape York Peninsula (Thomas 1921), but has not been recorded at that location again until recently when tracks were observed in a sand dune during a survey (Woinarski et al. 1999). Support that the tracks were made by the species came from the local Aboriginal community, who described a hopping mammal occurring in the dunes and coastal habitat. The northern hopping mouse has also been found at a number of localities in the Northern Territory, including Groote Eylandt (Johnson 1959, 1964; Dixon and Huxley 1985; Woinarski et al. 1999) and adjacent areas of mainland Arnhem Land (Woinarski et al. 1999).

The northern hopping mice construct complex burrow systems (Woinarski & Flannery 2008). The burrows are distinctive, with a 5 centimetre diameter entrance located approximately 2 metres away from a spoil mound. A

vertical shaft leading from the entrance is dug from below, with excavated soil used to create the mound. Pop-holes occur between the entrance and the mound, and active burrows are distinguished by tracks leading from the pop-holes (Woinarski & Flannery 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the northern hopping mouse in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, including but not limited to sand dune habitats (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs, particularly the distinctive associated spoil mounds and tracks following the protocol outlined by Ward (2009), where these searches are carried out over 200 metre long transects (description of the survey technique and recommended effort is provided in Section 3.2). Note that any suspected tracks or burrows in new localities (for example, Cape York Peninsula) should be photographed to aid in identification by a field person experienced in identifying *Notomys* indirect sign
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- spotlight surveys on foot or from a moving vehicle (description of technique and recommended survey effort provided in Section 3.3.3)
- pitfall trap surveys (as for other *Notomys* capture rates can be improved by using narrow PVC pipe rather than wider buckets, with a diameter of 16 centimetres and trap depth recommended to be at least 60 centimetres) conducted according to the technique description and recommended effort provided in Section 3.3.8
- use sand pads on non-sand substrate where this species is suspected to occur, conducted according to the description of the technique and recommended survey effort provided in Section 3.3.2
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- consider the placement of baited camera traps (same as for predator pads) in suitable habitat, concentrating on well-used runway areas (as told from the number of tracks), particularly as this species can be relatively easily separated from other sympatric species.

Elliott tapping is not recommended as this species is particularly trap-shy (Ward 2009). Hair sampling devices are not recommended for the northern hopping mouse, as this species is not included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change then hair sampling may provide an appropriate alternative detection technique. The survey method recommended is comparable with those recommended by NT DIPE (2005) (see Appendix).

Similar species in range

No similar species occur in the northern hopping mouse's range. Tracks may be confused with those of bird species and confirmation from an experienced mammalogist may be required in the field, or from plaster casts and photographs. As there are very few specimens of the northern hopping mouse from Cape York Peninsula, the collection of hair or tissue samples should be considered for future identification and/or molecular analysis, provided that the appropriate permission and licensing has been granted by the relevant Queensland and Northern Territory government organisations.



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Northern marsupial mole, karkarratul

Notoryctes caurinus

States and territories:	North-western Western Australia and possibly far western Northern Territory in the western Tanami Desert area.
Regions:	This species has been found in the Great Sandy, Little Sandy and Gibson Deserts of north-western Western Australia (Langford & Pavey 2002, Benshemesh and Aplin 2008).
Habitat:	Sandy desert regions, underground signs are most common on well vegetated dunes (Benshemesh 2004).
Habit:	Mostly underground, about 20 to 60 cm below the ground surface, moving about by digging back-filled tunnels in search of prey (Benshemesh 2008).
Avg. body weight:	As for the southern marsupial mole, body weight range 40–70 g (Benshemesh & Aplin 2008).
Activity pattern:	Unknown.
Diet:	Unknown, but suspected to be similar to the southern marsupial mole.
Breeding:	Unknown, but may be similar to the southern marsupial mole.

Description

The marsupial moles have specialised adaptations that have evolved in response to the species' burrowing lifestyle (Langford & Pavey, 2002). Their eyes are vestigial and hidden under the skin, their ears are reduced to a simple opening beneath the fur on either side of the head, and their conical shaped noses are covered with a tough, horny shield to protect against the sand. To burrow through the sand, the third and fourth digits of the forefoot are enlarged and possess large shovel-like claws for digging. They have a short, hard and leathery tail that is marked by distinct rings, ending in a horny 'knob'. The colouration of the fur can vary from near white through pinkish to rich golden red.

Given the similarity in appearance between southern and northern marsupial moles and the lack of reported information about the species' biology, discerning the ranges of the two marsupial mole species is difficult. Recent work suggests that the edges of the distributions of the two species exists somewhere in the Tanami Desert, with the southern marsupial mole occurring in the east and the northern marsupial mole in the western Tanami, but it remains uncertain whether these forms are sympatric (Benshemesh 2004).

Survey methods

The most efficient method of surveying for marsupial moles is to count the number of tunnels underground (Benshemesh 2005). A summary of the technique is provided below, and detailed in Section 3.2.7 (note that the surveyor should consult J Benshemesh for advice prior to conducting any surveys):

- survey trenches should be dug approximately 80 centimetres deep, 120 centimetres long and 40 centimetres wide



- the trench should be dug with caution, and the use of mechanical equipment should be avoided
- digging should cease if marsupial moles are observed
- trenches should be allowed to dry for between three to five days (few tunnels will be apparent until the soil is adequately dry)
- the tunnels will appear as circular or oval shapes, usually larger than 25 millimetres but depending on the angle made with the trench wall
- trenches should be dug at three levels on the dune: near the crest, mid slope, and at the base of the dune, positioned less than 1 km apart
- in suitable habitat two to six tunnels are usually found per square metre of vertical trench face.

Valuable information can also be obtained recording tracks, and photographs should be taken for confirmation by an expert, particularly in areas of uncertainty between the known ranges of the two species (Benshemesh 2004).

Other techniques that could be employed in areas up to 5 hectares in size, but are less reliable and efficient, include:

- daytime searches for potentially suitable habitat resources, such as sandy soil in the central desert regions (description of technique and recommended effort outlined in Section 3.1)
- early morning (that is, before the sun is too high, making tracks hard to discern, and before a breeze disturbs track definition) searches for signs of activity, particularly for tracks (photographs should be taken for confirmation by an expert) or individuals that may be observed on the surface following rain or during cold weather (description of technique and recommended effort outlined in Section 3.2). Any person undertaking track searches need to have experience at tracking and identifying small mammal track signs in arid desert country
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of technique and effort outlined in Section 3.2.3). Marsupial moles can be identified to genus from hair samples (see Table 2, Section 3.3.7), or to species if genetic techniques are used.

Similar species in range

The taxonomy of the *Notoryctes* is unclear, with a suggestion that there may be one or more currently undescribed species. Currently two species of marsupial moles are recognised: the southern marsupial mole *Notoryctes typhlops* and the northern marsupial mole *Notoryctes caurinus*. The two species are thought to have an overlap in distribution; however, this has not currently been demonstrated. Although the two species can be separated genetically, they are difficult to separate morphologically. Characters used include the slightly smaller size, the narrower and shorter snout, the lack of anterior molars and the remaining cheek teeth are smaller and simpler in structure in northern marsupial moles (Benshemesh 2008, Benshemesh & Aplin 2008). In addition, the tracks have been reported to be distinct between the two species (Benshemesh & Aplin 2008). Langford and Pavey (2002), in their description of the southern marsupial mole, refer to 'morphometric and dental studies' as the basis for the separation of the southern marsupial mole from the Great Sandy and Gibson Deserts from the northern species. Since distinguishing the species in the field may not be possible, identification is likely to require a hair sample, provided that the appropriate permission and licensing has been granted by the relevant state or territory government organisations.

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Northern quoll

Dasyurus hallucatus

States and territories: Western Australia, Northern Territory and Queensland.

Regions: Northern Australia, extending from southern Queensland (Maleny area on the Sunshine Coast hinterland) to the Pilbara, Western Australia.

Habitat: Wide range of eucalypt forest and woodland habitats associated with steep dissected rocky terrain; also found in rainforest patches, vegetation along creek lines, adjacent to mangroves, around human settlement and on beaches (Pollock 1999; Oakwood 2002, 2008). Important factors in the landscape include shallow soils, large cover of rocks including outcropping rock, proximity to permanent water and time since last fire (Woinarski et al. 2008). Dens occur in a wide range of situations including rock overhangs, tree hollows, hollow logs, termite mounds, goanna burrows and human dwellings (Woinarski et al. 2008).

Habit: Ground, tree and rocky escarpment dwelling.

Avg. body weight: Body weight varies in different parts of its distribution: range between 340 g and 1120 g (adult males) and 240 g and 690 g (adult females) (Oakwood 2008).

Activity pattern: Predominantly nocturnal; sometimes diurnal mostly in overcast weather or during the mating season (late May to early June) (Oakwood 2008).

Diet: Opportunistic omnivore heavily focused on invertebrates, particularly insects. Additionally, takes a variety of mammals, various birds (including bird eggs), frogs, nectar of eucalypt and grevillea flowers, and the fruits of a variety of plants. Scavenges on road-kills and from garbage bins and elsewhere around human settlements (Pollock 1999; Oakwood 2008; Woinarski et al. 2008).

Breeding: Reproduction is annual and highly synchronised within a population, but timing may vary between populations (Schmitt et al. 1989; Oakwood 2000). Give birth to between five and nine young (average seven) with only two or three young weaned after six months (Oakwood 2000).

Description

Although the northern quoll is the smallest of the quolls, being around the size of a small cat, it is the largest mammal species known to undergo male die-off after mating (Oakwood 2004). Formerly widely distributed, its range has now contracted to a number of disjunct populations (Braithwaite & Griffiths 1994), many of which are now threatened due to the continuing spread of the cane toad *Chaunus marinus* across northern Australia. The northern quoll is highly susceptible to the poison of this introduced species and rapid contractions to local extinction of populations have been reported following the invasion of this toad into the Cape York Peninsula (Burnett 1997) and in parts of Kakadu National Park (van Dam et al. 2002; Watson & Woinarski 2003). In response to the collapse of mainland populations in the Top End the species has been successfully translocated to two islands (Rankmore et al. 2008).

Survey methods

On the basis of previous surveys, the survey techniques recommended to detect the presence of the northern quoll in areas up to 5 hectares in size are cage trapping (description of technique and recommended effort provided in Section 3.3.10) and Elliott trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9. Trapping is best conducted between May and August to minimise possible disturbance during the reproductive period. Cage trapping is the generally accepted technique for targeting this species. However, in remote locations or where it is difficult to deploy large numbers of cage traps, Elliott traps are a suitable alternative, particularly large Elliott traps. Note that at Pine Creek in the Top End of the Northern Territory some Elliott traps were rolled down vertical mineshafts as northern quolls were attempting to extract the bait (Schulz & Menkhorst 1984). Trapping should be concentrated in rocky denning habitat, with some consideration of non-rocky foraging and dispersal habitats.

In Western Australia traps should be set for seven consecutive nights, unless two or more individuals are caught twice, in which case the traps should be closed after four nights of trapping. In the Northern Territory and Queensland traps should be set for a minimum of three nights. Where large Elliott traps are the primary trapping technique, a minimum of four cage traps should be used per trap configuration.

Traps should be baited with oats, sardines and peanut butter. Chicken wings and diced bacon are optional. A purified solution of low fat red meat and water can be sprayed on to shrubs and the ground within a 150 centimetres radius of each trap and reapplied on a daily basis (Wayne et al. 2008). Traps should be rebaited at least every second day (baits should be fresh).

Since population numbers may be very low or at some locations it may be difficult logistically to deploy cage traps, additional or complementary techniques to locate northern quolls that are not commonly reported in the literature include:

- daytime searches for potentially suitable habitat resources such as rock overhangs, crevices and boulders in areas of extensive outcropping rock in association with permanent water and no evidence of recent fires (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches (description of technique and recommended effort provided in Section 3.3.1) for latrines (also used as a technique to locate the spotted-tailed quoll) with numbers of distinctive twisted cylindrical scats deposited often on rock piles or boulders, usually on the highest point available, such as ridge tops or hill crests (Triggs 1996; Pollock 1999). Scats may also be deposited in other situations such as under boulders, in rock overhangs, road culverts and sheds (Pollock 1999). This technique has been recommended in remote areas as a simple detection technique (for example, Pollock 1999). However, such signs should be treated with caution where the spotted-tailed quoll occurs in sympatry and either confirmation of the internal grooming hairs deposited or direct detection survey techniques may be required. Additionally, care must be taken not to confuse scats with those of the cane toad, green tree frog *Litoria caerulea*, and water rat *Hydromys chrysogaster* (Pollock 1999). Scat searches are best in winter, when the scats remain in situ and are not deformed as a result of rain (S. Burnett pers. comm.)
- daytime searches or use of sand traps to identify the characteristic tracks of this species (refer to Section 3.3.2), where not in sympatry with the spotted-tailed quoll. Such sand traps are best done using a lure such as chicken bait and could include smoothing out sand on the floor of rock overhangs or smoothing sand around permanent water or the base of cliff faces



- remote cameras: a technique that is becoming widely used for the spotted-tailed quoll and commonly replacing hair sampling devices (refer to Section 3.3.6) in potentially suitable habitat. This technique could be used throughout the year and would be enhanced by using chicken as bait. This technique would be similarly suited to the northern quoll, with the advantage over traditional traps that cameras can be left in situ for several weeks before the need for visitation to replace batteries and the memory card. Such extended sampling with low labour intensity is highly suited to a species that may be in very low abundance or in remote locations where conventional trapping is logistically difficult. This technique can be used throughout the year as no handling of individuals is required
- hair tubes conducted according to the technique description and recommended effort provided in Section 3.3.7
- possibly spotlight surveys conducted according to the technique description and recommended effort provided in Section 3.3.3
- community liaison to provide additional records, particularly on private land.

Similar species in range

The northern quoll overlaps in parts of its range with the spotted-tailed quoll, *Dasyurus maculatus*; particularly in north-eastern Queensland with *D. m. gracilis*. Northern quolls are readily separated by their smaller size and lack of white spotted markings on their tails. Previously, parts of its range may have overlapped with the western quoll, *Dasyurus geoffroii*. However, the western quoll is now extinct in areas of overlap with northern quoll, being confined to south-western Western Australia. Northern quolls are separated from western quolls by their smaller size and the striated pads on their feet.

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Numbat

Myrmecobius fasciatus

States and territories: Western Australia.

Regions: South-western Western Australia reintroduced to some areas in NSW and South Australia.

Habitat: Remnant patches of wandoo and jarrah forests (Friend & Thomas 2003).

Habit: Ground-dwelling.

Avg. body weight: 471.5 g (females heavier than males) (Friend 1995).

Activity pattern: Diurnal.

Diet: Termites (Friend 1995).

Breeding: Breed once a year between February and April, with two to four offspring per litter (Friend 1995).

Description

The numbat is a small, brightly coloured dasyurid that is the only marsupial adapted to a diet of termites (Friend 1995). The species had a former distribution across much of southern Australia, from south-west Western Australia to western NSW. Its range is now restricted to a few isolated populations around Dryandra and Perup reserves in Western Australia (Friend 1995), but the numbat has been reintroduced to a number of other sites in the vicinity of these populations with mixed success (Friend & Thomas 2003). In south-western Western Australia, the species' known preferred habitat is mostly wandoo, powderbark wandoo and jarrah forests (Friend & Thomas 2003).

Numbats are diurnal and shelter in hollow logs and burrows, including those dug by other species (Bester et al. 2006; Cooper & Withers 2005). Cooper and Withers (2005) found that numbats may prefer burrows to hollow logs as shelters because they are better insulated than hollow logs and may offer better shelter from climatic extremes. However, Bester and colleagues (2006) suggested that their observations of higher burrow use than hollow log use reflects the availability rather than preference for these refuges. Numbats forage for termites by digging small holes in the ground (Friend 1995). They are mostly solitary, and their activity patterns appear to follow the availability of termites in the upper soil layers (Friend 1995), being most active in the early morning and late afternoon (Cooper & Withers 2004).

Numbats are a conspicuous species and their decline throughout their range has been well documented, particularly in the settled areas of the wheatbelt in Western Australia (Friend 1990; Peacock 2006). The primary reasons for the decline of the numbat include the introduction of feral predators, in particular foxes and cats (Friend & Thomas 2003). The control of introduced predators has been the key to the maintenance of extant populations of numbats and for the establishment of reintroduced populations (Friend 1990). Altered fire regimes and the clearing of bush for agriculture are also considered to play a role in the species' decline (Friend & Thomas 2003).

Survey methods

Consultation with the Science Division within the Western Australian DEC is advisable prior to undertaking surveys. Numbats appear capable of dispersing away from sites where they have been released, especially in areas not surrounded by farmland (Friend & Thomas 2003) and this should be considered when surveying near known numbat populations. The following survey techniques are recommended to detect the presence of the numbat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, particularly in mature wandoo woodland in Western Australia, and areas with hollow logs and termite mounds (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats and dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2, modified such that soil is raked smooth around potential foraging or shelter sites to facilitate the detection of tracks
- daytime searches for active fauna conducted either on foot or from a vehicle in the manner described and according to the effort recommended in Section 3.3.1
- possibly conducting observations at potential shelter sites, such as a burrow or a hollow log (description of the survey technique and recommended effort outlined in Section 3.3.4)
- collection of predator scats, owl casts or remains, targeting predatory bird/reptile/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2).

Should confirmation of the species' presence be required after detection of signs, then observations conducted at potentially active den sites at dawn or dusk, when the numbat leaves and returns to its den may produce a direct observation.

Similar species in range

There are no species that are similar in appearance to the numbat.

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Pilliga mouse

Pseudomys pilligaensis

Note that this species is now considered a southern population of the widespread delicate mouse *P. delicatulus* (Breed and Ford 2007; Ford 2008). Recent trapping in fauna surveys in northern NSW have revealed a continuous distribution of the delicate mouse to the Pilliga region. Under the EPBC Act this latest taxonomic change has not been formally recognised. Therefore, this species profile considers the Pilliga population of the delicate mouse.

States and territories: NSW.

Regions: Pilliga.

Habitat: Mixed Cypress-Eucalypt Woodland – dominant canopy trees include red stringy bark *Eucalyptus macroryncha*, scribbly gum *Eucalyptus rossii* and black cypress pine *Callitris endlicheri*. Paull (2009) found breeding sites to be correlated with a well-developed low shrub cover less than 50 cm high, mainly in broombush and kurricabah/bloodwood scrublands. The species showed a preference for early and late post-fire stages of vegetation and an avoidance of intermediate age habitats post fire (5–15 years old).

Habit: Ground-dwelling.

Avg. body weight: 11 g (Fox 1995).

Activity pattern: Nocturnal.

Diet: Herbivore: stem, seed and leaf material of grasses and forbs from the Pilliga scrub (Jefferys & Fox 2001).

Breeding: In captivity the breeding season extends from October to February, with a 24 day gestation period recorded to produce approximately three young (Fox & Briscoe 1980).

Description

The Pilliga mouse was regarded as exceptional among the Muridae as it was formerly considered to have a very small and isolated distribution, restricted to a small region within NSW (Dickman et al. 2000). It was only described in 1980 (Fox & Briscoe 1980) and since then has been detected in NPWS biodiversity studies and other trapping work in the Pilliga (Lim 1992, Paull 2004). However, recent genetic work has indicated that this species should now be considered a southern population of the delicate mouse rather than a separate species (Breed & Ford 2007, Ford 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Pilliga mouse in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as shrubs where burrows might be associated (description of the survey technique and recommended effort is provided in Section 3.1)



- daytime searches for signs for burrows, focussing on the habitat with bushes that may provide suitable cover for burrow entrances, and searching for signs of excavation of soil (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- possibly hair sampling device surveys (description of the survey technique and recommended effort is outlined in Section 3.3.7), which have previously been used to detect the species' presence (Lim & Johnson 1991). Note, however, that the Pilliga mouse is not included among those species known to be distinguishable from hair samples (Table 2)
- Elliott A trapping surveys, following the technique and recommended effort described in Section 3.3.9, using a mixture of rolled oats, peanut butter and sultanas for bait. Traps should be adjusted to ensure the sensitivity will be light enough to be triggered by the small species (approximately 8 grams; Tokushima et al., 2008)
- pitfall trapping surveys conducted according to the technique and recommended effort described in Section 3.3.8. It is not considered necessary to bait pitfall traps as the purpose of the trapping program outlined here is to detect the species and not maximise the number of captures. Furthermore, permission to bait pitfalls should be sought from the relevant animal care and ethics authority, as this is not standard for this technique.

Note that this species is eruptive. During extended dry periods (when it is likely to be present, but in low densities), either a higher sampling effort is required to determine the species' presence or, if possible, sampling should be delayed until more favourable conditions arise.

Similar species in range

The common house mouse *Mus musculus* overlaps in range with the Pilliga mouse and so an experienced mammalogist must confirm the presence of this species in new localities. The two species can be distinguished by the larger eyes of the Pilliga mouse and usually (but not always) by the presence of a notch behind the front incisors of the house mouse.

Should hair or tissue samples be considered necessary for identification and/or molecular analysis, appropriate permission and licensing needs to be been granted by the relevant state or territory government organisation.

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Plains rat

Pseudomys australis

States and territories: South Australia and Northern Territory.

Regions: North-south band west of Lake Eyre.

Habitat: Gibber desert, particularly in areas of deep cracking clay 'gilgai' associated with minor drainage features and depressions of gilgai on gibber plains (Brandle et al. 1999).

Habit: Ground-dwelling.

Avg. body weight: 40 g (Brandle and Pavey 2008).

Activity pattern: Nocturnal, partly diurnal (Menkhorst & Knight 2004).

Diet: Omnivorous: seeds, stems, fungi and arthropods (Brandle & Moseby 1999).

Breeding: Breeds opportunistically after rain (Brandle & Moseby 1999).

Description

The plains rat is one of the larger *Pseudomys* species and is distinguished by having relatively large ears, a rounded snout and bicoloured tail (grey above and white underneath) (Pavey 2000).

It was formerly distributed across much of arid and semi-arid Australia, but is now restricted to a 600 kilometre north-south band to the west of the Lake Eyre Basin, with an outlying population at Lake Torrens (Read et al. 1999). The species mostly inhabits the cracking clay depressions and minor drainage lines on arid gibber plains and cracking clay plains (Brandle & Pavey 2008). The population size in favourable seasons is known to expand rapidly, when the species can also be found on surrounding dunes.

Plains rats occur in colonies that are usually small and difficult to locate, especially during periods of lower rainfall when populations collapse quickly (Brandle & Moseby 1999). The species constructs shallow burrows connected by runways that are occupied by up to 20 individuals when the species is not breeding and by one male and two to three females during a breeding event (Brandle & Pavey 2008). The burrows are often among the roots of perennial shrubs (Breed & Ford 2007). They may also live in cracks in drainage depressions where they make cup-shaped nests up to 50 centimetres beneath the surface (Breed & Ford 2007).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the plains rat in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as gilgai habitats associated with drainage features in gibber plains, but also sand dunes after rainfall (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs, including burrows, tracks and scats (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)

- Elliott A trapping surveys, conducted according to the technique description and recommended effort provided in Section 3.3.9, using a mixture of rolled oats, peanut butter and sultanas for bait
- possibly pitfall trap surveys conducted according to the technique and recommended effort provided in Section 3.3.8
- possibly a hair sampling device survey as the plains rat is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7), and
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area and discussion with graziers and farm hands, particularly in dry periods when densities are likely to be low.

The survey methods recommended are comparable with those recommended by the Northern Territory DIPE (2005) and Owens (2000) for the detection of many arid species. If possible, surveys to determine the species' presence should be conducted after rain when the population density and distribution is highest, in order to maximise the probability of locating this species.

Similar species in range

A number of other rodents overlap in distribution with the plains rat, including the desert mouse *Pseudomys desertor*, the house mouse *Mus musculus*, and the dusky hopping mouse *Notomys alexis*. The plains rat can be distinguished by its relatively large size, stocky build and long ears compared to other rodent species.

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Proserpine rock wallaby

Petrogale persephone

States and territories: Queensland.

Regions: 26 sites in the Whitsunday Shire, eastern Queensland (Menkhorst & Knight 2001).

Habitat: Rocky outcrops in pockets of semi-deciduous vine forest on foothills near grassy open forest and woodland (Johnson & Eldridge 2008).

Habit: Ground-dwelling.

Avg. body weight: 4.3–10.2 kg (males) and 3.5–8.1 kg (females) (Johnson & Eldridge 2008).

Activity pattern: Nocturnal/partly diurnal (suns in cooler weather).

Diet: Herbivore: grasses, shrubs and forbs.

Breeding: Breeding occurs throughout the year (Johnson & Delean 1999).

Description

The Proserpine rock wallaby has the smallest known distribution of any rock wallaby, being known from only 26 sites in the vicinity of Proserpine in eastern Queensland, including the Conway and Clarke Ranges, Mt Dryander and several islands in the Whitsunday group (for example, Gloucester Island). Proserpine rock-wallabies shelter in boulder outcrops, foraging on the grassy understorey of surrounding forest and woodland, but are not known to move far from the rock shelter (Menkhorst & Knight 2001).

On Gloucester Island National Park, Proserpine rock wallaby habitat includes rock piles and outcrops covered in dry vine scrub and beach scrub, while at higher elevations, rocky creeks associated with open acacia forest are also utilised (Nolan & Johnson 2001). Johnson and colleagues (2003) released this species on Hayman Island where volcanic outcrops with low vine thickets was the main habitat type, although prior to the eradication of goats on the island, floral diversity was low.

The species is threatened by development in the Whitsundays, which includes associated impacts from road mortalities and predation by domestic dogs (Nolan & Johnson 2001). Johnson and colleagues (2003) reported that this species suffered depredation from eagles at a reintroduction site, and authorities also undertook an eradication program to remove goats from the site.

Survey methods

On the basis of the survey techniques included in Section 3.3.11 and other similar studies, the following survey techniques are recommended to detect the presence of the Proserpine rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelter sites (caves, rock boulders and rock ledges) in semi-deciduous vine habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)

- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- Baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6), and
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat. Helicopter surveys are not likely to be as useful as for other rock wallabies, due to the species' habitat occurring in vine thickets.

The known range of the Proserpine rock wallaby overlaps with that of the unadorned rock wallaby *Petrogale inornata*; however, both species appear spatially separated on the basis of habitat preferences. Should confirmation of the species identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Sections 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

The distribution of the Proserpine rock wallaby occurs near the unadorned rock wallaby. The species are distinguished by differences in habitat preferences and the larger size of the Proserpine rock wallaby, along with its brown fur, lack of bold facial patterns, the presence of rufous patches at the base of the tail and ears, and most individuals have a white tail tip (Menkhorst & Knight 2001; Nolan & Johnson 2001; Johnson & Eldridge 2008). The Proserpine rock wallaby inhabits deciduous vine forest habitats, whereas the unadorned rock wallaby occurs in rocky habitat within open forests (Nolan & Johnson 2001). The Proserpine rock wallaby has not been recorded with the unadorned rock wallaby at any known site (Johnson & Eldridge 2008).

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Quokka

Setonix brachyurus

States and territories: Western Australia.

- Regions:** Mainland: restricted to two locations at Perup Forest Block, near Manjimup and Garden Island south of Perth (Hayward et al. 2005), and Rottneest and Bald Islands off the south-western Western Australian coast (Menkhorst & Knight 2001).
- Habitat:** Mainland: forest habitats with dense wet ground-cover or swampy flats (*Agonis* species dominated swamps of northern jarrah forests) (Hayward et al. 2005). Rottneest Island: wide range of semi-arid habitats, gardens, and in the vicinity of the township (Kitchener 1995).
- Habit:** Ground-dwelling.
- Avg. body weight:** 3600 g (males) and 2900 g (females) (Kitchener 1995).
- Activity pattern:** Mostly nocturnal: during hotter conditions in November animals converge at night around freshwater soaks (Kitchener 1995).
- Diet:** Herbivore: grasses, sedges, succulents and foliage of shrubs.
- Breeding:** Mainland: capable of breeding throughout the year (Kitchener 1995). Rottneest Island: brief breeding season oestrus in January in mild years, March in hot years (Kitchener 1995).

Description

The quokka is a small macropod, which has a range restricted to south-western Western Australia. On Rottneest Island, quokkas are relatively abundant and common, but they are rare on the mainland, with populations isolated as a result of habitat fragmentation (see Alacs et al. 2003).

During winter local populations are widely dispersed, but during November when temperatures rise quokkas converge at night around permanent fresh water soaks that are used exclusively by a group of animals from the surrounding area (Kitchener 1995). Individuals are thought to form large groups that remain within territories (Kitchener 1995). Males form dominance hierarchies that are established according to body size and strength, which determine competitive ability to gain access to females in oestrus (Kitchener 1995). Males moving between females within the population create “runways” through the dense understorey of the habitat, and detection of these in combination with scat surveys can be used to identify the species’ presence at a locality (Hayward et al. 2005).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the quokka in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as areas with a dense and moist understorey on the mainland and a variety of habitats on the offshore islands (description of the survey technique and recommended effort is outlined in Section 3.1), and
- daytime searches for signs of activity, including runways, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2); however, where the quokka occurs in sympatry with other macropods, scats may need to be collected and analysed using genetic techniques to distinguish between species. Scats should be collected from across the entire area from searches conducted during the day. Fresh pellets (less than one day old) should be frozen at –20 degrees celsius until DNA extraction can be undertaken as per the method used by Alacs and colleagues (2003). However, further advice should be sought from an expert regarding the appropriate collection process prior to the commencement of any field work.

For the purpose of detecting the presence of the quokka from a subject site, cage trapping is not considered necessary at the first stage of a detection survey. Should cage trapping surveys be considered necessary, a description of the recommended survey effort is provided in Section 3.3.9. Appropriate permission and licensing must be sought from the relevant Western Australian government organisation.

Similar species in range

Quokkas and their scats are similar in appearance to other small-medium sized macropods that may occur in sympatry in south-western Western Australia, such as the western brush wallaby, the tammar wallaby, the woylie *Bettongia penicillata*, and the western grey kangaroo. Scats of male quokkas cannot be distinguished from those of other similar sized macropods; however, the presence of scats or tracks in combination with runways made by male quokkas makes identification more positive.

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Recherche rock wallaby

Petrogale lateralis hacketti

States and territories: Western Australia.

Regions: Recherche Archipelago: Mondrain, Wilson and Combe Islands, southern Western Australia (Eldridge & Pearson 2008).

Habitat: Rock boulders, escarpments and cliff-lines.

Habit: Ground-dwelling.

Avg. body weight: 5000 g (Eldridge & Pearson 2008).

Activity pattern: Nocturnal/partly diurnal.

Diet: Herbivore: grasses, shrubs and forbs.

Breeding: Unknown.

Description

Taxonomy within *Petrogale* has been investigated over the past decade through a number of morphological, chromosomal and molecular genetic studies (see Eldridge et al. 2001; Campeau-Peloquin et al. 2001 for summaries). It is believed that this genus has undergone recent and rapid radiation (Eldridge & Close 1997). These survey guidelines follow the taxonomy used in Eldridge and Pearson (2008), which recognises:

- *P. l. lateralis*
- *P. l. hacketti*
- *P. l. pearsoni*
- the West Kimberley race, and
- the MacDonnell Ranges race.

Like all rock wallabies, the Recherche rock wallaby inhabits areas associated with boulder outcrops and escarpments and shelters in caves, on rock ledges and among boulders during the day. Shelter sites form an essential part of a rock wallaby's home range, but animals forage away from their shelter sites during the night (usually at only a short distance but for many species the distance is unknown). All rock wallabies are herbivores that feed on grasses, forbs and shrubs.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Recherche rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelters sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)

- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- use of baited camera traps (description of technique and effort is outlined in Section 3.3.6)
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat or possibly from a helicopter according to the suggested survey technique and effort provided in Section 3.3.11 (minimising disturbance to animals to ensure wallabies do not fall).

The known range of the Recherche rock wallaby is restricted to the Recherche Archipelago (see Eldridge & Pearson 2008) where it does not overlap in distribution with other rock wallaby species. Should confirmation of the species' identity be required, then cage trapping surveys (conducted according to the description and recommended survey effort provided in Sections 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples may need to be considered. These survey techniques can only be conducted with appropriate permission and licensing from relevant state or territory government organisations.

Similar species in range

No other rock wallaby species are known to occur in the restricted range of the Recherche rock wallaby.

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Red-tailed phascogale

Phascogale calura

- States and territories:** Current Western Australia; historic: Western Australia, Northern Territory, South Australia and Victoria.
- Regions:** Currently this species is confined to parts of south-western Western Australia that receive an annual rainfall of 300–600 mm. Formerly the species ranged patchily across the southern interior of Australia, including much of southern and central Western Australia, to the southern Northern Territory and across to south-eastern South Australia and the north-west of Victoria (Bradley et al. 2008).
- Habitat:** Its preferred habitat is climatic vegetation communities dominated by wandoo *Eucalyptus wandoo* and rock oak *Casuarina huegeliana* alliances, with *Gastrolobium* and *Oxylobium* species present (Kitchener 1981; Bradley et al. 2008).
- Habit:** Mostly arboreal but also feeds extensively on the ground (Bradley et al. 2008).
- Avg. body weight:** 60 g (males) and 43 g (females) (Bradley et al. 2008).
- Activity pattern:** Mainly nocturnal but has been seen to emerge during the day (Bradley et al. 2008).
- Diet:** Opportunistic carnivore that feeds on a variety of small insects and spiders, in addition to small birds and mammals, particularly the house mouse *Mus musculus* and carrion (Kitchener 1981; Bradley et al. 2008).
- Breeding:** Mating usually takes place in July with males reproductively senescent after the first year. After a 28–30 day gestation females give birth to up to 13 young, with an average litter size of 7. Young are weaned before the end of October (Kitchener 1981; Bradley et al. 2008).

Description

The red-tailed phascogale is a small dasyurid with characteristic rusty red coloured fur at the base of the tail. The species was formerly widespread across south-western Western Australia (its present-day distribution) central Australia (through Western Australia, Northern Territory to South Australia) and two disjunct populations in the Lake Torrens region of central eastern South Australia and in the vicinity of the Murray River in north-western Victoria/south-western NSW (Kitchener 1981). Within its restricted present-day range the species is largely confined to isolated reserves that exceed 450 hectares, but also occurs in some small, privately tenure woodland remnants that have not been disturbed by farming activities (Bradley et al. 2008).

The preferred habitat of the red-tailed phascogale appears to be climax vegetation communities dominated by wandoo and rock oak. Dense stands of rock oak in association with senescent wandoo (important for nest sites) provide suitable habitat for the species (Bradley et al. 2008). Occurring as a shrub layer within this floral community are monosodium fluoroacetate producing plant species (*Gastrolobium* and *Oxylobium* spp.), which are poisonous to domestic stock and introduced carnivores (Kitchener 1981; Bradley et al. 2008).

The persistence of the red-tailed phascogale in some Western Australian Wheatbelt nature reserves is likely to be due to a combination of factors, including the protection afforded to them from agriculture by plants toxic

to domestic stock, introduced predators and infrequent fires. The reserves have been protected from frequent burning regimes, which means they have largely retained the rich floristic and structural climax conditions that provide habitat for red-tailed phascogale (Kitchener 1981).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the red-tailed phascogale in areas up to 5 hectares in size:

- daytime searches for potential nest sites in hollow-bearing trees or hollow logs (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, such scratches on tree trunks tracks or scats on the ground in the vicinity of potential nesting sites (description of the survey technique and recommended effort is outlined in Section 3.2)
- stagwatching surveys at potential nest sites (description of the survey technique and recommended effort is described in Section 3.3.4)
- spotlight surveys along transects, tracks or roads, depending on the nature of the site should be conducted according to the method described in Section 3.3.3. (additional surveys from a vehicle may also be made)
- an arboreal hair sampling survey conducted according to the method described in Section 3.3.7
- if the species is not detected through the above methods, then an arboreal trapping program comprising modified arboreal Elliott A traps according to the method recommended in Section 3.3.9 is recommended, if permission and licensing is approved by relevant Western Australian government authorities. A standard bait of a peanut butter honey and rolled oats mixture is recommended, but including chopped bacon or sardines may also be effective
- Camera traps with baited stations (both arboreal and terrestrial) (description of the survey technique and recommended effort is outlined in Section 3.3.6)
- Community liaison to detect in the location of additional populations of the species.

Similar species in range

Both the red-tailed phascogale and the brush-tailed phascogale occur in south-western Western Australia, but their ranges are largely discrete. The red-tailed phascogale can be distinguished by the red coloured fur at the base of its tail (Bradley et al. 2008).

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Rufous hare wallaby (Bernier Island)

Lagorchestes hirsutus bernieri

States and territories: Western Australia

Regions: Bernier Island.

Habitat: Sand plains with low shrubs and spinifex hummock grassland (Johnson & Burbidge 2008).

Habit: Ground-dwelling.

Avg. body weight: 1620 g (Richards et al. 2001).

Activity pattern: Nocturnal.

Diet: Herbivore: spinifex, forbs and grasses.

Breeding: Breeding on Bernier Island occurs between March and September (this was the only period sampled), but the timing of breeding events may be mediated by rainfall (Richards et al. 2001).

Description

There are three rufous hare wallaby subspecies: two from Western Australia, *L. h. bernieri* from Bernier Island, *L. h. dorrae* from Dorre Island, and an unnamed subspecies restricted to the central Northern Territory. The rufous hare wallaby once ranged across central Western Australia and into the Northern Territory, but impacts from introduced predators and changes in land use and burning frequency have severely fragmented its former distribution. The last known remaining mainland population of the rufous hare wallaby occurred in the Tanami Desert, but was destroyed by wildfire (Lundie-Jenkins 1993) and since then reintroduction programs have struggled because of cat and fox predation (Lundie-Jenkins 1993; Gibson et al. 1994). Reintroduced animals have been recorded sheltering in habitats not utilised by natural populations (under shrubs rather than under spinifex) and this species may be more plastic in its microhabitat selection than previously thought (Hardman & Moro 2006).

Spinifex makes up a large proportion of the species' diet, but it also feeds on forbs and grasses when they are available after rainfall (Johnson & Burbidge 2008). Likewise, female reproductive cycles are also probably related to rainfall, with breeding deferred during drought conditions (Richards et al. 2001). Rufous hare wallabies shelter in depressions or burrows (sometimes over 70 centimetres deep) scraped out from under low lying vegetation (Johnson & Burbidge 2008). Aboriginal people hunted rufous hare wallabies and their use of fire while hunting this culturally significant species contributed to a mosaic of fire histories across the landscape (Johnson & Burbidge 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the rufous hare wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes spinifex grasslands (description of the survey technique and recommended effort is outlined in Section 3.1)



- daytime searches for signs of activity, including shelter sites, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2). Tracks may be indistinguishable from other wallaby species present on Bernier Island, however, rufous hare wallaby scats have a distinctive flattened tubular shape that should be distinguished from other macropod scats
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2).

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:

- observations conducted at dusk/early night at potential resource sites such as watering points according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10, using universal bait and possibly lucerne hay. However, given the conservation status of this species and its susceptibility to capture myopathy (Cole et al. 1994), every effort should be made to minimise stress and disturbance to animals during a trapping program (for example, Langford & Burbidge 2001) or to use non-invasive techniques wherever possible.

The survey method recommended has been designed for surveys on Dorre and Bernier Islands where the rufous hare wallaby is known to exist. Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities in Western Australia. Any signs of this species on the mainland should be reported immediately to appropriate government authorities.

Similar species in range

On Bernier Island there are a number of other macropodoidea species, including the banded hare wallaby *Lagostrophus fasciatus* and the burrowing bettong *Bettongia lesueur lesueur*, as well as the western barred bandicoots *Perameles bougainville* which may possibly be misidentified during spotlight surveys.

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Rufous hare wallaby (central mainland form), mala

Lagorchestes hirsutus unnamed subsp.

States and territories:	Northern Territory.
Regions:	Tanami Desert.
Habitat:	Sand plains with low shrubs and spinifex hummock grassland (Johnson & Burbidge 1995).
Habit:	Ground-dwelling.
Avg. body weight:	1220 g (males) and 1310 g (females) (Johnson & Burbidge 2008).
Activity pattern:	Nocturnal.
Diet:	Herbivore: spinifex, forbs and grasses.
Breeding:	Breeding has been recorded throughout the year when resources are available (Johnson & Burbidge 2008).

Description

There are three rufous hare wallaby subspecies: two from Western Australia, *L. h. bernieri* from Bernier Island, *L. h. dorrae* from Dorre Island, and an unnamed subspecies (the mala) restricted to the central Northern Territory. The rufous hare wallaby once ranged across central Western Australia and into the Northern Territory, but impacts from introduced predators and changes in land use and burning frequency have severely fragmented its former distribution. The last known remaining population of the mala occurred in the Tanami Desert, but was destroyed by wildfire (Lundie-Jenkins 1993) and since then reintroduction programs have struggled because of cat and fox predation (Lundie-Jenkins 1993; Gibson et al. 1994). Reintroduced animals have been recorded sheltering in habitats not utilised by natural populations (under shrubs rather than under spinifex) and this species may be more plastic in its microhabitat selection than previously thought (Hardman & Moro 2006).

Spinifex makes up a large proportion of the species' diet, but it also feeds on forbs and grasses when they are available after rainfall (Johnson & Burbidge 2008). Likewise, female reproductive cycles are also probably related to rainfall, with breeding deferred during drought conditions (Richards et al. 2001). Rufous hare wallabies shelter in depressions or burrows (sometimes over 70 centimetres deep) scraped out from under low lying vegetation (Johnson & Burbidge 2008). Aboriginal people hunted rufous hare wallabies and their use of fire while hunting this culturally significant species contributed to a mosaic of fire histories across the landscape (Johnson & Burbidge 2008).

Survey methods

Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities in Western Australia. Any signs of this species on the mainland should be reported immediately to appropriate government authorities.

Similar species in range

The rufous hare wallaby overlaps in distribution with the spectacled hare wallaby.

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Rufous hare wallaby (Dorre Island)

Lagorchestes hirsutus dorreae

States and territories: Western Australia.

Regions: Dorre Island.

Habitat: Sand plains with low shrubs and spinifex hummock grassland (Johnson & Burbidge 2008).

Habit: Ground-dwelling.

Avg. body weight: 1580 g (males) and 1740 g (females) (Johnson & Burbidge 2008).

Activity pattern: Nocturnal.

Diet: Herbivore: spinifex, forbs and grasses.

Breeding: Breeding on Dorre Island occurs between March and September, but the timing of breeding events may be mediated by rainfall (Richards et al. 2001).

Description

There are three rufous hare wallaby subspecies: two from Western Australia, *L. h. bernieri* from Bernier Island, *L. h. dorreae* from Dorre Island, and an unnamed subspecies restricted to the central Northern Territory. The rufous hare wallaby once ranged across central Western Australia and into the Northern Territory, but impacts from introduced predators and changes in land use and burning frequency have severely fragmented its former distribution. The last known remaining mainland population of the rufous hare wallaby occurred in the Tanami Desert, but was destroyed by wildfire (Lundie-Jenkins 1993) and since then reintroduction programs have struggled because of cat and fox predation (Lundie-Jenkins 1993; Gibson et al. 1994). Reintroduced animals have been recorded sheltering in habitats not utilised by natural populations (under shrubs rather than under spinifex) and this species may be more plastic in its microhabitat selection than previously thought (Hardman & Moro 2006).

Spinifex makes up a large proportion of the species' diet, but it also feeds on forbs and grasses when they are available after rainfall (Johnson & Burbidge 2008). Likewise, female reproductive cycles are also probably related to rainfall, with breeding deferred during drought conditions (Richards et al. 2001). Rufous hare wallabies shelter in depressions or burrows (sometimes over 70 centimetres deep) scraped out from under low lying vegetation (Johnson & Burbidge 2008). Aboriginal people hunted rufous hare wallabies and their use of fire while hunting this culturally significant species contributed to a mosaic of fire histories across the landscape (Johnson & Burbidge 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the rufous hare wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes Spinifex grasslands (description of the survey technique and recommended effort is outlined in Section 3.1)

- daytime searches for signs of activity, including shelter sites, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2). Tracks may be indistinguishable from other wallaby species present on Dorre Island, however, rufous hare wallaby scats have a distinctive flattened tubular shape that should be distinguished from other macropod scats
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2).

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:

- observations conducted at dusk/early night at potential resource sites such as watering points according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10, using universal bait and possibly lucerne hay. However, given the conservation status of this species and its susceptibility to capture myopathy (Cole et al. 1994), every effort should be made to minimise stress and disturbance to animals during a trapping program (for example, Langford & Burbidge 2001) or to use non-invasive techniques wherever possible.

The survey method recommended has been designed for surveys on Dorre and Bernier Islands where the rufous hare wallaby is known to exist. Should surveys be required on the mainland, then further expert advice should be sought from the relevant government authorities in Western Australia. Any signs of this species on the mainland should be reported immediately to appropriate government authorities.

Similar species in range

On Dorre Island there are a number of other macropodoidea species including the banded hare wallaby *Lagostrophus fasciatus* and the burrowing bettong *Bettongia lesueur lesueur*, as well as the western barred bandicoot *Perameles bougainville* which may possibly be misidentified during spotlight surveys.

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Sandhill dunnart

Sminthopsis psammophila

States and territories:	Western Australia, South Australia and Northern Territory.
Regions:	<p>Western Australia: Queen Victorian Spring Nature Reserve and Mulga Rocks in the south-western edge of the Queen Victoria Desert (Pearson & Robinson 1990, Churchill 2003).</p> <p>South Australia: Yarle Lakes, Ooldea and Mount Christie in the Yellabinna sand dunes (Pearson & Robinson 1990) and various localities on the Eyre Peninsula (Churchill 2003, Way 2008).</p> <p>Northern Territory: Collected from the Lake Amadeus region in 1894, with no recent records although remains have been identified from owl pellets at Uluru and Kata Tjuta.</p>
Habitat:	Poorly understood, but found in a variety of sandy habitats, including desert oak, <i>Allocasuarina decaisneana</i> mallee, tea-tree, eucalypt and <i>Callitris</i> woodlands with an understorey of hummock grass, <i>Triodia</i> or <i>Plectrachne</i> spp. and usually with sand dunes present (Pearson & Churchill 2008).
Habit:	Ground-dwelling.
Avg. body weight:	33 g (females); 36 g (males) (Pearson & Churchill 2008).
Activity pattern:	Nocturnal.
Diet:	A wide variety of invertebrates (Pearson & Churchill 2008).
Breeding:	Spring to early autumn (Pearson & Churchill 2008).

Description

The sandhill dunnart is larger than all other dunnarts, with the exception of the Julia Creek dunnart, *Sminthopsis douglasi*, but the two species do not overlap in distribution. The sandhill dunnart is distinguished by dark eye rings and a distinctive tail that is pale grey above and darker grey below. The tail tapers towards the tip and has a vertical crest of hairs on the terminal quarter.

The sandhill dunnart was first collected at Lake Amadeus in the Northern Territory in 1894, but was not recorded again until 1967 in South Australia. Since then, it has been captured in the arid zone of Western Australia and South Australia. Capture sites are characterised by a sandy substrate with a spinifex grass understorey (Pearson & Churchill 2008).

In a recent study on the Eyre Peninsula, mid-aged (stage three of a five stage age classification) spinifex *Triodia irritans* hummocks were preferentially selected by radio-tracked sandhill dunnart for shelter during the day (Churchill 2003). The spinifex hummocks in this growth phase had live spiny foliage around the periphery, but the older spines in the centre were softer, and could be moulded by the dunnarts to form a nest for shelter (Churchill 2003). Large-sized stage three hummocks were restricted to unburnt sand dune slopes within the site, which indicated that the sandhill dunnart preferred habitat available within this particular seral stage of

spinifex growth (Churchill 2003). Suitable habitat is usually associated with open mallee communities with a diverse shrub layer, with species including yarell *Eucalyptus gracilis*, ridge-fruited mallee *E. incrassate*, red mallee *E. oleosa*, beaked red mallee *E. socialis* and scrub cypress pine *Callitris verrucosa* (Way 2008).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the sandhill dunnart in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as mid-aged spinifex hummocks (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- pitfall trapping surveys (at least 60 centimetres deep) conducted according to the technique and recommended effort provided in Section 3.3.8
- Elliott E/A trapping surveys (especially in winter) conducted according to the technique and recommended effort provided in Section 3.3.9
- hair sampling device surveys as the sandhill dunnart is included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- daytime searches for signs such as tracks in sandy substrates in suitable habitat (description of the survey technique and recommended effort is provided in Section 3.2). Note that care is required in the separation of this species from other sympatric small mammal species
- consider the placement of camera traps in suitable habitat as this technique is ideal for cryptic species occurring at low densities, particularly as this species can be relatively easily separated from other sympatric dunnart species
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area.

In addition, sand tray/soil plot surveys may provide a suitable survey method for detection in areas that do not have a sandy substrate. A description of the technique and recommended survey effort is provided in Section 3.3.2.

Similar species in range

The distributional range of the sandhill dunnart overlaps with a number of other dunnart species, including the Ooldea dunnart *S. ooldea*, striped-faced dunnart *S. macroura*, hairy-footed dunnart *S. hirtipes*, little long-tailed dunnart *S. dolichura*, grey-bellied dunnart *S. griseoventer*, long-tailed dunnart *S. longicaudata*, Gilbert's dunnart *S. gilberti*, lesser hairy-footed dunnart *S. youngsoni* and the fat-tailed dunnart *S. crassicaudata*. The sandhill dunnart can be distinguished in the field by its relatively larger body size and distinctive tail (Pearson & Churchill 2008).



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Shark Bay mouse, djoongari

Pseudomys fieldi

States and territories:	Historically Western Australia, South Australia and Northern Territory but currently exist only in Western Australia.
Regions:	Extant on Bernier Island, Shark Bay but recently translocated to three locations in the same region: Doole Island, North West Island, Heirisson Prong (Morris et al. 2000), Faure Island and Montebello Island (Breed and Ford 2007).
Habitat:	Occurs mainly in coastal dune habitat dominated by beach Spinifex and coastal daisy bush, but also found further inland on islands where <i>Triodia</i> and <i>Acacia</i> spp. occur (Morris et al. 2000).
Habit:	Ground-dwelling.
Avg. body weight:	45.5 g (Morris and Robinson 2008).
Activity pattern:	Nocturnal.
Diet:	Omnivorous: flowers, stems, fungi, insects and spiders.
Breeding:	Breeds between May and November on Bernier Island, producing up to five young per litter (Morris et al. 2000).

Description

The Shark Bay mouse is a long-haired mouse that has been previously referred to as *Pseudomys praeconis* until taxonomic revision placed the two type specimens as the same species. Sub-fossil remains from cave deposits have been used to determine that the former distribution of the Shark Bay mouse covered much of arid and semi-arid Australia west of the Flinders Ranges and north to Uluru (Chapman & Kitchener 1977; Baynes 1990; Morris et al. 2000). Two mainland specimens have been collected: first at Shark Bay in 1858, and then at Alice Springs in 1859. In 1989 an extensive survey of likely habitat in the Shark Bay area failed to detect the presence of the species (Sanders & Harold 1990). Since then, a relatively large population (6000–7000 individuals) has been identified on Bernier Island, and from this source population the species has been re-introduced to Doole Island, North West Island, Faure Island, Montebello Island and Heirisson Prong in Shark Bay, Western Australia (Morris et al. 2000; Breed & Ford 2007), although the attempt at Heirisson Prong appears to have been unsuccessful (Breed & Ford 2007).

The Shark Bay mouse appears to use communal burrows constructed from a variety of surface covers, including beachcast seagrass, and grasses and shrubs on sand dunes (Morris & Robinson 2008). The burrows are only shallow, which may have attributed to the species' decline in response to predation by introduced cats and foxes (Morris et al. 2000). Furthermore, the burrows tend to be used more frequently during the breeding season between May and November (Morris & Speldewinde 1992).



Survey methods

On the basis of previous surveys mentioned, the following survey techniques are recommended to detect the presence of the Shark Bay mouse in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as coastal dune habitat with spinifex tussocks, coastal daisy bushes and beachcast seaweed, but also in habitats with *Triodia* and *Acacia* spp. further inland (description of the survey technique and recommended effort is provided in Section 3.1)
- daytime searches for signs including burrows, excavated earth, runways, tracks and scats (description of the survey technique and recommended effort is provided in Section 3.2)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- Elliott A trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9 using a mixture of rolled oats, peanut butter and sultanas for bait.

Hair sampling devices are not recommended because the Shark Bay mouse is not included among those species known to be distinguishable from hair samples (see Table 2, Section 3.3.7). Should this situation change then hair sampling may provide an appropriate alternative detection technique.

Similar species in range

No similar species in range, although this species may be confused with the western mouse *Pseudomys occidentalis* on mainland sites. If a specimen of the Shark Bay mouse is captured on the mainland, hair or tissue samples should be considered for identification and/or molecular analysis, provided that appropriate permission and licensing has been granted by relevant state or territory government organisations.

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Smoky mouse, konoom

Pseudomys fumeus

States and territories: Victoria, NSW and ACT.

Regions: Victoria: Grampians, Otway Range, East Gippsland, Highlands and Mt Stradbroke area (Menkhorst 1995).
NSW: Mt Poole and Mullica in the south-east Forests National Park near Eden, and bones of sub-fossil remains from Jenolan Caves, Wombelano Caves, Yarrangobilly and Marble Arch (Ford et al. 2003).
ACT: Bullshead and Mt Kelly, Brindabella Range (Jurkis et al. 1997).

Habitat: Various, including coastal heaths, sub-alpine heaths, dry forest or woodland and fern gullies in wet forest (Seebeck & Menkhorst 2000). Characteristic of all habitats, except fern gullies are the predominance of heathy shrubs, particularly from the families Papilionaceae and Epacridaceae (Menkhorst & Seebeck 1981).

Habit: Ground-dwelling.

Avg. body weight: Variable between populations: 49 g (NSW), 70 g (Grampians) (Ford 2008).

Activity pattern: Nocturnal.

Diet: Primarily herbivorous, in addition to underground fungi and insects such as the Bogong moth, *Agrotis infusa* (Cockburn 1981a; Ford et al. 2003).

Breeding: Breeds between October and April (two litters produced per season) (Cockburn 1981b; Woods & Ford 2000).

Description

The smoky mouse is a small rodent with a fragmented range within the ACT, NSW and Victoria. There are two forms of the species: the western form occurs from the Grampians west of Melbourne, and the eastern form is found in East Gippsland, south-eastern NSW and the Brindabella Ranges of the ACT. Subfossil remains suggest that the species' range has declined in recent times (Jurkis et al. 1997) possibly due to a reduction in suitable habitat of forest with a diverse sclerophyll understorey related to post-fire succession (Menkhorst 1995).

The breeding and feeding patterns of the smoky mouse are interrelated and seasonal. In summer the smoky mouse feeds on seeds, shrubby legumes and bogong moths when available, and in winter it switches to a diet of underground fungi found around the roots of some shrubs and grasses (Menkhorst 1995). Females tend to be found in favoured habitats where shrubs flowering in September to November attract bogong moths, and individuals with home ranges away from these resources (particularly males) can die of starvation at this time.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the smoky mouse in areas up to 5 hectares in size:



- daytime searches for potentially suitable habitat resources such as ridgetops with a northern aspect and a proportionately high cover of rock and potential food resources such as a dominance of Papilionaceae and Epacridaceae (description of the survey technique and recommended effort is provided in Section 3.1)
- collection of predator scats, owl casts or remains in predatory bird/mammal nests/dens (description of the survey technique and recommended effort is provided in Section 3.2)
- hair sampling device surveys using a mixture of rolled oats, peanut butter and pistachio nut oil for bait, conducted according to the description of the technique and the recommended effort outlined in Section 3.3.7, as the smoky mouse is included among those species distinguishable from hair samples (see Table 2, Section 3.3.7)
- Elliott A/E trapping surveys conducted according to the technique description and recommended effort provided in Section 3.3.9
- camera traps used in association with bait stations (see Section 3.3.6). For identification from photographs, cameras should be approximately 25 centimetres above the ground and the bait station approximately 1.5 metres from the camera (Nelson 2009). An effective remote camera survey protocol for the smoky mouse is to deploy two cameras at each site for at least one week, with the cameras placed at least 100 metres apart (Nelson et al. 2010).
- searches for road-kills, particularly during hot weather.

The abundance of the smoky mouse fluctuates over time (Ford et al. 2003), which means that its distribution is both spatially and temporally patchy (Watts & Aslin 1981). Therefore, techniques suited for low population densities (for example, camera traps) need to be considered as primary techniques.

Similar species in range

The smoky mouse overlaps in distribution with the bush rat *Rattus fuscipes* and the house mouse *Mus musculus*, the swamp rat *Rattus lutreolus*, the black rat *Rattus rattus* and the heath rat *Pseudomys shortridgei*. The smoky mouse is larger than the house mouse, smaller than the black rat and has a longer tail to body ratio and darker fur than the three native rats. Its pink feet also distinguish it from the dark-footed swamp rat and the heath rat.

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Southern brown bandicoot

Isoodon obesulus obesulus

States and territories: NSW, Victoria, Tasmania, South Australia and Western Australia.

- Regions:**
- NSW – south-eastern (Braithwaite 1995);
 - Victoria – approximately 150 metre wide strip along the coast (Braithwaite 1995)
 - South Australia – four regions, including the Mount Lofty Ranges, the southeast and Kangaroo Island (status on the Eyre Peninsular is uncertain) (Paull 1995)
 - Tasmania – widespread, absent from all islands except Bruny Island and West Sisters Island in the Furneaux Group. It has been introduced to Maria Island (Rounsevell et al 1991)
 - Western Australia – south-eastern region (Braithwaite 1995).
- Habitat:** Various – forest, heath, swamp and coastal scrub with sandy soil and scrubby ground-cover vegetation, particularly in areas which are subject to intermittent fires (Braithwaite 1995).
- Habit:** Ground-dwelling.
- Avg. body weight:** 850 g males and 700 g females (Braithwaite 1995).
- Activity pattern:** Nocturnal.
- Diet:** Omnivore: invertebrates, tubers and fungi (Braithwaite 1995).
- Breeding:** Breeding from winter to late summer, with two to four litters of between three and four young (Braithwaite 1995).

Description

Three subspecies of the southern brown bandicoot occur within a fragmented but widespread distribution across Australia as follows:

- *I. o. obesulus* from southern Western Australia, South Australia, Victoria, NSW and Tasmania
- *I. o. nauticus* from Nyuts Archipelago off the South Australian coast, and
- *I. o. peninsulae* from the east coast of Cape York, Queensland.

Southern mainland populations will be treated as *I. o. obesulus* in this report but see Pope and colleagues (2001) and Zenger and colleagues (2005) for discussion about southern brown bandicoot taxonomy.

The southern brown bandicoot prefers open forest, heath and swamp habitats (Cooper 1998), particularly with a mosaic of patches with different burning histories (Braithwaite 1995). Fire increases the diversity of resources like plants, insects and fungi that provide food and are necessary for population growth and increased fecundity in this species (Braithwaite 1995). Individuals shelter in nests constructed from plant matter in leaf litter or dense understorey vegetation during the day, and at night forage on insects and fungi (Braithwaite 1995). This species appears to have a high degree of morphological and behavioural plasticity. For example,

Cooper (1998) noted that bandicoots from open forests were on average larger than those from swamp-reed habitats. Lobert and Lee (1990) found differences in the timing and length of the breeding season, the number of litters produced per season and the rates of growth in populations of the southern brown bandicoot from Tasmania and Victoria. Paull (1995) found that southern brown bandicoot habitat is sensitive to fire management regimes and that over-frequent fire removes the preferred microhabitats for this species.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the southern brown bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat, such as areas with a dense understorey and thick ground-cover, perhaps focussing on areas where fire has produced a mosaic of habitats that vary according to the time since burning (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats, nests and diggings (description of the survey technique and recommended effort is outlined in Section 3.2). However, where the southern brown bandicoot occurs in sympatry with other bandicoot species, direct detection techniques should be used to distinguish between the species
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- hair sampling surveys (including the use of baited open tubes) with ten hair tunnels per hectare set in areas showing evidence of recent diggings and suitable habitat. These surveys should be conducted in autumn, according to the description of the technique provided in Section 3.3.7. A minimum of two surveys, each of 14 day duration, should be conducted, timed at least one month apart and at least one undertaken following significant rainfall
- baited camera traps using universal bait (description of the survey technique is outlined in Section 3.3.6) using one camera per hectare. Autumn is preferred, but can be year round if validated with supporting evidence. A minimum of two surveys, each of 14 day duration, should be conducted, timed at least one month apart and at least one undertaken following significant rainfall
- community liaison to detect the location of additional populations of the species.

It is recommended that hair sampling surveys be conducted to distinguish between bandicoot species in a staged detection process, with initial effort focussing on searching for signs and soil plot surveys. Conducted in concert with baited camera traps, the efficacy of survey effort is likely to increase.

Live trapping (using cage traps) is not recommended to determine presence due to its inefficiency (southern brown bandicoot are often considered to be “trap shy”) and the tendency of females to eject pouch young when trapped.



Similar species in range

The southern brown bandicoot occurs in sympatry with two species of bandicoot, including the long-nosed bandicoot *Perameles nasuta* on mainland eastern Australia and the eastern barred bandicoot *Perameles gunnii* in Tasmania.

The longer nose and larger ears of the long-nosed bandicoot distinguish it from the southern brown bandicoot. The white striped fur on the rump of the eastern barred bandicoot distinguishes this species from the southern brown bandicoot, which has a uniformly brown/grey coloured pelage. Furthermore, the southern brown bandicoot occurs in sympatry with several *Potorous* spp, which produce similar but smaller and more conical foraging pits (usually indistinguishable in the field to all but experienced observers). The distribution of the southern brown bandicoot overlaps with the long-nosed potoroo *Potorous tridactylus* along east coast mainland and Tasmania, Gilbert's potoroo *Potorous gilbertii* in Two Peoples Bay, Western Australia, and the long-footed potoroo *Potorous longipes* in north-eastern Victoria and adjacent area of ACT and NSW. The forepaw tracks of bandicoots are distinguished from those made by potoroos by the presence of three rather than five digits (B Triggs pers. comm.).

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Southern brown bandicoot (Nyuts Archipelago)

Isoodon obesulus nauticus

States and territories: South Australia.

Regions: East Franklin, West Franklin and Saint Francis Islands, South Australia

Habitat: Heath and coastal scrub.

Habit: Ground-dwelling.

Avg. body weight: 850 g males and 700 g females (Braithwaite 1995).

Activity pattern: Nocturnal.

Diet: Unknown, but probably invertebrates, tubers and fungi.

Breeding: Unknown.

Description

The Nyuts Archipelago southern brown bandicoot *I. o. nauticus* has a range restricted to the Franklin Islands in the Great Australian Bight, Nyuts Archipelago and Saint Francis Islands off the coast, near Ceduna, South Australia. Subfossil evidence of the species has also been recorded on two other islands off the coast of South Australia (Flinders Island and Revesby Island) (Paull 1995). The relationship between this subspecies and other southern brown bandicoot subspecies is unresolved (see Pope et al. 2001). The subspecies and their distributions have been described in the previous species profile for the mainland subspecies of southern brown bandicoot, *Isoodon obesulus*.

Copley and colleagues (1990) estimated the population size of the Nyuts Archipelago southern brown bandicoot on the Franklin Island to be approximately 1000 and relatively stable. The Franklin Island populations as well as those on Saint Francis Island are protected by the inclusion of the islands in conservation parks.

Survey methods

Surveys to detect the presence of the Nyuts Archipelago southern brown bandicoot within its known range should focus on detecting signs of foraging and tracks, rather than expending effort trapping or conducting hair sampling surveys. Given that the species' highly restricted range does not overlap with other bandicoot species, then the application of direct detection methods is not considered necessary to confirm the species' identity. Therefore, the following survey techniques are recommended to detect the presence of the Nyuts Archipelago southern brown bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources. A description of habitat preferences for this sub-species is not available and so all habitats should be searched (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats, nests and conical foraging holes (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens in areas where the species distribution may be in question (description of the survey technique and recommended effort is outlined in Section 3.2)

- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- baited camera traps using universal bait (description of the survey technique is outlined in Section 3.3.6) using one camera per hectare. Autumn is preferred, but can be year round if validated with supporting evidence. A minimum of two surveys, each of 14 day duration, should be conducted, timed at least one month apart and at least one undertaken following significant rainfall
- community liaison to detect the location of additional populations of the species.

Similar species in range

There are no other species of bandicoot that occur within the known range of the Nuyts Archipelago southern brown bandicoot. However, the species is similar in appearance to the mainland subspecies.

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Southern marsupial mole, yitjarritjarri, itjaritjari

Notoryctes typhlops

Distribution:	Distributed across much of Australia's sandy desert country in Western Australia, Northern Territory and South Australia.
Habitat:	Sand desert country, most often recorded on sand dunes with various acacias and other shrubs, sometimes in association with spinifex (Benshemesh 2004). They can also occur in sandy plains and possibly river flats, especially where aeolian dunes also occur. Most locations are those with deep loose soil (Benshemesh 2004).
Habit:	Mostly underground, about 20–60 cm below the ground surface, moving about by digging back-filled tunnels in search of prey (Benshemesh 2008).
Avg. body weight:	Poorly known. Weight range from a limited sample was 40–70 g (Benshemesh 2008).
Activity pattern:	Unknown daily activity pattern, as the species spends virtually all of its time underground. Occasional individuals come to the surface, such as after heavy rain or during cold weather (Benshemesh 2008). It is thought that such individuals may be under stress.
Diet:	Poorly known. Limited data suggests it is largely insectivorous, with ant larvae, sawfly larvae, beetles, beetle larvae and cossid moth larvae recorded eaten by captive and wild specimens (Benshemesh & Johnson 2003). It has also been recorded eating geckoes, spiders and centipedes in captivity (Benshemesh 2008).
Breeding:	Very little known. Records available indicate that one or two young are born and raised to independence in the pouch (Langford & Pavey 2002). Nothing is known about how individuals find each other, mate and raise young whilst underground.

Description

The southern marsupial mole, although widespread across the sandy deserts of Australia, remains an enigma. 'Blind with shovels for hands and a subterranean lifestyle, marsupial moles have mystified scientists for over a hundred years and inspired a rich Aboriginal mythology' (Benshemesh 2008). It is so poorly known that the endangered listing is a precautionary measure as their status is described as 'unknown, but probably common' (Benshemesh 2008).

Given the similarity in appearance between southern and northern marsupial moles (see 'similar species' below) and the lack of reported information about the species' biology, discerning the ranges of the two marsupial mole species is difficult. Recent work suggests that the edges of the distributions of the two species exists somewhere in the Tanami Desert, with the southern marsupial mole occurring in the east and the northern marsupial mole *N. caurinus* in the western Tanami, but it remains uncertain whether these forms are sympatric (Benshemesh 2004).

Marsupial moles have specialised adaptations that have evolved in response to the species' burrowing lifestyle (Langford & Pavey, 2002). Their eyes are vestigial and hidden under the skin, their ears are reduced to a simple opening beneath the fur on either side of the head, and their conical shaped noses are covered with a

tough, horny shield to protect against the sand. To burrow through the sand, the third and fourth digits of the forefoot are enlarged and possess large shovel-like claws for digging. They have a short, hard and leathery tail that is marked by distinct rings, ending in a horny 'knob'. The colouration of the fur can vary from near white through pinkish to rich golden red.

Survey methods

The most efficient method of surveying for marsupial moles is to count the number of tunnels underground (Benshemesh 2005). A summary of the technique is provided below (note that the surveyor should consult J Benshemesh for advice prior to conducting any surveys):

- survey trenches should be dug approximately 80 centimetres deep, 120 centimetres long and 40 centimetres wide
- the trench should be dug with caution, and the use of mechanical equipment should be avoided
- digging should cease if marsupial moles are observed
- trenches should be allowed to dry for between three to five days (few tunnels will be apparent until the soil is adequately dry)
- the tunnels will appear as circular or oval shapes, usually larger than 25 millimetres (but depending on the angle made with the trench wall)
- trenches should be dug at three levels on the dune: near the crest, mid slope, and at the base of the dune, positioned less than 1 kilometre apart. In suitable habitat, two to six tunnels are usually found per square metre of vertical trench face.

Valuable information can also be obtained recording tracks, and photographs should be taken for confirmation by an expert, particularly in areas of uncertainty between the known ranges of the two species (Benshemesh 2004).

Other techniques that could be employed in areas up to 5 hectares in size, but are less reliable and efficient, include:

- daytime searches for potentially suitable habitat resources, such as sandy soil in the central desert regions (description of the survey technique and recommended effort is outlined in Section 3.1)
- early morning (that is, before the sun is too high, making tracks hard to discern, and before a breeze disturbs track definition) searches for signs of activity, particularly for tracks (photographs should be taken for confirmation by an expert) or individuals that may be observed on the surface following rain or during cold weather (description of the survey technique and recommended effort is outlined in Section 3.2). Any person undertaking track searches needs to have experience at tracking and identifying small mammal track signs in arid desert country, and
- collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and effort is outlined in Section 3.2.3). Marsupial moles can be identified to genus from hair samples (see Table 2, Section 3.3.7), or to species if genetic techniques are used.



Similar species in range

The taxonomy of the *Notoryctes* is unclear, with a suggestion that there may be one or more currently undescribed species. Currently two species of marsupial moles are recognised: the southern marsupial mole *Notoryctes typhlops* and the northern marsupial mole *Notoryctes caurinus*. The two species are thought to have an overlap in distribution; however, this has not currently been demonstrated. Although the two species can be separated genetically, they are difficult to separate morphologically. Characters used include the slightly smaller size, the narrower and shorter snout, the lack of anterior molars and the remaining cheek teeth are smaller and simpler in structure in the northern marsupial mole (Benshemesh 2008; Benshemesh & Aplin 2008). In addition, the tracks have been reported to be distinct between the two species (Benshemesh & Aplin 2008). Langford and Pavey (2002), in their description of the southern marsupial mole, refer to 'morphometric and dental studies' as the basis for the separation of the southern marsupial mole from the Great Sandy and Gibson Deserts from the northern species. Since distinguishing the species in the field may not be possible, identification is likely to require a tissue or hair sample, provided that the appropriate permission and licensing has been granted by the relevant state or territory government organisation.

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Spectacled hare wallaby (Barrow Island)

Lagorchestes conspicillatus conspicillatus

States and territories: Western Australia.

Regions: Barrow Island.

Habitat: Spinifex hummock grassland (Burbidge & Johnson 2008).

Habit: Ground-dwelling (shelters in grass hummocks).

Avg. body weight: 1600–4650 g (Burbidge & Johnson 2008).

Activity pattern: Nocturnal.

Diet: Herbivore; grazes on shrubs and spinifex tips on Barrow Island (Burbidge & Johnson 2008). On the mainland the diet comprises forbs, grasses and succulents (Ingleby & Westoby 1992).

Breeding: Breeding has been recorded throughout the year with peaks in March and September (Burbidge & Johnson 1995).

Description

Spectacled hare wallabies are small macropods, which inhabit tropical grasslands, open woodlands and shrublands across central and northern Australia. The Barrow Island subspecies is isolated but its population is stable, and was estimated to be approximately 10 000 in 1988 (Burbidge & Johnson 2008). This species has the largest range among the extant hare wallabies, but its abundance is declining. The decline is probably in response to predation by introduced predators and land use changes, including possible changes in burning patterns (Ingleby & Westoby 1992).

Spectacled hare wallabies are solitary, and shelter in tunnels among the spinifex grass on Barrow Island (Burbidge & Johnson 2008). This species is well adapted to high ambient temperatures and does not drink even when free water is available. On Barrow Island it grazes on colonising shrubs and spinifex leaf tips (Burbidge & Johnson 2008). On Barrow Island, Short and Turner (1991) found that this species may have an advantage over a sympatric macropod, the euro *Macropus robustus isabellinus*, in its ability to survive without free water and its use of both long unburned areas and areas of moderate disturbance.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the spectacled hare wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, which includes spinifex grasslands (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including shelter sites, tracks and scats (description of the survey technique and recommended effort is outlined in Section 3.2). Tracks may be indistinguishable from other kangaroo and wallaby species present on Barrow Island. Spectacled hare wallaby scats have a distinctive flattened tubular shape that should be distinguished from other macropod scats



- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- camera traps baited with universal bait and added almond, walnut or truffle oil (see Potoroo profiles for further information) are likely to prove useful for positively identifying and minimising impact on animals and are also cost-effective (description of the survey technique and recommended effort is outlined in section 3.3.6)
- searches at shelter sites or the use of hair collecting devices to collect hair samples for identification (description of the survey technique and recommended effort is outlined in Section 3.3.7).

If confirmation of the species is required from the presence of signs, then one or more of the following survey techniques should be employed:

- observations conducted at dusk/early night at potential resource sites such as watering points according to the description of the technique and the recommended effort provided in Section 3.3.4
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- a survey conducted on the central Queensland population of the mainland subspecies, *L. c. leichardti*, captured wallabies using a technique (devised by Robertson & Gepp, 1982), whereby an animal was spotted and stunned (no further sedatives were administered due to the likelihood of predation once released), before being captured in a hessian bag where the animal was processed and radio-collared (McCosker, 1997)
- cage trapping surveys using universal bait conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10. Consideration should be given to minimising the handling of animals and non invasive techniques should be used where possible.

Similar species in range

The spectacled hare wallaby is the only hare wallaby species on Barrow Island. However, a number of other macropod species occur on the island, including the burrowing bettong *Bettongia lesueur*, the golden bandicoot *Isodon auratus*, the black-flanked rock wallaby *Petrogale lateralis lateralis* and the Barrow Island euro *Macropus robustus isabellensis*. The tracks of these species may be indistinguishable.

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Spotted-tailed quoll (north Queensland), yarri

Dasyurus maculatus gracilis

States and territories:	Queensland.
Regions:	North-eastern Queensland in the wet tropics.
Habitat:	Restricted to eight disjunct mountain-top rainforests above 900 m within the wet tropics area (Burnett 2000).
Habit:	Ground and tree dwelling. Shelters in cavities and hollows in figs <i>Ficus</i> species, hollow tree trunks, caves, boulder piles and fern clumps (Burnett 1993).
Avg. body weight:	Male mean weight = 1.6 kg (n=25), female mean weight = 1.15 kg (n=24) (Jones et al. 2001).
Activity pattern:	Nocturnal/partly diurnal. Hunts arboreal prey in their hollows during the day (Burnett 2000).
Diet:	Opportunistic predator of a wide range of arboreal and terrestrial mammals, birds, reptiles and insects. They also are recorded scavenging (Burnett 1993; 2000). Ringtail possums were recorded in 41 per cent of scats (Burnett 1993).
Breeding:	Mating occurs between May and August, and young are born after 21 days gestation. The average litter size is 5 and offspring remain in the pouch for seven weeks. They are then suckled as den-young until 18–20 weeks, when they are weaned between mid-November and late December (Edgar & Belcher 1995; Jones et al. 2001).

Description

The spotted-tailed quoll is the largest and most arboreal of the quolls, with distinctive white spots on its coat and tail (distinguishing it from other quolls) (Edgar & Belcher 1995). Its range is associated with forest habitats that are not fragmented or isolated. It is a rare and cryptic species that occurs at low population densities and occupies large home ranges that vary in size, depending on habitat richness and female spacing (Belcher 2000; Nelson, 2006; Van Dyck & Strahan 2008). The species' abundance is related to the availability of resources, including prey species and suitable den sites (Belcher 2000). The abundance and distribution of the spotted-tailed quoll has declined across its range, due primarily to loss and fragmentation of habitat, but surveys to document this decline are scarce because the species is very difficult to detect (Lunney & Matthews 2001).

The spotted-tailed quoll shelters during the day in dens located in caves, among rocks, hollow logs, low tree hollows and burrows (Edgar & Belcher 1995; Belcher & Darrant 2006). The animals defecate at specific points within their home range, particularly in the vicinity of their den, at sites referred to as latrines. Latrines possibly have a function relating to intra-specific communication, such as marking a territory (Belcher 1994; Kruuk & Jarman 1995). Peak latrine use occurs during the breeding season, suggesting that these are used to enable males to monitor the reproductive status of females (Belcher 1994). They may also further be used to mark territorial boundaries and landscape features, and to communicate presence without physical contact (Belcher 1994; Van Dyck & Strahan 2008).

Spotted-tailed quolls are solitary, with females defending exclusive home range territories (600–1000 hectares), whereas males have larger and undefended home ranges, which overlap a number of female home ranges (2000–4500 hectares) (Belcher 2000; Belcher & Darrant 2004). Males move greater distances than females, especially during the breeding season when they rove in search of oestrous females. Less competitive males (sub-adults, old or sick individuals) disperse away from female home range areas during the breeding season, and are often observed at that time in areas that would not normally be suitable habitat (Belcher 2000).

Survey methods

Given that spotted-tailed quolls have home ranges in excess of several hundred hectares, the likelihood of detection in a 5 hectare sampling unit is extremely small and surveys conducted at this scale are not appropriate for such a wide-ranging species. Sampling units of 100 hectares may be more appropriate.

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the spotted-tailed quoll:

- daytime searches for potentially suitable habitat resources, such as areas associated with a gully or a ridge and potential den sites (caves, hollow logs or even dense understorey vegetation such as *Lantana* species that provides suitable cover – see Ecovision Environmental Consultants 1996). A description of the survey technique and recommended effort is outlined in Section 3.1
- daytime searches for signs of activity, including community consultation, tracks, scats and latrines (description of the survey technique and recommended effort is outlined in Section 3.2). However, where the spotted-tail quoll (north Queensland) occurs in sympatry with the northern quoll *Dasyurus hallucatus* species presence may need to be confirmed through the application of direct detection survey techniques. Hair samples may be present in scats as a result of grooming, and species identification may be possible from an analysis of such hairs if they occur
- consultation with local people, particularly investigating potential Indigenous knowledge of this species' presence in an area
- hair sampling device (hair funnels) surveys, following the description of the technique and recommended effort provided in Section 3.3.7, and using a mixture of sardines, tuna oil and flour for bait. The spotted-tail quoll (north Queensland) is included among those known to be distinguishable from hair samples (see Table 2, Section 3.3.7)
- baited camera traps using 'chuditch' bait (consisting of meat meal, sardines, fish oil, chicken oil and rolled oats) are a more cost effective survey method and also allow for concurrent data (M Schulz pers. obs.; Nelson 2008).

Cage trapping surveys are not considered necessary at the first stage of detection surveys as long as hair funnel or camera trap surveys are employed, as these are an appropriate and effective alternative. Should cage trapping surveys be required, then it is recommended that they be conducted according to the description and recommended survey effort provided in Section 3.3.10, provided that permission and licensing has been granted from the relevant government organisation. Cage trapping should not be conducted between mid-August and mid-November when females may have large pouch young or den-young.

Surveys conducted between April and September may detect males in areas where they may not usually occur, either as they move in search of females to mate with or move away from other more competitive males. The locations of these records may indicate important supplementary habitats such as corridors within fragmented landscapes.



Similar species in range

The spotted-tail quoll (north Queensland) overlaps in distribution with the northern quoll *Dasyurus hallucatus*, but can be distinguished by its larger size and spotted tail.

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Spotted-tailed quoll (southeast mainland and Tasmania)

Dasyurus maculatus maculatus

States and territories: Tasmania, Victoria, NSW and Queensland.

Regions: South-eastern mainland and Tasmania.

Habitat: Utilises a range of habitats including rainforest, damp forest, open forest and open woodland. Commonly associated with gullies, rocky escarpments and outcrops (Belcher 2000; Belcher et al. 2001).

Habit: Ground and tree-dwelling.

Avg. body weight: Average adult weights in south-eastern Australia are: males 2.8 kg (range 2.0–4.2 kg) and females 1.7 kg (range 1.2–2.1 kg) (Belcher 2003). In Tasmania adult weights are: males 3.5 kg (n=10) and females 1.8 kg (n=9) (Jones et al. 2001). Maximum weights recorded are up to 7 kg (males) and 4 kg (females) (Edgar & Belcher 1995).

Activity pattern: Crepuscular nocturnal, but often hunts for arboreal prey in their hollows during the day.

Diet: Carnivore: up to 80 per cent of diet made up of medium-sized (500–5000 g) mammals (for example, rabbits, common brushtail and common ringtail possums, bandicoots) and carrion. Young quolls are more dependent on invertebrates, reptiles, small mammals and birds, as recorded from a study in Victoria and New South Wales (Belcher 1995; Glen & Dickman 2006a). Greater gliders are a major prey item in damp forests (Glen & Dickman 2006a; Belcher et al. 2007)

Breeding: Mating occurs between late May and early August, and young are born after a 21 day gestation period. The average litter size is 5 and offspring remain in the pouch for seven weeks. Offspring are left in the den whilst the female hunts. They become fully independent at 18–20 weeks (Edgar & Belcher 1995; Belcher 2003; Van Dyck and Strahan 2008). From a limited sample, the average number of young weaned was three (Belcher 2003).

Description

The spotted-tailed quoll is the largest and most arboreal of the quolls, with distinctive white spots on its coat and tail (distinguishing it from other quolls) (Edgar & Belcher 1995). Its range is associated with forest habitats that are not fragmented or isolated. It is a rare and cryptic species that occurs at low population densities and occupies large home ranges that vary in size, depending on habitat richness and female spacing (Belcher 2000; Nelson, 2006; Van Dyck & Strahan 2008). The species' abundance is related to the availability of resources, including prey species and suitable den sites (Belcher 2000). The abundance and distribution of the spotted-tailed quoll has declined across its range, due primarily to loss and fragmentation of habitat, but surveys to document this decline are scarce because the species is very difficult to detect (Lunney & Matthews 2001).

The spotted-tailed quoll shelters during the day in dens located in caves, among rocks, hollow logs, low tree hollows and burrows (Edgar & Belcher 1995; Belcher & Darrant 2006). The animals defecate at specific points within their home range, particularly in the vicinity of their den, at sites referred to as latrines. Latrines possibly

have a function relating to intra-specific communication, such as marking a territory (Belcher 1994; Kruuk & Jarman 1995). Peak latrine use occurs during the breeding season, suggesting that these are used to enable males to monitor the reproductive status of females (Belcher 1994). They may also further be used to mark territorial boundaries and landscape features, and to communicate presence without physical contact (Belcher 1994; Van Dyck & Strahan 2008).

Spotted-tailed quolls are solitary, with females defending exclusive home range territories (600–1000 hectares), whereas males have larger and undefended home ranges, which overlap a number of female home ranges (2000–4500 hectares) (Belcher 2000; Belcher & Darrant 2004). Males move greater distances than females, especially during the breeding season when they rove in search of oestrous females. Less competitive males (sub-adults, old or sick individuals) disperse away from female home range areas during the breeding season, and are often observed at that time in areas that would not normally be suitable habitat (Belcher 2000).

Survey methods

Given that spotted-tailed quolls have home ranges in excess of several hundred hectares, the likelihood of detection in a 5 hectare sampling unit is extremely small and surveys conducted at this scale are not appropriate for such a wide-ranging species. Sampling units of 100 hectares may be more appropriate.

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the spotted-tailed quoll:

- daytime searches for potentially suitable habitat resources, such as areas associated with a gully or a ridge and potential den sites (caves, hollow logs or even dense understorey vegetation such as *Lantana* species that provides suitable cover – see Ecovision Environmental Consultants 1996) (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, scats and latrines (description of the survey technique and recommended effort is outlined in Section 3.2). Latrine searches should be limited to areas where there are rocky habitats which can be targeted for searching. Where the spotted-tailed quoll occurs in sympatry with the eastern quoll, *Dasyurus viverrinus* in Tasmania, the species present may need to be identified through the application of direct detection survey techniques. Hair samples may be present in scats as a result of grooming, and species identification may be possible from an analysis of such hairs if they occur
- hair sampling device (hair funnels) surveys, following the description of the technique and recommended effort provided in Section 3.3.7, placed 100 metres apart and using a mixture of sardines, tuna oil and flour for bait. Hair funnels should be set for a minimum of 14 consecutive nights. The spotted-tailed quoll is included among those known to be distinguishable from hair samples which will provide a high probability of detection (see Table 2, Section 3.3.7). Forty widely spaced hair-tubes within a 100 hectare sampling unit has approximately 96% likelihood of detection on occupied sites (Nelson 2007)
- recent surveys have found remote cameras to be the most cost-effective technique and allow concurrent data to be collected on other carnivores, particularly cats and foxes (Nelson 2008) (see Section 3.3.6). Cameras should be left on site for a minimum of three weeks.

Cage trapping surveys are not considered necessary at the first stage of detection, provided hair funnel surveys or remote cameras are employed, as they are an appropriate and effective alternative. Should cage trapping surveys be required, then it is recommended that they be conducted according to the description and recommended survey effort provided in Section 3.3.10, provided that permission and licensing has been



granted from the relevant government organisation. Cage trapping should, however, not be conducted between early September and mid-November when females may have large pouch young or den-young.

The optimal survey time is during the breeding season, with peak activity occurring between May and August. Surveys conducted during April to August may detect males in areas where they may not usually occur, either as they move in search of females to mate with or move away from other more competitive males. The locations of these records may indicate important supplementary habitats such as corridors within fragmented landscapes.

Similar species in range

The spotted-tailed quoll in Tasmania overlaps in distribution with the eastern quoll *Dasyurus viverrinus*. Spotted-tailed quolls can be distinguished by their larger size and spotted markings on their tails.

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Tammar wallaby

Macropus eugenii eugenii

States and territories: South Australia

- Regions:** Formerly occurred in parts of southern mainland South Australia, including the Eyre and Yorke Peninsulas, Mid North and Adelaide Plains, the Mt Lofty Ranges and the Fleurieu Peninsula east to the Murray River (Poole et al. 1991). However, the former range of this species is poorly understood due to the uncertain relationship between recognised subspecies and their actual former distributions (Wood Jones 1923 – 1925). Individuals have been re-introduced from New Zealand to Innes National Park on the southern tip of Yorke Peninsula, South Australia (DEH 2004).
- Habitat:** Coastal scrubs, heathland, dry sclerophyll forest and mallee with dense patches of understorey for shelter and grassy areas for foraging.
- Habit:** Ground-dwelling.
- Avg. body weight:** 7 kg (Warburton 1990).
- Activity pattern:** Nocturnal.
- Diet:** Herbivorous, principally feeding on grasses but will also forage on other herbs, shrubs and the foliage of small trees (DEH 2004).
- Breeding:** The tammar Wallaby is unusual in macropods in that it has a seasonal pattern of breeding, with most young born in late January to early February and none between July and December (Hinds 2008).

Description

The mainland tammar wallaby was extinct on mainland South Australia by the 1930s due to a combination of factors, including extensive clearing of habitat, predation by foxes and hunting (DEH 2004). Individuals were introduced from South Australia to Kawau Island, New Zealand, by the former Governor of the South Australian colony. Later individuals were introduced to the Rotorua district in New Zealand in 1912 and again in 1940 where they spread into the Waikato region and are now recognised as a pest (Warburton 1995). Morphometric studies raised the possibility that the skull morphology of the New Zealand animals matched those of the extinct mainland tammar wallaby (Poole et al. 1991). Investigation of the origin of these populations using microsatellite markers confirmed the New Zealand populations did not originate from Kangaroo Island but rather from the previously considered extinct mainland South Australian population (Taylor & Cooper 1999). Rediscovery of this wallaby occurring as an exotic species in New Zealand resulted in a repatriation program, with 85 individuals repatriated in 2003–2004 (DEH 2004). A successful captive breeding program resulted in a number of releases into Innes National Park on the lower Yorke Peninsula, coupled with a fox control program.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the mainland tammar wallabies in areas up to 5 hectares in size:

- daytime searches for signs of activity, including scats and pads (description of the survey technique and recommended effort is outlined in Section 3.2). However, caution is required, as scats and pads can readily be confused with sympatric macropod species
- cage trapping surveys as described for the translocation program (DEH 2004). Particular care must be taken to avoid injury to animals captured
- where cage trapping proves difficult deploy aids, such as fenceline traps and nets laid across pads, to aid in capture
- car-based or on-foot spotlight surveys, particularly to locate tagged individuals, where capture is not required
- community liaison to provide information on individuals that occur outside Innes National Park (description of the survey technique and recommended effort is provided in Section 3.2.1)
- camera traps on pads or along fencelines where there are unconfirmed sightings, for example private land adjacent to Innes National Park (see Section 3.3.6).

Similar species in range

The mainland and Kangaroo Island (*M. e. decres*) subspecies are difficult to separate with any certainty (Wood Jones 1923 – 1925). There are no other similar-sized macropod species extant in the mainland tammar wallaby's former distribution.

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Tasmanian devil

Sarcophilus harrisii

States and territories: Tasmania.

Regions:	Widespread across Tasmania, excluding the Bass Strait and other offshore islands. Prior to European settlement this species was widespread on the Australian mainland but became extinct between 430 and 5000 years ago, possibly through competition with dingoes and increasing aridity (Jones 2008).
Habitat:	Preferred habitats of the Tasmanian devil are open dry eucalypt forests, grassy woodlands and coastal scrub, with the highest populations occurring in a mosaic of grazing land and dry open forest and woodland in the medium to drier rainfall zone of the east, north and north-western parts of Tasmania (Jones & Barmuta 2000; Jones 2008). It avoids steep slopes and rocky areas and is present in lower densities in wet eucalypt forests, rainforests and buttongrass moorlands of the west and south-west parts of Tasmania (Jones & Barmuta 2000). The Tasmanian devil also occurs in modified habitats, such as forestry plantations, along roads, farmland and urban fringes, including rubbish tips. Dens may either be dug at a shallow angle and up to 15 metres in length or individuals may utilise common wombat <i>Vombatus ursinus</i> burrows. They may also shelter in logs, thickets of undergrowth such as tussock grass patches, caves, rock clefts and beneath buildings (Triggs 1996; Jones 2008).
Habit:	Primarily ground dwelling.
Avg. body weight:	8 kg (males) and 6 kg (females).
Activity pattern:	Predominantly nocturnal.
Diet:	An opportunistic predator and a specialist scavenger, with social feeding (maximum number of 22 individuals) at the carcasses of larger prey (Jones 2008). Primary prey species are macropods, possums and wombats that are captured by a combination of ambush and short pursuit (Jones & Barmuta 2000). Cannibalism is considered fairly common in this species (Pfennig et al. 1998).
Breeding:	The Tasmanian devil is promiscuous. It breeds once a year primarily between February and March, producing four young that are reared in dens (Guiler 1970; Jones 2008).

Description

The Tasmanian devil is an iconic species that is the world's largest living marsupial carnivore. It can prey on species as large as wallabies and is an efficient scavenger leading to them being referred to as the 'bush undertakers'. Although this species is wide ranging with movements of 50 kilometres recorded, there are two distinct subpopulations, with one subpopulation confined to the north-west of the state, west of the Forth River and south to Macquarie Heads (Jones et al. 2004). The first indication of their presence is often the presence of distinctive scats and screaming sounds enough to 'raise the dead' when mating or interacting at prey carcasses. In the last 10 years Devil Facial Tumour Disease, an infectious neuroendocrine cancer, has caused major population declines (locally up to 80 per cent) across two thirds of the species' range (Tasmanian



Department of Primary Industries, Water and Environment 2005), with newly infected populations continuing to be recorded. The largest declines have been recorded in areas which formerly supported high densities and, like other infectious diseases, it may not persist in or threaten low density populations.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the Tasmanian devil in areas up to 5 hectares in size:

- daytime searches for scats (description of the survey technique and recommended effort is provided in Section 3.2.2). Scats are diagnostic, being grey in colour with large, sharp bone fragments intertwined with fine fur (Triggs 1996). Scats are often deposited in latrine sites, such as at track junctions and creek crossings. However, care must be taken not to confuse scats with those of the feral dogs, foxes and the spotted-tailed quoll *Dasyurus maculatus*, particularly when they are wet and misshapen
- daytime searches for tracks on soft substrate (description of the survey technique and recommended effort is provided in Section 3.2.4) or using sand traps to identify the characteristic tracks of this species (refer to Section 3.3.2)
- cage trapping, but instead of using cage traps (as described in Section 3.3.10) deploy PVC UV-resistant storm water pipe that can readily be cleaned and disinfected to avoid the spread of Devil Facial Tumour Disease, baited with any type of meat for three to five consecutive nights and having a trail of meat or fish oil leading to each trap site
- spotlight surveys, particularly vehicle-based over a distance of 10 kilometres. This has been used as a standard since 1975 across much of the species' range (see for example Hawkins et al 2006 and Hocking & Driessen 1992). This approach differs to the technique description and recommended effort provided in Section 3.3.3
- identification of characteristic vocalisations, such as those uttered during feeding and breeding interactions (for example, Jones 2008)
- deployment of hair tubes, particularly in areas with low densities (description of the survey technique and recommended effort is provided in Section 3.3.7)
- use of remote cameras, particularly at deposited carcasses (description of the survey technique is outlined in Section 3.3.6)
- community liaison to provide additional records, particularly on private land or urban areas.

Similar Species in Range

The Tasmanian devil is distinctive and unlikely to be confused with any sympatric species.

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Water mouse, false water rat

Xeromys myoides

States and territories: Queensland and Northern Territory.

Regions: Patchily distributed in coastal regions.

Queensland: between Cooloolo National Park and Proserpine, including Fraser, Bribie and Stradbroke Islands (Gynther & Janetzki 2008).

Northern Territory: coastal areas west of the Gulf of Carpentaria, including Melville Island (Gynther & Janetzki 2008).

Habitat: Mangrove swamps, saltmarsh communities, freshwater swamps and lakes close to fore dunes (Gynther & Janetzki 2008).

Habit: Semi-aquatic and ground-dwelling.

Avg. body weight: 41 g (Gynther & Janetzki 2008).

Activity pattern: Nocturnal/crepuscular.

Diet: Carnivorous: marine and freshwater invertebrates.

Breeding: Breeds at any time of year, with individuals of all age classes found in communal nest mounds, but the breeding structure is unknown (Van Dyck 1997).

Description

Little is known of the ecology or biology of the water mouse, which has been recorded in mangrove or coastal floodplain habitats in the Northern Territory, Papua New Guinea and Queensland (Van Dyck 1994). The abundance of marine invertebrate prey, particularly crabs (Van Dyck 1994) probably influences the species' presence more than just the physical or vegetation community (Woinarski et al 2000).

Initially the species was detected when its large and elaborate mud nests were observed in the Northern Territory (Magnussen et al. 1976), but the species does not always construct such nests, sometimes using simple burrows made into the banks of the high tide mark instead (Van Dyck 1997). The presence of small middens (from the remains of their feeding) at the base of hollow mangroves has been observed at locations where the species has been detected (Van Dyck 1994).

Survey methods

The following survey techniques are recommended in the draft EPBC Act policy statement 3.20 [Significant impact guidelines for the water mouse](#).

Primary survey techniques

Best practice surveys for the water mouse include implementation of all primary survey techniques either with or without the use of supplementary survey techniques.

Habitat assessment, daytime searches and Elliott trapping are the three most reliable methods for detecting the presence of the water mouse. Surveyors should examine aerial photos and topographical maps before

commencing a habitat assessment or trapping program. This will target and identify elevated, dry supralittoral areas within mangrove communities which may support active nest mounds.

Daytime searching

Daytime searches should include transect style searches spaced at 50–100 metre intervals, or in quadrats, and involve one to two hours spent looking for nesting structures for every one hectare of intertidal or supralittoral water mouse habitat.

Elliott trapping

Elliott trapping (Size A) must be carried out at night. Elliott trapping is the only reliable method for estimating water mouse population density. Elliott traps should be baited with pilchards cut in half, mullet pieces or commercial cat food. The minimum survey effort required to trap the water mouse is 400 trap nights per four to five hectares of potential water mouse habitat.

Supplementary survey techniques

Pitfall trapping, spotlighting and hair tubing can be used to increase the probability of detecting the water mouse. However, these techniques are not required where primary techniques are implemented.

Similar species in range

This species can readily be separated from the sympatric water rat by its much smaller size, lack of a partially webbed hindfeet, and lack of the distinctive white-tipped tail. It can be separated from the sympatric black rat by the tail (not significantly longer than the head and body length), its short ears, sleek grey dorsal fur and white belly fur (Menkhorst & Knight 2004).

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Western barred bandicoot (Shark Bay)

Perameles bougainville bougainville

States and territories: Western Australia.

Regions: Bernier and Dorre Island, Shark Bay.

Habitat: Dense scrubby vegetation behind dunes.

Habit: Ground-dwelling; nests in shallow scapes under prostrate shrubs (Friend & Burbidge 1995).

Avg. body weight: 226 g (Friend & Burbidge 1995).

Activity pattern: Nocturnal.

Diet: Omnivore: insects, seeds, roots, tubers herbs and small vertebrates (Friend 2008).

Breeding: Births recorded from April to October, with between one to three young born per litter (Friend 2008).

Description

The western barred bandicoot from Shark Bay is one of several bandicoot subspecies described from mainland and island specimens collected in the 1800s (Friend 2008). The species has become extinct on the mainland but *P. b. bougainville* persists on Dorre and Bernier Islands in Shark Bay, Western Australia (Friend 2008). The small size of the Islands (Dorre Island 53 square kilometres and Bernier Island 44 square kilometres) restricts the area available to the western barred bandicoot population. The population is relatively small (2200–4400 combined), and fluctuates with rainfall, but the species remains abundant within its restricted range (Short et al. 1998).

The western barred bandicoot is nocturnal, sheltering during the day in a concealed nest made from plant material in a hollow scrape beneath low shrub or other suitable cover (Short et al. 1998). The bandicoots emerge at dusk to forage for insects and dig for roots and other plant material (Friend 2008). Male home ranges are larger than those of females (2.5–14.2 hectares relative to 1.4–6.2 hectares), but the home range of both sexes decreases with an increase in population density (Short et al. 1998).

Introduced predators, changed fire regimes and the expansion of arid zone grazing are implicated in the demise of the mainland populations of the western barred bandicoot (Richards & Short 1997). As part of the recovery program for this species, a small population (originating from the Shark Bay Islands) has recently been re-introduced into a predator-free controlled site at Heirisson Prong, mainland Shark Bay (Richards & Short 1997). One of the purposes of the reintroduction program is to mitigate against the possibility of catastrophic events (such as an outbreak of disease, the introduction of a predator or fire) destroying the island populations.

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the western barred bandicoot in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as a densely vegetated understorey habitat (description of the survey technique and recommended effort is outlined in Section 3.1)
- daytime searches for signs of activity, including tracks, scats, nests and conical foraging holes (description of the survey technique and recommended effort is outlined in Section 3.2)
- collection of predator scats, owl casts or remains, targeting predatory bird/mammal nests/dens (description of the survey technique and recommended effort is outlined in Section 3.2)
- soil plot surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.2
- spotlight surveys conducted according to the description of the technique and the recommended effort provided in Section 3.3.3
- cage trapping surveys conducted according to the description of the technique and the recommended effort outlined in Section 3.3.10
- hair sampling surveys using baited hair traps should be used as this species can be identified from hair samples (B Triggs pers. comm.; Table 2), A description of the survey technique and recommended effort is outlined in Section 3.3.7
- baited camera traps using universal bait (description of the survey technique and recommended effort is outlined in Section 3.3.6).

Existing methodology as used on Dorre and Bernier Islands is likely to be most effective for detecting the western barred bandicoot. Should surveys be required on the mainland, then expert advice should be sought from relevant government authorities in Western Australia. Any signs of this species on the mainland should be reported immediately to the Western Australian DEC.

Similar species in range

There are no similar species within the known range of the western barred bandicoot.

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Western ringtail possum

Pseudocheirus occidentalis

States and territories: Western Australia.

- Regions:** Its former distribution was considered to have covered much of the south-west of Western Australia, for example in the 1970s it was known to occur in wheatbelt reserves near Pingelly (de Tores 2008). However, it is currently confined to five regional locations (de Tores et al. 2004, 2008):
- near-coastal area between Bunbury and Albany
 - the Swan Coastal Plain near Busselton and urban Busselton
 - a population 90 km inland in the Western River catchment area
 - within the Jarrah *Eucalyptus marginata* and Jarrah-Marri *Corymbia calophylla* forests near Collie
 - riverine stands of peppermint near the Harvey river east of Harvey.
- Habitat:** The habitat differs across the species' known range. For example, it is closely associated with peppermint *Agonis flexuosa* dominated forest and woodland, with a tuart *Eucalyptus gomphocephala* canopy in some areas along the coast south of Bunbury, in peppermint forest in the Busselton area and in jarrah *E. marginata*, wandoo *E. wandoo* and marri forest in inland localities (de Tores 2008).
- Habit:** Arboreal.
- Avg. body weight:** 575 g (Jones 1995).
- Activity pattern:** Nocturnal.
- Diet:** Leaves of various trees depending on the location. Peppermint is common near the coast, whereas further inland jarrah and marri predominate (Jones 1995).
- Breeding:** Breeding can occur throughout the year but most births occur during late autumn to winter, with a lull during the summer (de Tores 2008). Young emerge from the pouch after three months but continue to suckle for another three to four months (Jones et al. 1994b).

Description

The western ringtail possum is one of two large possums in Western Australia, with overlap in distribution occurring between the western ringtail possum and the common brushtail possum *Trichosurus vulpecula* (Menkhorst & Knight 2001). The species' range once occurred from Perth to Albany in south western Western Australia, but since 1990 its distribution and density within the range has declined, particularly away from the coast (de Tores 2008).

Across the species' range it is known to shelter in dreys constructed from leaves in areas close to the coast, but at a distance beyond 4 kilometres from the coast individuals use tree hollows instead of dreys. The use of dreys is similar to the common ringtail possum *Pseudocheirus peregrinus* from eastern Australia. Within a

home-range area (between 0.5–2.5 hectares depending on the location, with larger home-ranges recorded in eucalypt forests away from the coast), an individual western ringtail possum may use between three to eight nest sites (Jones 1995). The home-ranges of adjacent individuals overlap, but individuals spend most of their time alone (Jones et al. 1994b).

Although no national recovery plan currently exists for the western ringtail possum, recovery actions and significant impact thresholds are outlined in the EPBC Act Policy statement 3.10 (DEWHA 2008a) as well as its supporting background paper (DEWHA 2008b).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the western ringtail possum in areas up to 5 hectares in size:

- daytime searches for potential den sites in hollow-bearing trees (particularly at sites greater than 4 kilometres from the coast). The survey technique and recommended effort is described in Section 3.1
- daytime searches for signs of activity, such as nests (dreys) in trees, scratches on tree trunks or scats on the ground below trees with hollows or dreys (description of the survey technique and recommended effort is described in Sections 3.3.9, 3.2.6 and 3.2.2)
- stagwatching surveys at potential nest sites (dreys and tree hollows) The survey technique and recommended effort is described in Section 3.3.4
- spotlight surveys conducted according to the method outlined in Section 3.3.3 along transects, tracks or roads (Note: depending on the nature of the site, additional surveys from a vehicle may also be made)
- discussion with locals, particularly in areas where densities are low or the species' presence is unconfirmed.

An arboreal cage trapping program where surveying in habitats other than jarrah forest (for example peppermint and tuart forest types) in conjunction with scat and spotlight surveys to determine the most effective survey technique for different habitats. However, the technique is time-consuming and spotlighting is equally effective.

A possible alternative survey method would be the use of hair sampling devices.

The deployment of camera traps may be an effective and time-efficient technique, particularly in localities where densities are low or the species' presence requires confirmation.

Similar species in range

The western ringtail possum can be easily distinguished from the sympatric common brushtail possum as it is shorter, has smaller rounded ears and a slender prehensile tail which is as long as the rest of its body (Menkhorst & Knight 2004).



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Woylie, brush-tailed bettong

Bettongia penicillata ogilbyi

States and territories: Western Australia (excluding translocated populations).

Regions: Confined to three reserves and surrounding areas in the wheatbelt of Western Australia: Dryandra Forest, Tutanning Nature Reserve and Perup Forest. The former range of this subspecies is unclear but it was widespread south of the tropics, including the central Western Australian deserts and into the southern region of the Northern Territory, where it had disappeared by 1960 (Burbidge et al. 1988). The woylie has been established by translocation at a number of localities in Western Australia, South Australia and New South Wales (for example, Priddel & Wheeler 2004; Martin et al. 2006).

Habitat: The remaining locations for the woylie are all characterised by open forest and woodland with a tussock grass ground layer or understorey of woody scrub and the presence of thickets of the plant genus *Gastrolobium* (Papilionaceae), which contains monofluoroacetic acid (de Torres & Start 2008). Formerly the woylie occurred in a more diverse range of habitats, including arid *Triodia* grasslands. During the day the woylie shelters in a nest constructed of grass or shredded bark located in a shallow depression concealed under a bush, the foliage of a grass tree, *Xanthorrhoea*, fallen log or other cover (Christensen & Leftwich 1980).

Habit: Ground dwelling.

Avg. body weight: Males 980–1850 g; Females 750–1500 g (de Torres & Stuart 2008).

Activity pattern: Nocturnal.

Diet: Principally underground fungi (native truffles) supplemented by tubers, bulbs, grains, seeds, insects and resin exudates from *Hakea* (Proteaceae) species (de Torres & Start 2008). The woylie can store food in their cheek pouches for subsequent caching.

Breeding: Breed continuously under suitable conditions, giving birth to one (rarely two) young and producing up to three young per year (Christensen 1980; de Torres & Start 2008).

Description

‘Woylie’ is the indigenous Nyoongar name which refers to the ability of this species to carry nesting material with the tip of its prehensile tail. The woylie formerly occupied large areas of arid and semi-arid regions of southern Australia, comprising two subspecies: the woylie *B. p. ogilbyi* that is now confined to a small number of localities in far south-western Australia, and the brush-tailed bettong *B. p. penicillata* that formerly occurred in eastern Australia, but is now extinct (Burbidge et al. 1988). The boundaries of occurrence of these two subspecies are unclear and the subspecies status of former populations in central Australia is unknown. Reasons for the extinction of the eastern subspecies and the major contraction in range of the woylie are attributed to fox and feral cat predation (Burbidge et al. 1988; de Torres & Start 2008). Other factors include habitat destruction and alteration, including changes to fire regimes and impacts associated with domestic and



feral herbivores (Start et al. 1995). Since 2001, woylie numbers in the last remaining localities have suffered declines of greater than 93 per cent in some populations. These recent declines have been attributed to an as-yet unknown disease predisposing individuals to predation by foxes and feral cats (Henstridge et al. 2008; Wayne 2009).

Survey methods

On the basis of previous surveys, the following survey techniques are recommended to detect the presence of the woylie in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources such as open forest and woodland with tussock grass ground layer and thickets of *Gastrolobium* (description of the survey technique and recommended effort is provided in Section 3.1)
- in areas of higher densities: cage trapping surveys using a mixture of peanut butter, rolled oats and sardines conducted according to the procedure adopted in the Woylie Conservation Research Project Operations Handbook. Due to an unknown disease being implicated in recent population declines, cage trapping requires a high standard of hygiene – for example, not moving traps between locations and ensuring traps are hygienically maintained (CALM 2005; Chapman et al. 2005). Additionally, capture in traps may result in the physical injury of trapped animals, capture myopathy, rejection of pouch young and the risk of predation through daytime release.

However, where the species is at low densities or confirmation of sightings is required, trapping may be an inefficient technique on its own so should be conducted in conjunction with a variety of other techniques, such as:

- car-based spotlight surveys along fixed transects conducted according to the procedure adopted in the Woylie Conservation Research Project Operations Handbook
- daytime searches for signs of activity, including diggings, tracks and nests (description of the survey technique and recommended effort is outlined in Section 3.2). However, caution is required to distinguish diggings and tracks from other sympatric mammal species and the location of nests should follow the technique of Christensen and Leftwich (1980)
- searches for distinctive nest depressions immediately following fire before any significant rain or wind events (following Christensen & Leftwich 1980)
- deployment of hair tubes, particularly in areas with low densities (description of the survey technique and recommended effort is provided in Section 3.3.7), provided that expertise to identify hair samples is available
- use of camera traps accompanied with bait stations, baited with peanut butter, rolled oats and sardines (see Section 3.3.6)
- scats are difficult to locate, but any scat searches should use molecular based methods to confirm the identity of the macropod species present (Alacs et al. 2003)
- community liaison to search for additional locations, particularly on private land (description of the survey technique and recommended effort is provided in Section 3.2.1).

Similar species in range

The woylie in south-western Australia can be distinguished from other small macropods by the dark tail with the end half possessing a distinctive ridge-like or brush-like appearance. Additional characteristics separating the woylie from other small macropods in south-western Australia are: a) quokka *Setonix brachyurus* is larger in weight (up to 4.2 kilograms) and has a shorter tail lacking the crest of blackish fur on the end half; b) Gilbert's potoroo *Potorous gilberti* is smaller, confined to dense heathland, is darker, possesses a longer, pointed muzzle, and the tail is noticeably shorter than the head-body length; and c) burrowing bettong *Bettongia lesueur* lives in burrows, lacks the tail crest and is yellow-grey rather than grey to greyish-brown on the dorsal surfaces.

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Yellow-footed rock wallaby

Petrogale xanthopus xanthopus

States and territories: South Australia and NSW.

Regions: South Australia: Flinders Ranges, Gawler Ranges and Olary Hills.
NSW: Gap and Coturaundee Ranges.

Habitat: Rock outcrops, including sandstones, limestone-dolomite, conglomerate-tillite, granite-porphry, escarpments and boulder piles within the semi-arid zone (Lim et al. 1987).

Habit: Ground-dwelling.

Avg. body weight: 6–11 kg (Sharman et al. 1995).

Activity pattern: Nocturnal/partly diurnal (basks in cool weather).

Diet: Herbivore: grasses, shrubs and forbs (Sharman et al. 1995).

Breeding: Breeding occurs throughout the year, but the number of births increases after rainfall (Eldridge 2008).

Description

The yellow-footed rock wallaby is found in rugged semi-arid regions of South Australia and NSW. A second subspecies *Petrogale xanthopus celeris* was detected in the mid 1980s from south-western Queensland (Sharman et al. 1995). The species is one of the most colourful macropods, with distinctive yellow coloured fur on its ears, arms and legs, a yellow and brown striped tail, and white markings on the sides of its body and on either side of its face.

Like other rock wallabies, yellow-footed rock wallabies inhabit rocky outcrops and boulder piles. Individuals shelter in caves, crevices and under trees or shrubs (particularly Queensland populations of *P. x. celeris*) during the day and move away from their shelters at night to feed (Lim et al. 1987; Sharp 1997). Home ranges for this species are larger than in other similarly sized macropods and this may relate to the aridity of the species' habitat (Sharp 2009).

Decline in the yellow-footed rock wallaby may be linked to competition with feral herbivores, hunting, and predation by introduced carnivores (Eldridge 2008). Recovery of some populations can be brought about by the control of these introduced species (Eldridge 2008).

Survey methods

On the basis of the surveys outlined in Section 3.3.11 and other similar studies, the following survey techniques are recommended to detect the presence of the yellow-footed rock wallaby in areas up to 5 hectares in size:

- daytime searches for potentially suitable habitat resources, such as shelter sites (caves, rock boulders and rock ledges) in suitable boulder pile, escarpment and cliff-line habitats (description of the survey technique and recommended effort is outlined in Section 3.3.11)



- daytime searches for signs of activity, including tracks, scats and rock shelters worn smooth from resting (description of the survey technique and recommended effort is outlined in Section 3.3.11)
- possibly the collection of predator scats, owl casts or remains, targeting predatory bird and mammal nests and dens (description of the survey technique and recommended effort is outlined in Section 3.2.3)
- baited camera traps may be of use in confirming the presence and identity of rock wallabies (description of the survey technique and recommended effort is outlined in Section 3.3.6), and
- observations for rock wallabies basking during the day, or becoming active at dusk, using binoculars from a location on the ground beneath suitable habitat, or possibly from a helicopter according to the suggested survey technique and effort provided in Section 3.3.11 (minimising disturbance to animals to ensure wallabies do not fall).

Should cage trapping surveys (conducted according to the description and recommended survey effort provided in Sections 3.3.10 and 3.3.11) or genetic analysis of hair or tissue samples taken from captured wallabies be required, then appropriate permission and licensing must be sought from the relevant South Australian and NSW government organisation.

Similar species in range

No other rock wallaby species are known to occur within the range of the yellow-footed rock wallaby.

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APPENDIX A: STATE AND TERRITORY GUIDELINES AND OTHER SURVEY METHOD DOCUMENTS

Where available, existing fauna survey guidelines were obtained from a range of Australian state and territory departments and agencies (Table A1, below). The survey methods and effort described in these documents was reviewed to assist with framing these guidelines and to examine the consistency of survey techniques. In addition to fauna survey guidelines, a range of other documents was sourced (for example, regional biodiversity studies), as the survey methods described in these documents have sometimes been adopted as standard practice for other studies. In many cases, the techniques recommended are appropriate but a greater survey effort, or the use of a combination of specific survey techniques, is likely to be required to detect the presence of rare threatened mammal species.

Table A1: Formal guidelines and references sourced from government departments and agencies containing prescribed survey techniques and effort.

State or territory	Government department / organisation	Author and date	Title
NSW	Department of Environment, Climate Change and Water (DECCW)	DECCW (2004)	Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities - Working Draft
NSW	NSW National Parks and Wildlife Service (NPWS) ²	NSW NPWS (1997)	<i>NSW Comprehensive Regional Assessments Vertebrate Fauna Surveys 1996-1997 Summer Survey Season Field Survey methods.</i> Amended January 1997
NSW	NSW Department of Land and Water Conservation (DLWC) ¹	NSW DLWC (1999)	<i>Interim Guidelines for targeted and general flora and fauna surveys under the Native Vegetation Conservation Act 1997.</i>



State or territory	Government department / organisation	Author and date	Title
NSW	State Forests NSW (SFNSW)	SFNSW (1999)	<i>Integrated Forestry Operations Approval Package Terms of Licence under the Threatened Species Conservation Act 1995.</i> Approval pursuant to Part 4 of the Forestry and National Parks Estate Act 1998
NSW	Wyong Shire Council	Wyong Shire Council (1999)	<i>Flora and Fauna Guidelines for Development.</i>
NSW	Lower Hunter & Central Coast Region	Murray et al. (2002)	Flora and Fauna Survey Guidelines: Lower Hunter Central Coast Region.
NSW	Lower Hunter & Central Coast Regional Environmental Management Strategy Steering Committee	Ecotone Ecological Consultants (2001)	<i>Lower Hunter & Central Coast Regional Environmental Strategy: Fauna Survey & Mapping Project - Module 1 - Fauna Surveys.</i>
SA	National Parks and Wildlife South Australia (SA). Department for Environment and Heritage	Owens (2000)	<i>Guidelines for Vertebrate Surveys in SA.</i>
NT	NT Department of Infrastructure Planning and Environment (DIPE)	NT DIPE (2002)	<i>Summary of Fauna Survey methods.</i>
NT	NT Department of Conservation and Natural Resources (DCNR)	NT DCNR (2002)	<i>Summary of Fauna Survey methods.</i>
NT	Biodiversity Conservation Division, Department of Infrastructure, Planning and Environment, 2005	NT DIPE (2005)	Draft Guidelines for the Biodiversity Component of Environmental Impact Assessment
WA	Department of Conservation & Land Management (CALM)	Morris (1992)	<i>How to survey and collect data from potential fauna management areas.</i> Mammal Conservation Course
Qld	Gold Coast City Council, Environmental Planning Section, Strategic & Environmental Planning Branch	Gold Coast City Council (2002)	<i>Gold Coast City Council Planning Scheme Policy: Guidelines for preparing ecological site assessments during the development process.</i>
Qld	Environmental Protection Agency (EPA) Southern Region	Qld EPA Southern Region (1999)	<i>Guidelines for Flora and Fauna Surveys. Southern Region</i>

State or territory	Government department / organisation	Author and date	Title
Qld	Resource Sciences Centre, Department of Natural Resources	Eyre et al. (1997)	<i>Proposed Vertebrate Fauna and Microhabitat Survey Methodology for Comprehensive Regional Assessment, SE Queensland.</i> Appendix 3 of <i>Biodiversity assessment in managed forests - a review of methodologies appropriate for Montreal Criteria and indicators.</i> Eds. A.P.N. House and G.C.Smith.
Qld	Sustainable Forest Science Unit (SFSU), Forestry and Wildlife Division, Natural Resource Sciences of the Queensland Environmental Protection Agency	Qld CRA/RFA Steering Committee (1998)	Systematic vertebrate fauna Survey Project: Stage 1 - Vertebrate Fauna in the southeast Queensland Bioregion.



Table A2: Targeted survey techniques for detection of medium and large size mammals.

Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
NSW DECCW (2004)	<p>effort not specific for mammals</p> <p>30 min per site</p> <p>all scats collected for identification</p>	<p>six traps for a minimum of four nights</p> <p>trapping intensity should be increased with decreased abundance</p> <p>trapping should not be conducted for more than four consecutive nights (ACEC)</p>
NSW NPWS (1997)	<p>effort not specific for mammals</p> <p>search for predator and herbivore scats conducted along 200 m transect per site (2 ha area = 200 m x 100 m) and vicinity (time not specified)</p> <p>all scats collected for identification.</p> <p>Summary: search conducted within 2 ha survey site area.</p>	<p>Cage trapping surveys and effort not prescribed.</p>

Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
NSW DLWC (1999)	<p>specific for medium and large-sized mammal scats, tracks, scratches and nests</p> <p>30 min search per site ('survey effort per stratification site up to 50 ha plus an additional effort for every additional 100 ha')</p> <p>track search along one kilometre of track.</p> <p>Summary: 30 minutes per survey site.</p> <p>Survey site size not specified for fauna but the following quadrat sizes were prescribed for vegetation quadrats:</p> <p>20 m x 20 m (0.25 ha) for coastal and tableland areas</p> <p>20 m x 50 m (0.5 ha) for slopes and plains</p> <p>10 m x 10 m (0.1 ha) for temperate grasslands.</p> <p>Quadrats are located in stratification units according to the following:</p> <p>at least one quadrat per stratification unit <2 ha</p> <p>2 quadrats per 2–50 ha of stratification unit</p> <p>3 quadrats per 51–250 ha of stratification unit</p> <p>4 quadrats per 51–250 ha of stratification unit</p> <p>5 quadrats per 251–500 ha of stratification unit</p> <p>10 quadrats per 501–1000 ha of stratification unit plus one.</p>	<p>25 Elliott B traps and six cage traps (minimum) per site (i.e. slopes and plains)</p> <p>set traps for four consecutive nights</p> <p>bait not specified</p> <p>consider trap saturation where common species may prevent detection of rarer species</p> <p>do not trap for more than four consecutive nights.</p> <p>Summary: 24 cage trap-nights per 0.5 ha (48 per ha) and 100 Elliott B trap nights per 0.5 ha site (200 trap-nights per ha).</p>



Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
SFNSW (1999)	<p>Pursuant to Section 8.7.2 and Schedule Prescription 32, Section 2.6 as follows:</p> <p>a minimum of four person hours per 200 ha of net survey area must be spent continuously searching for the following features (limited to features relevant to this review) along a 4 km traverse that must cover all forest types and environmental gradients of the subject area (compartment):</p> <p>latrine and den sites of the spotted-tailed quoll</p> <p>predator scats collected for analysis</p> <p>sap feed trees and den trees of relevant glider species (including the yellow-bellied glider but not exclusively the EPBC Act listed subspecies from northern Queensland)</p> <p>identification of distinctive scats (e.g. brush-tailed rock wallaby)</p> <p>potential long-nosed potoroo diggings</p> <p>wombat burrows.</p> <p>Summary: 4 hrs (one person) search per 200 ha area.</p> <p>Soil Plots (Draft Feral and Introduced Predator Control Plan, Schedule 7):</p> <p>1 m wide soil plots (sand or soft dirt) established across vehicle tracks</p> <p>plots monitored for presence of predator tracks (target feral predators) through checks in the morning.</p>	<p>Cage and Elliott B trapping surveys and effort not prescribed.</p>

Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
Wyong Shire Council (1999)	<p>search for large sized mammal scats opportunistically during other surveys</p> <p>in small sites search along tracks for carnivore scats (for sites over 100 ha in size use 1000 m transects)</p> <p>identify predator scats and analyse for remains of prey species.</p> <p>Summary: opportunistic search within sites <100 m, otherwise 1000 m transects</p>	<p>place six Elliott B/cage traps in a transect(s) at 10-20 m intervals</p> <p>bait traps alternatively with a meat-based bait (e.g. singed chicken) and peanut butter based bait</p> <p>set for four consecutive nights.</p> <p>Summary: 24 trap-nights per site.</p>
Murray et al. (2002)	<p>search for predator scats of medium and large sized species</p> <p>walked searches along transects (e.g. 500–1000 m).</p> <p>Summary: conduct scat/track searches along transects (500–1000 m).</p>	<p>place ten Elliott B/cage traps in a transect(s) at intervals appropriate to the habitat (intensive survey for a specified habitat or widespread for sparse populations)</p> <p>bait traps alternatively with a meat based bait (e.g. singed chicken) and peanut butter mixture</p> <p>set for between three and four consecutive nights.</p> <p>Summary: a minimum of 40 trap-nights per site.</p>
Ecotone Ecological Consultants (2001)	<p>Diurnal survey effort not described.</p> <p>Summary: Approximately 75 sites, each comprising a grid (250 m long and 50 m wide) for trapping and a 500 m transect for spotlight surveys.</p>	<p>place three cage traps per site, positioned at the beginning, end and middle of transects (approx 250 m apart)</p> <p>set open doors near fauna runways</p> <p>bait traps with sandwich made from peanut butter and fish-based cat food</p> <p>cover traps for protection against weather</p> <p>set open for four consecutive nights.</p> <p>Summary: minimum of 12 trap-nights per 1.25 ha site (9.6 trap-nights per ha).</p>



Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
Owens (2000)	<p>one to two hours spent searching survey site for signs of fauna activity</p> <p>pastoral site 1000 m x 1000 m/10 ha or agricultural site 100 x 100 m/1 ha</p> <p>target small caves or hollow trees for predator casts (for example owl pellets), droppings, sub-fossil bone and old stick-nest rat nests</p> <p>collect material if it cannot be identified.</p> <p>Summary: one to two hour search per site (1–10 ha).</p>	<p>place two cage traps per trap-line, with two trap-lines per pastoral site (1000 m x 1000 m/10 ha) and one per agricultural site (100 m x 100 m/1 ha)</p> <p>place cages on the ground near potential habitat resources</p> <p>bait traps with a standard mixture of peanut butter and oats</p> <p>place traps flat on the ground</p> <p>check treadle mechanism is sensitive and operational</p> <p>mark and label trap location</p> <p>add paper to for nesting material and cover trap with plastic bag in case of rain</p> <p>place rocks on top of the cage to protect against crows</p> <p>set traps for four consecutive nights.</p> <p>Summary: 8 trap-nights per ha agricultural site / 16 trap-nights per 10 ha pastoral site (1.6 per ha).</p>
NT DIPE (2005)	<p>Three searches during the day (morning, midday, late afternoon), 10 mins each per quadrat (50 m x 50 m)</p> <p>collect carnivore scats for hair analysis</p>	<p>Four cage traps per 50 x 50 m quadrat, one in each corner</p> <p>traps open for three nights</p> <p>cages can be baited with fruit or meat scraps</p> <p>check traps early morning</p>

Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
NT DIPE (2002)	<p>effort described not specific for mammals</p> <p>10 min. searches to be conducted three times (morning, midday and late afternoon) per survey site (quadrat 50 m x 50 m in northern NT and 100 m x 100 m in arid areas of southern NT, sites separated by at least 500 m)</p> <p>search includes looking under bark, raking leaf litter, turning rocks and logs and looking in crevices</p> <p>signs identified to species or collected (for example scats or bones); carnivore scats collected for prey analysis.</p> <p>Summary: 30 minute searches (total) per site (0.5–1 ha).</p>	<p>place four cage traps at each corner of a quadrat (50 m x 50 m in northern NT and 100 x 100 in semi-arid habitats)</p> <p>bait traps with a mixture of oats, peanut butter and honey (can also use vanilla essence, cat biscuits and tuna)</p> <p>mark location of traps clearly</p> <p>set traps open for three nights</p> <p>check traps in the morning and bait in the afternoon.</p> <p>Summary: 12 trap-nights per site (0.5–1 ha).</p>
NT DCNR (2002)	<p>effort not specific for mammals</p> <p>ten minute searches to be conducted five times (morning, midday and late afternoon) per survey site (250 m linear transect separated from other sites by at least 500 m)</p> <p>search includes looking under bark, raking leaf litter, turning rocks and logs and looking in crevices</p> <p>signs identified to species or collected (for example scats or bones); carnivore scats collected for prey analysis.</p> <p>Summary: 30 minute searches (total) per site (250 m).</p>	Cage and Elliott B trapping surveys and effort not prescribed.



Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
Morris (1992)	<p>Diurnal survey method not prescribed but size of survey sites described as two to three forest blocks (at least 10 000 ha).</p>	<p>set 30 cage traps in three lines of ten, spaced at 30–50 m intervals</p> <p>set 70 cage traps along tracks at 200 m intervals (covers 14 km of track),</p> <p>bait traps with a mixture of rolled oats, peanut butter and sardines suspended over the treadle</p> <p>mark trap locations with flagging tape</p> <p>set traps for a minimum of four nights</p> <p>replicate survey in spring and autumn</p> <p>check traps early morning and afternoon (for reptiles).</p> <p>Summary: 400 trap-nights per 10 000 ha site (one trap per 25 ha).</p>
Gold Coast City Council (2002)	<p>effort not specific for mammals</p> <p>2 hr diurnal search (minimum) per site (size not specified)</p> <p>conducted in middle of day</p> <p>search site for animal signs.</p> <p>Summary: 2 hr search per site.</p>	<p>one Elliott B trap and two medium-sized cages traps placed 10 m apart in transects on the ground near potential habitat resources</p> <p>to be conducted in conjunction with Elliott A and arboreal mammal trapping</p> <p>bait not specified</p> <p>set traps for four consecutive days.</p> <p>Summary: nine trap-nights per site.</p>

Reference	Diurnal searches for signs and habitat resources (all size classes, but focus on medium and large mammals)	Cage and Elliott B trapping surveys for medium sized mammals
Qld EPA Southern Region (1999)	<p>effort not specific for mammals</p> <p>search site for animal signs</p> <p>conduct search for approximately 4 hrs per day per site in the middle of the day.</p> <p>Summary: survey site size not specified but trapping grid is approximately 1 ha, hence 4 hrs search time per 1 ha area (approximate).</p>	<p>place 20 possum (cage) traps on the ground and in trees for a combined ground-dwelling and arboreal mammal targeted survey</p> <p>space traps at 5 m intervals and arrange in five transects</p> <p>use a variety of baits (rolled oats and peanut butter and or bacon, oil or canned fish)</p> <p>set traps for four nights</p> <p>check traps early morning and late afternoon.</p> <p>Summary: 80 cage trap-nights per site.</p>
Qld CRA/ RFA Steering Committee (1998)	<p>a 300 m x 50 m survey plot was set up at each survey site,</p> <p>search for predator scats within a 200 m x 50 m area of the survey plot (koala and rock wallaby scats were also targeted)</p> <p>all scats collected for identification and analysis of prey remains</p> <p>no prescribed search duration.</p> <p>Summary: search 1 ha site.</p>	Cage and Elliott B trapping surveys and effort not prescribed.
Eyre et al. (1997)	<p>effort not specific for mammals</p> <p>search for signs within an area of 100 m x 20 m at each site</p> <p>collect predator scats for prey analysis</p> <p>time of search not indicated.</p> <p>Summary: 0.20 ha search area per site.</p>	Cage and Elliott B trapping surveys and effort not prescribed.



Table A3: Hair sampling, Elliott A and pitfall trapping.

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
NSW DECCW (2004)	<p>20 hair tubes (10 small and 10 large) per site</p> <p>tubes set for at least four consecutive nights</p> <p>a person with specialist expertise in the analysis of animal hair samples is required to analyse samples</p>	<p>25 Elliot traps for four consecutive nights</p> <p>traps must be kept open for a minimum of three nights and a maximum of four nights</p> <p>trap line should be spaced 20–50 m apart</p> <p>trapping intensity should be increased with decreased abundance</p> <p>trapping should not be conducted for more than four consecutive nights (ACEC)</p>	<p>pits should be either plastic buckets (28 cm diameter and 40 cm deep) or PVC pipe (15 cm diameter and 60 cm deep)</p> <p>at least 5 m of drift fence either side (approx. 30 cm high, with lower 5 cm buried into soil)</p> <p>24 trap-nights, with pits open for a minimum of four nights</p>
NSW NPWS (1997)	<p>50 large (900 mm diameter) hair tubes (ten spaced at 10–15 m intervals within the survey sites and an additional 20 placed at 100 m intervals between sites)</p> <p>alternate tubes baited with singed meat (chicken) or a mixture of peanut butter, rolled oats and pistachio nut oil</p> <p>tubes set for approximately ten consecutive nights.</p> <p>Summary: 100 trap-nights per 2 ha site plus 200 trap-nights between sites (50 trap-nights per ha).</p>	<p>Elliott trapping is an optional survey method, effort not specified other than “trapping session will be configured to the habitat under consideration”</p> <p>minimum 10 Elliott A traps spaced at 10 m intervals</p> <p>bait not specified</p> <p>set traps for four consecutive nights</p> <p>hair samples should be taken from all specimens for reference.</p> <p>Summary: minimum of 40 trap-nights per 2 ha site (20 trap-nights per ha).</p>	<p>Pitfall trap surveys not prescribed.</p>

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
NSW DLWC (1999)	<p>20 hair tubes (10 large and 10 small) per site</p> <p>tubes set for at least four consecutive days/nights</p> <p>bait not specified but alternate baits (chicken or peanut butter bait mix) can be used.</p> <p>Summary: minimum of 80 trap-nights per 0.5 ha site (160 trap nights per ha).</p>	<p>space Elliott traps at 20–25 m intervals</p> <p>sampling effort per stratification unit equivalent to 100 trap-nights (for example, 25 traps for four nights, 10 for 10 nights or 20 for five nights)</p> <p>bait not specified</p> <p>consider trap saturation where common species may prevent detection of rarer species</p> <p>do not trap for more than four consecutive nights.</p> <p>Summary: 100 trap-nights per 0.5 ha site (200 trap-nights per ha).</p>	<p>six pits constructed from either PVC pipe (150 mm diameter and 600 mm deep) or plastic buckets (280 mm diameter and 400 mm deep) (number not specified)</p> <p>use the PVC cap at the base of PVC lined pits</p> <p>5 m of drift-fence (300 mm high with lower 50 mm buried in soil) around each pit</p> <p>set traps for a minimum of four nights</p> <p>sampling effort equal to 24 trap-nights (that is, six pitfalls per stratification unit up to 50 ha area).</p> <p>Summary: 24 trap-nights per 0.5 ha site (48 trap-nights per ha).</p>



Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
NSWSF (1999)	<p>20 hair tubes per 200 hectares for 10 nights</p> <p>2 km x 1 km transects comprised of 10 hair tubes spaced 100 m apart</p> <p>place one transect along a gully line and the second along a mid-slope contour</p> <p>bait tubes alternately with meat and peanut butter bait.</p> <p>Summary: 200 trap-nights per 200 ha compartment (one trap-night per ha).</p>	<p>place 75 Elliott A traps spaced 10 m apart</p> <p>bait with a mixture of peanut butter, rolled oats and honey</p> <p>set open for four consecutive nights.</p> <p>Summary: 300 trap-nights per 200 ha compartment (1.5 trap-nights per ha).</p> <p>Targeted Elliott A trapping for the Hastings River Mouse is summarised as follows:</p> <p>minimum effort of 100 Elliott A traps for every 50 ha of habitat (as defined in SFNSW 1999) per compartment, with an additional 100 traps set per 50 ha above 50 ha;</p> <p>traps in four transects of 25 traps, spaced 10 m apart</p> <p>set open for four consecutive nights.</p> <p>Summary: 400 trap-nights per 50 ha (8 trap-nights per ha)</p>	Pitfall trap surveys not prescribed.
Wyong Shire Council (1999)	<p>optional</p> <p>four small hair tubes set for 10 nights.</p> <p>Summary: 40 sampling nights per site</p>	<p>Place 40 Elliott A traps along transect(s) at 10–20 m intervals</p> <p>bait with peanut butter and rolled oats</p> <p>set for four consecutive nights.</p> <p>Summary: 160 trap-nights per site.</p>	Pitfall trap surveys not prescribed.

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
Murray et al. (2002)	<p>optional</p> <p>number or size of hair tubes not specified</p> <p>bait with either a mixture of peanut butter and rolled oats or a meat based bait</p> <p>set for between five and 10 consecutive nights per site.</p> <p>Summary: Effort variable.</p>	<p>place 10 Elliott A traps along transect(s) at intervals appropriate to the habitat (intensive survey for a specified habitat or widespread for sparse populations)</p> <p>bait with peanut butter and rolled oats</p> <p>set for between three and four consecutive nights.</p> <p>Summary: minimum of 40 trap-nights per site.</p>	<p>pitfalls constructed from either PVC pipe (150 mm diameter and 600 mm deep) or plastic buckets (280 mm diameter and 400 mm deep)</p> <p>no effort other than set for between five and 10 consecutive nights per site.</p> <p>Summary: Effort variable.</p>
Ecotone Ecological Consultants (2001)	<p>ten 90 mm hair tubes set on the ground at 20 m intervals;</p> <p>tubes baited with peanut butter and fish-based cat food mixture (target spotted-tailed quoll)</p> <p>set for ten consecutive nights.</p> <p>Summary: 100 trap nights per ~1.25 ha site (80 trap nights per ha).</p>	Elliott A trap surveys not conducted.	Pitfall trap surveys not conducted.



Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
Owens (2000)	<p>optional</p> <p>four hair tubes (200 mm length and 50 mm diameter PVC tube) per pastoral site (1000 by 1000 m/10 ha) and two hair tubes per agricultural site (100 m x 100 m/1 ha);</p> <p>one hair tube nailed to a tree (arboreal) and one on the ground set at either end of the pitfall trap-lines</p> <p>bait with mixture of peanut butter and oats</p> <p>the number of days hair tubes are set for is not indicated.</p> <p>Summary: Variable effort.</p>	<p>place 15 Elliott A traps spaced 10 m apart per trap line</p> <p>two trap lines per pastoral site (1000 x 1000 m/10 ha) and one per agricultural site (100m x 100 m/1 ha)</p> <p>place Elliott A trap line parallel, but at least 10 m away from the pitfall trap-line and two cage traps,</p> <p>bait traps with a standard mixture of peanut butter and oats</p> <p>place traps flat on the ground and under shrubs or on western side of bushes to prevent overheating in the morning sun</p> <p>check treadle mechanism is sensitive and operational,</p> <p>mark and label trap location,</p> <p>add paper for nesting material and cover trap with plastic bag in case of rain,</p> <p>traps are set for four consecutive nights.</p> <p>Summary: 120 trap-nights per 10 ha pastoral site (12 trap- nights per ha) and 60 trap-nights per agricultural site.</p>	<p>trap lines of six pitfall traps (polyplastic sheets rolled into tubes 121 mm diameter and 455 mm deep) spaced 10 m apart and connected by 60 m flywire drift-fence</p> <p>two trap-lines per pastoral site (1000 m x 1000 m/10 ha) and one per agricultural site (100 m x 100 m/1 ha)</p> <p>where two trap-lines are set, they must be more than 200 m apart</p> <p>a flywire bottom is held in place with a rubber band to prevent escapes, and</p> <p>traps are set for four consecutive nights.</p> <p>Summary: 48 trap-nights per 10 ha pastoral site (4.8 trap-nights per ha) and 24 trap-nights per ha agricultural sites.</p>

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
NT DIPE (2002)	Hair sampling surveys are optional and survey effort and method were not specified.	<p>place 20 Elliott A traps 8 m apart along the perimeter of a quadrat (50 m x 50 m in northern NT and 100 m x 100 m in semi-arid habitats)</p> <p>bait traps with a mixture of oats, peanut butter and honey (can also use vanilla essence, cat biscuits and tuna)</p> <p>mark location of traps clearly</p> <p>set traps open for three nights</p> <p>check traps in the morning and baited in the afternoon.</p> <p>Summary: 60 trap-nights per 0.5-1 ha site.</p>	<p>four pitfall traps (20 L plastic buckets) with 10 m of drift-fence placed within a 50 m x 50 m quadrat;</p> <p>place the four traps in different microhabitats (for example bare ground, dense grass or close to trees)</p> <p>set traps open for three nights</p> <p>check traps in the morning and again at midday.</p> <p>Summary: 12 trap-nights per 0.5-1 ha site.</p>



Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
NT DCNR (2002)	Hair sampling surveys are optional and survey effort and method were not specified.	<p>place 25 Elliott A traps spaced 10 m apart along a 250 m transect (in association with 50m x 50 m vegetation quadrat)</p> <p>mark trap locations with flagging tape</p> <p>check traps each morning, at midday and in the late afternoon (Elliott traps can be left open during the day in winter)</p> <p>bait traps with peanut butter and rolled oats mixture, using vanilla essence, cat biscuits and tuna if required</p> <p>re-bait traps each afternoon</p> <p>set traps open for three consecutive nights.</p> <p>Summary: 75 trap-nights per ha site.</p>	<p>four pitfall traps (two white and two black) scattered within site</p> <p>pitfalls consist of a 20 L plastic bucket and a 10 m drift fence</p> <p>locate pitfalls in different microhabitats</p> <p>check traps each morning, at midday and in the late afternoon</p> <p>mark traps with flagging tape</p> <p>set traps open for three consecutive nights.</p> <p>Summary: 12 trap-nights per ha site.</p>
NT DIPE (2005)	Hair sampling surveys are optional and survey effort and method were not specified.	<p>20 Elliot traps around the perimeter of a 50 m x 50 m quadrat 8 m apart</p> <p>bait mixture of oats, peanut butter and honey; vanilla essence, cat biscuits and tuna can be added</p> <p>traps opened for three nights</p>	<p>4 pitfall traps scattered within 50 m x 50 m quadrat</p> <p>pits are 20 L plastic buckets with 10 m drift fence in different microhabitats</p> <p>traps open for three nights</p>

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
Morris (1992)	Hair sampling surveys are optional and survey effort and method were not specified.	<p>place a minimum of 10 Elliott A traps in a straight line at 20 m intervals (200 m transect) per habitat type</p> <p>prescribed effort of 100 Elliott traps (60 set in three lines of 20 traps spaced at 20 m intervals) for an area of 10 000 ha comprising three habitat types (two to three forest blocks)</p> <p>bait traps with a mixture of rolled oats, peanut butter and sardines</p> <p>mark tapes with flagging tape</p> <p>set traps for a minimum of four nights</p> <p>replicate survey in spring and autumn</p> <p>check traps in early morning and afternoon (for reptiles).</p> <p>Summary: 400 trap nights per 10 000 ha site (one trap-night per 25 ha).</p>	<p>five to ten pitfall traps (PVC 150 mm diameter and 400 mm deep or buckets 300 mm diameter 400 mm deep) arranged in a straight line at 20 m intervals per habitat type</p> <p>prescribed effort of 15 pitfalls (three lines of 5 traps spaced at 20 m intervals) for an area of 10 000 ha comprising three habitat types (two to three forest blocks)</p> <p>fly-wire collector (drift-fence)</p> <p>set traps for a minimum of four nights</p> <p>replicate survey in spring and autumn</p> <p>check traps in early morning and afternoon (for reptiles).</p> <p>Summary: Equates to minimum of 60 trap-nights per 10 000 ha site (one trap-night per ~170 ha).</p>



Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
Gold Coast City Council (2002)	Hair tubes of different sizes (size and number not specified) set for two weeks.	<p>place a minimum of 20 Elliott A traps 10 m apart in transects on the ground and in trees</p> <p>to be conducted in conjunction with Elliott B (one trap) and cage trapping (two or more)</p> <p>bait not specified</p> <p>set traps for four consecutive days.</p> <p>Summary: 80 trap-nights per site.</p>	<p>three or more pitfall traps (20 L buckets) arranged in row with a 20 m drift-fence (the number of pitfalls and length of the trap-line will depend on the size of the site)</p> <p>set traps for four days and nights</p> <p>check traps early morning and late afternoon.</p> <p>Summary: minimum of 12 trap-nights per site.</p>
Qld EPA Southern Region (1999)	Hair sampling surveys are optional and survey effort and method were not specified.	<p>Place 100 Elliott A traps on the ground and in trees for a combined ground-dwelling and arboreal mammal targeted survey</p> <p>Space traps at 5 m intervals and arrange in five transects</p> <p>use a variety of baits (rolled oats and peanut butter and or bacon, oil or canned fish)</p> <p>set traps for four nights</p> <p>check traps early morning and late afternoon.</p> <p>Summary: 400 trap-nights (includes arboreal trap-nights) per ha.</p>	Not prescribed for mammals.

Reference	Hair sampling device surveys	Elliott trapping survey	Pitfall trapping survey
Qld CRA/ RFA Steering Committee (1998)	<p>10 hair tubes placed 20 m apart along 200 m transect</p> <p>baited with a mixture of rolled oats and peanut butter</p> <p>set open for nine nights.</p> <p>Summary: 90 trap-nights per ha site.</p>	<p>place 25 Elliott A traps 8 m apart along 200 m transect</p> <p>bait with a mixture of rolled oats and peanut butter</p> <p>set traps for three consecutive nights</p> <p>mark captured animals' toenails with toluene-free nail polish to monitor recaptures.</p> <p>Summary: 75 trap-nights per ha site.</p>	<p>one pitfall trap line of five pitfall traps (10 L buckets) placed 5 m apart</p> <p>connect pitfall traps with a 30 m long fly-wire drift-fence</p> <p>set open for three consecutive nights.</p> <p>Summary: minimum 15 trap-nights per ha site.</p>
Eyre et al. (1997)	<p>10 hair tubes placed 20 m apart along a 200 m transect at opportunistic sites (200 m x 50 m transect located in stratified habitat type)</p> <p>baited with a mixture of rolled oats and peanut butter</p> <p>set hair tubes for 10 consecutive nights.</p> <p>Summary: 100 sampling-nights per ha site.</p>	<p>place 20 Elliott A traps 10 m apart along a 200 m transect at opportunistic sites (200 m x 50 m transect located in stratified habitat type)</p> <p>bait with a mixture of rolled oats and peanut butter</p> <p>set traps for four consecutive days</p> <p>mark captured animals' toenails with toluene-free nail polish to monitor recaptures.</p> <p>Summary: 80 trap-nights per ha site.</p>	Pitfall survey not prescribed.



Table A4: Spotlight, hair sampling, arboreal trapping, stagwatching and call playback.

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
NSW DECCW (2004)	2 searches, each for 1 hour along a traverse of 1 km if vehicle spotlighting is required, 100 w spotlight twice over 1 km at a speed below 5 km/h	Three tubes used at 10 sampling sites	Arboreal trap method and survey effort not prescribed	Stagwatching method and survey effort not prescribed	Initial listening period of 10–15 mins spotlight search for 10 mins call each target species intermittently for 5 mins, followed by 10 min listening period 10 mins of spotlighting and listening after all calls have been made one consensus per night, unless sites are greater than 1 km apart

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
NPWS (1997)	<p>Spotlight on foot along a 2 km long transect for each 2 ha (100 m x 200 m) site;</p> <p>conducted by two people with two spotlights</p> <p>spotlight survey is only conducted once.</p>	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	<p>Broadcast pre-recorded species calls for two min</p> <p>listen for two min per site</p> <p>once per site</p> <p>conduct immediately following a spotlight survey, with additional spotlighting required at the end of the call playback survey to see if any species have been attracted to the area.</p>



Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
NSW DLWC (1999)	<p>Foot spotlight survey:</p> <p>two people with two 100 w spotlights along 1 km transect; walking at a speed of 1 km per hour should take approximately one hour</p> <p>replicate over two separate nights.</p> <p>Vehicle spotlight survey (200 ha area):</p> <p>drive 1 km of track</p> <p>maximum speed of 5 km per hour</p> <p>replicate over two separate nights.</p>	<p>three hair tubes (size not specified) set in each of ten habitat trees per 100 ha;</p> <p>tubes set for at least four consecutive nights</p> <p>bait not specified.</p> <p>Summary: 120 sampling-nights per 100 ha site.</p>	<p>Arboreal trap method and survey effort not prescribed.</p>	<p>Stagwatching method and survey effort not prescribed.</p>	<p>Listen for 10 minutes</p> <p>spotlight the area for 10 minutes</p> <p>play pre-recorded calls of target species for five minutes followed by 10 minutes of spotlighting</p> <p>conduct playback survey at two sites per stratification unit (plus additional per 100 ha above 200 ha)</p> <p>replicate playback survey twice on two separate nights.</p>

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
SFNSW (1999)	<p>Foot spotlight survey:</p> <p>two people with 50 w spotlights along 2 km transect (either two by 1 km transects or one 2 km transect) per 200 ha compartment</p> <p>walking at a speed of 1 km per (survey should not be less than 1 hr in duration)</p> <p>replicate over two separate nights.</p> <p>Vehicle spotlight survey - transects can be surveyed from a vehicle on one of the two nights as follows:</p> <p>use the same transects as for foot surveys</p> <p>vehicle speed must not exceed 5 km per hour</p> <p>use 100 w spotlights.</p> <p>Transects can be established along roads/tracks or away from roads.</p>	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	<p>Yellow-bellied glider among target species:</p> <p>ten minutes of listening,</p> <p>broadcast pre-recorded calls for five minutes (per species) and listen for two minutes</p> <p>conduct at two sites for every 200 ha compartment (additional call playback survey to be conducted for every additional 100 ha of survey area), separated by at least 1 kilometre</p> <p>where a 2 km long transect is used for spotlighting, conduct survey at the beginning and at the end of the transect</p> <p>replicate twice on separate nights</p> <p>sites should also be selected in potentially suitable habitat.</p>



Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Wyong Shire Council (1999)	one person-hour spotlight survey per site use at least a 50 w spotlight.	optional four small hair tubes attached to tree trunks 1.5 m above the ground baited with meat to target the brush-tailed phascogale set for 10 nights. Summary: 40 sampling-nights per site.	mount six Elliott B traps (per ha) on platforms in trees 2–4 m above the ground set traps at 10 degrees to facilitate drainage from rain position traps on the south-western side of trunks to shade against morning sun cover traps with plastic bag in case of rain use a handful of dry leaf litter for bedding bait with a mixture of rolled oats, honey and peanut butter trap for four to five nights. Summary: 30 trap-nights per site.	Place an observer at the base of a hollow-bearing tree watch for period of 40 minutes following dusk.	Call playback method and survey effort not prescribed.

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Murray et al. (2002)	spotlight survey conducted on foot at a rate of 1 km per hour across representative sampling sites replication per vegetation community required for sites <10 ha.	optional four small hair tubes attached to tree trunks 1.5 m above the ground bait with meat to target the brush-tailed phascogale set for ten nights. Summary: 40 sampling-nights per site.	six to ten Elliott B traps per site mounted on platforms in trees 2–4 m above the ground one site per 0.5-1 ha in all habitats, set traps open for 3–4 consecutive nights set traps on a ten degree angle to facilitate drainage from rain place a handful of dry leaf litter for bedding bait with a mixture of peanut butter, honey and rolled oats. Summary: Variable effort.	place an observer at the base of a hollow-bearing tree watch for period of 40 minutes following dusk.	Call playback method and survey effort not prescribed



Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Ecotone Ecological Consultants (2001)	<p>spotlight along a 500 m transect per site</p> <p>conduct spotlight survey following call playback survey</p> <p>two observers on foot using 50 w, 12 volt, 12 amp powered spotlights walking at a slow pace for at least 30 minutes.</p> <p>Equates to 30 minutes per 500 m (that is, 16.6 m per minute).</p>	<p>five 40 mm hair tubes attached to trees at each site</p> <p>bait with peanut butter, honey and rolled oats mixture, and</p> <p>set open for 10 nights.</p> <p>Summary: 50 trap-nights per ha site.</p>	<p>set five Elliott A traps and five Elliott B traps alternatively in two parallel lines per site,</p> <p>place traps 50 m apart on platforms mounted approx. 3 m of the ground</p> <p>shade traps and cover with a plastic bag with dry leaves supplied</p> <p>bait traps with rolled oats, honey and peanut butter mixture and sprayed with dilute honey mixture</p> <p>set open for four nights.</p> <p>Summary: 40 trap-nights per ha site.</p>	<p>Stagwatching method and survey effort not prescribed.</p>	<p>Initial 10–15 minutes of listening</p> <p>then pre-recorded calls played for five minutes</p> <p>followed by five minutes of listening</p> <p>use a 50 w spotlight to scan the area at the end of the survey.</p>

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Owens (2000)	not formally prescribed and not limited to arboreal mammals head torches and car vehicle lights between sites foot surveys around sites, particularly rocky sites where pitfall traps could not be installed.	optional four hair tubes (200 mm length and 50 mm diameter PVC tube) per pastoral site (1000 m x 1000 m/10 ha) and two per agricultural site (100 m by 100 m/1 ha) one hair tube nailed to a tree (arboreal) and on the ground at either end of the pitfall trap-lines baited with a mixture of peanut butter and oats the number of trap days is not indicated. Summary: Variable effort.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed
NT DIPE (2002)	Not specific to arboreal mammals. Conduct two separate 10 minute spotlight surveys in each quadrat site on separate nights.	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed.



Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
NT DCNR (2002)	Not specific to arboreal mammals. Conduct two separate 10 minute spotlight surveys in each quadrat site on separate nights.	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed.
NT DIPE (2005)	not specific to arboreal mammals two searches at night of 50 m x 50m quadrat	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call-playback method and survey effort not prescribed.
Morris (1992)	not specific to arboreal mammals 100 w powered spotlights spotlight surveys are conducted from a vehicle at 10–20 km per hr transects placed in all forest habitats transects equal to 15–25 km of track each night conduct two spotlight surveys within each four day sampling period use a survey distance of 50 m from track.	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call-playback method and survey effort not prescribed.

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Gold Coast City Council (2002)	30–50 w hand-held spotlights or head torches and conduct survey on foot two hours spotlighting (moving at a leisurely pace) per night of the survey period conduct across representative sampling sites.	Arboreal hair sampling, method and survey effort not prescribed.	Set five glider traps on platforms fixed to trees, as described in Mawberry, (1989) A New Trap Design for the Capture of Sugar Gliders.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed



Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Qld EPA Southern Region (1999)	<p>use high powered spotlights and head torches (not specified)</p> <p>conduct spotlight surveys over a period of three hrs.</p>	Arboreal hair sampling, method and survey effort not prescribed.	<p>combined ground-dwelling and arboreal survey effort - place 100 Elliott A traps and 20 cage traps on the ground and in trees</p> <p>space traps at 5 m intervals and arrange in five transects</p> <p>use a variety of baits (rolled oats and peanut butter and/or bacon, oil or canned fish)</p> <p>set traps for four nights</p> <p>check traps early morning and late afternoon.</p> <p>Summary: variable effort.</p>	Stagwatching method and survey effort not prescribed.	Call playback surveys are recommended but not described.

Reference	Spotlight survey	Hair sampling device surveys	Arboreal trap surveys (cage and Elliott B)	Stagwatching survey	Call playback survey
Qld CRA/ RFA Steering Committee	two observers traversing a 300 m transect with 30 w/50 w spotlights 0.5 hours (one person-hour). Spotlight surveys from vehicles along tracks between the survey sites were used to collect incidental records.	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed.
Eyre et al. (1997)	two observers traverse a 200 m long and 50 m wide transect use 30 w/50 w spotlights conduct survey for a maximum 1.5 person-hours.	Arboreal hair sampling, method and survey effort not prescribed.	Arboreal trap method and survey effort not prescribed.	Stagwatching method and survey effort not prescribed.	Call playback method and survey effort not prescribed.



GLOSSARY OF ACRONYMS

ACEC	Animal Care and Ethics Committee (NSW)
CALM	Department of Conservation and Land Management (WA). Now DEC
DECC	Department of Environment Climate Change. Now DECCW
DECCW	Department of Environment Climate Change and Water (NSW)
DEWHA	Department of the Environment, Water, Heritage and the Arts
DPIWE	Department of Primary Industries, Parks, Water and Environment (Tasmania)
EPA	Environmental Protection Authority
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
NPWS	National Parks and Wildlife Service (NSW). Now DECCW
NRETAS	Department of Natural Resources, Environment, the Arts and Sport (NT)
NSW DLSW	NSW Department of Land and Water Conservation. Now the NSW Department of Water and Energy
NT DCNR	Northern Territory Department of Conservation and Natural Resources. Now NRETAS
NT DIPE	Northern Territory Department of Infrastructure and Planning. Now NRETAS
NSW DPI	Department of Primary Industries. Combines the Former NSW Agriculture and NSW State Forests.
SA DEH	South Australia Department of Environment and Heritage
TSC Act	<i>Threatened Species Conservation Act</i>
VIC DSE	Department of Sustainability and the Environment (VIC)
WA DEC	Western Australia Department of Environment and Conservation (formerly CALM)
WWF	World Wildlife Fund for Nature, Australia

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FRONT COVER IMAGES (left to right)

Shark Bay Mouse (Babs & Bert Wells (CALM)) Tasmanian Devils (Dave Watts) Mountain Pygmy Possum (Lind Broom).

BACK COVER IMAGES (left to right, top to bottom)

Spotted-Tailed Quoll (Dave Watts) Bridled Nailtail Wallaby (M. Evans) Shark Bay Mouse (Babs & Bert Wells (CALM)) Southern Brown Bandicoot (Andrew Tatnell & the Department of Sustainability, Environment, Water, Population and Communities).

