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THE CARNIVOROUS MARSUPIALS

Can you imagine a mammal that weighs as little as a penny yet leaps five times its own height to take down prey far larger than itself? If not, can you visualise a rapacious killer that dispatches each victim with a deft bite to the neck before ripping its head off?

How about flesh-loving devils that relentlessly pursue victims to exhaustion then simply tear them to pieces? The hunting pack squabbles over the carcass in a screaming feast all night long, making enough racket to wake the dead. By morning, not a trace of the victim remains. Even its bones are ground to powder by a formidable predator sporting the most powerful jaws for its size of any living mammal.

What of maniacal male mammals that unceremoniously grab females by the neck to mate in frenzied sex sessions lasting up to 14 hours straight? The males invariably mate themselves to death, poisoned by their own raging hormones. Females are nymphs, and their clutch of young will have several fathers. With greedy mouth and grasping arms, their babies race each other to the mother's pouch. Once there, they attach to the first available nipple, suckling its life-giving milk. With all teats taken, late arrivals to the pouch simply wither and die.

What about prehistoric forms that include apex predator equivalents of lions, tigers, bears, wolves and even sabre-toothed, flesh-eating kangaroos?

Collectively, these animals are known as carnivorous marsupials. They include ~136 living species, inhabiting remote parts of Australia, the Americas and New Guinea. These unique creatures are secretive, rarely encountered and little understood.

Many of Earth's species, among them carnivorous marsupials, have succumbed to the pressures imposed by human sprawl – sent to extinction in the last few hundred years. Many more carnivorous marsupials are under serious threat of extermination, amid Earth's sixth and first human-caused, mass extinction.

How can we save the survivors that remain?

More practically perhaps, as a society, why would we wish *to save them?*

First, humanity must appreciate these unique and secretive animals and decide they *need* to be saved – this requires knowledge and understanding. Without such knowledge, we can, and will do, little or nothing collectively to intervene. Recent decades are testament to this. To ultimately save and conserve our precious carnivorous marsupials, then, we must first and foremost get to know them. That is the aim of this book.

What are marsupials?

Marsupials form one of three groups that together comprise the living mammals. There are more than 5500 living species of mammals; over 330 of these are marsupials, five are monotremes, while the dominant remainder comprises placental mammals. Most female mammals, including all placentals and marsupials, give birth to live young and then suckle them with nutritious milk, but female monotremes, which include the platypus and echidnas, lay eggs. After hatching, the young of these ancient mammals are fed on milk crudely oozed from skin glands on the mother's belly. Despite these differences, all

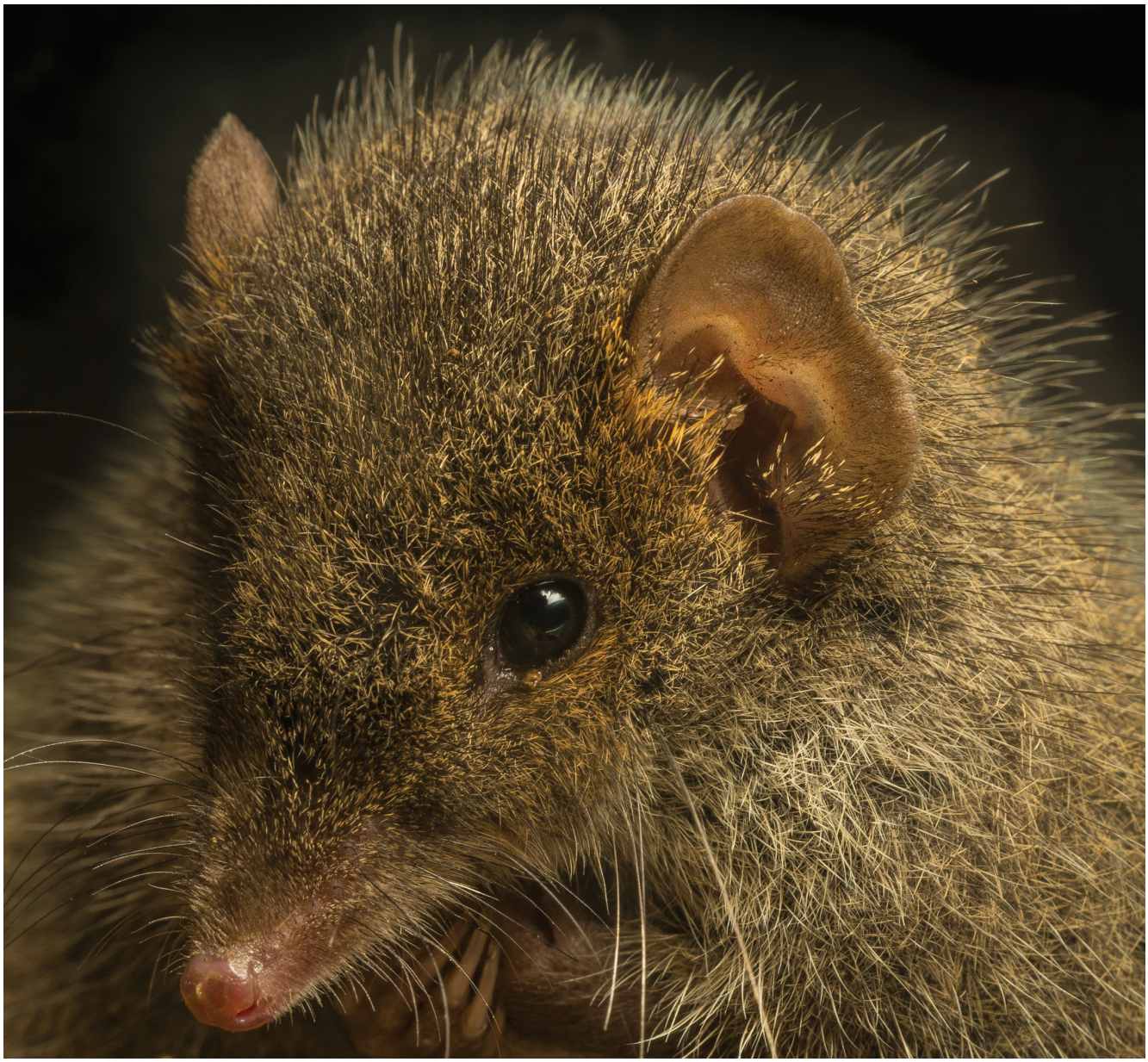

Fig. 1.1. The Endangered Black-tailed Dusky Antechinus (*Antechinus arktos*) is found only in the highest, wettest ancient Gondwanan rainforests of eastern Australia. Source: Gary Cranitch.

mammals are united by their ability to produce milk and also by their possession of fur. These traits distinguish them from other vertebrates (animals with backbones). Other modern groups of vertebrates include amphibians, reptiles, birds and fishes.

There are numerous differences between placental and marsupial mammals, especially relating to reproduction. Female placental mammals, including humans, nurture their young before birth with a placenta. Offspring come into the world fairly well developed. Marsupials, in contrast – including iconic species such as koala, kangaroos and wombats – are born at a very immature stage of development and look like pink jelly-beans. Although a simple placenta forms in all marsupial species, it nourishes the young for a relatively short part of their overall development; in some species, this may be just a few days. The tiny young crawl up to the mother's 'marsupium' or pouch, attaching to nipples there. The marsupial pouch may be fully developed, as in kangaroos, or it may be simply a naked depression on the belly with some skin folds that only partially protect the young as they grow. The latter is the case in most carnivorous marsupials. In marsupials, most of the reproductive effort occurs during a prolonged suckling period. Male placentals have testicles behind/under the penis. Marsupial males

Fig. 1.2. The Silver-headed Antechinus (*Antechinus argentus*) (viewed from the underside) – one of Australia's rarest mammals and likely endangered. This is 'Polly-Jean', a pit-tagged two-year-old mother with eight, 4-week-old young. Antechinuses have no discrete 'pouch', just a depression on the belly which cannot contain the rapidly growing offspring for long. By 6 weeks old, the young are simply too large for the mother to carry around. She leaves them in a nest of leaves while she forages, returning several times during the night to suckle the babies on her nutritious milk. Source: Andrew Baker.

have the opposite arrangement. Male placentals may have non-functioning nipples, while male marsupials typically have no nipples at all, although some at least have mammary cells as pouch young.

What makes a marsupial 'carnivorous'?

Animal dietary strategies have traditionally and simply been divided into three broad categories. Herbivores eat plants, carnivores eat meat and omnivores eat both. However, this classification is too vague to account for the complexity of all feeding strategies. Some animals switch diets at different parts of their life cycle or even between seasons. Others consume mostly flesh and incidentally eat plants when ingesting the guts of their herbivorous prey. Some animals have very specific diets. For example, there are those that consume solely fruit (frugivores) or nectar (nectarivores). Others, such as a few species of bats, eat only blood (sanguivores). There is overlap in many prey categories. For example, species preying mostly on insects are insectivorous, but broadly speaking they may be considered carnivorous because they kill and eat animal prey. Insects are animals too! What's more, finding out an animal's diet is not a trivial exercise, especially for solitary and secretive species that are

Fig. 1.3. Carnivorous marsupial diets vary, but most of the smaller species, such as this Common Planigale (*Planigale maculata*), eat a variety of invertebrates. Source: Steve Murphy.

difficult to find and observe under natural conditions. Such elusive animals must be caught, their scats (i.e. faeces or poo) collected and analysed under a microscope. The scattered hard fragments of pre-digested prey remains in faeces are not easily identified, even by experts. Sometimes, prey items such as soft-bodied worms and slugs cannot be seen in scats at all. In such cases, only an analysis of DNA (see following section) in the faeces may reveal the identity of prey items. In short, this means there is conjecture as to how best to categorise the diet of any animal. For our purposes, it is debatable how many marsupials may be considered carnivorous. In part, this is because not all species have been subjected to study. However, many species that **have** been well studied include variable amounts of fruit or other plant products in their diet. Here, we nominate as carnivorous those marsupials with diets that consist by majority (more than 50%) of vertebrate or invertebrate prey. Even so, some marsupials inevitably fall across the grey borders of 'carnivory' into other dietary categories, and we mention some of these at the end of the next chapter.

Diversity: how many carnivorous marsupials are there?

Earth's creatures are taxonomically positioned using a system invented by Carolus (Carl) Linnaeus in the 1700s to impose a classifying order on relationships. The structuring may be familiar: kingdom, phylum, class, order, family, genus and species. These various groupings describe relationships between organisms and their evolutionary patterns are often represented in diagrams called 'trees of life'. The kingdom is the most all-encompassing category and, for creatures, includes all animal life. Species, by contrast, can be viewed as very fine branches on the tree of life and represent collections of individuals that are similar in appearance, genetic structure and behaviour. Because of the extraordinary diversity of animals – living as well as extinct – these categories are themselves often sub-divided. For example, all mammals are grouped together within the phylum Chordata with the other vertebrate groups mentioned earlier, but are separated from them within their own class, Mammalia. Marsupials are then grouped below the level of class but above the level of order in their own intermediate category, the 'infraclass' Marsupialia. Some scientists have proposed alternatives to this arrangement, but all agree that marsupials form a large and diverse group within the class Mammalia.

Some debate also surrounds the formal definition of species. We return to this issue in more detail in Chapter 4, but provide a brief background here as a primer. For most creatures, a good rule of thumb is that members of the same species can be recognised if they are at least **potentially** able to breed with each other. We emphasise the word 'potentially' here for good reason. Species sometimes have broken and discontinuous distributions due to loss of habitat, changes in climate or other reasons, and these isolated populations may then begin to diverge from each other as they adapt progressively to local conditions. Animals in these isolates could potentially interbreed if they were able to come together, and thus conform to our definition of species, but the isolated populations may be given their own 'subspecies' names if they are different enough to warrant it. How much difference is enough? This remains a vexed question, but increasingly it is being answered by detailed molecular studies of an organism's DNA. DNA (deoxyribonucleic acid), the double-helix molecule that carries the building blocks of life, differs between all living things and, most usefully for biologists, allows us to identify different organisms. It is not usually necessary to describe the entire genetic material of animal species to understand their relationships with each other; comparisons of selected regions of DNA can suffice. In essence, if these selected regions of DNA are compared and show little or no difference between populations, the populations can be considered to belong to the same species. Assuming differences in DNA have gradually accrued over time, increasing differences in the DNA are suggestive of subspecies, and then of species, genera, or even more distant relationships on the basis that they are increasingly less likely to be interbreeding. Here, we note where DNA analyses have been used to identify species and to describe relationships between groups of species, and use the concept of subspecies mostly to describe geographically different populations of the same species.

Genus and species names, which are often of Greek or Latin derivation, are *italicised*, and together form the scientific name of a species. The combination of genus and species (e.g. *Antechinus arktos*) is unique for every organism on Earth. Unlike common names, which can sometimes be the same

Fig. 1.4. An excellent example of living carnivorous marsupial diversity. The extraordinary, Endangered Numbat (*Myrmecobius fasciatus*) is a survivor of an ancient group. DNA and morphological analyses suggest that Numbat ancestors last shared common ancestry with other marsupials ~30–40 million years ago. Source: Jiri Lochman.

for different species, scientific names cannot be confused. To maintain readability we use species' common names throughout the text, but also provide the scientific name at the first mention in each chapter. If we are discussing several species in the same genus, we also use the scientific shorthand of abbreviating the genus name to just its first letter. Thus, if *Antechinus arktos* is mentioned and we then refer to another antechinus species, it will be introduced as *A.* followed the specific name (e.g. *A. adustus*, *A. stuartii*). We also follow the convention of capitalising the first letters of species' common names, such as Rusty Antechinus (*A. adustus*) and Brown Antechinus (*A. stuartii*). This ensures clarity in referring to the species in question rather than adjectives to describe their colour or behaviour.

The living carnivorous marsupials total ~136 species within 32 genera and six families. Almost half (45%) of these occur only in Australia – some 61 species in 15 genera, three families and two orders. But almost as many carnivorous marsupials (43%) reside only in the Americas, totalling 58 species in 13 genera, three families and three orders. These are found mostly in South America, but also the southern and central reaches of North America, with four species (in as many genera) found in the Central American isthmus and Mexico. Eleven per cent of the world's carnivorous marsupials are found only in New Guinea, including 15 species in six genera, one family and one order. Just two species (1%) of carnivorous marsupial species are shared between northern Australia and New Guinea. These two countries, plus New Zealand, comprise the majority, by landmass, of Australasia. Yet New Zealand has no native marsupials – and just two living native land mammals, both bats (derived from Australia). The Americas share no living marsupials whatsoever with Australasia. Thus, most living carnivorous marsupials are 'endemic' to their landmass – found there and nowhere else. And some species, as we shall discover, have very limited distributions indeed.

So the reader can better appreciate their diversity, we briefly introduce each of the carnivorous marsupial genera in Chapter 2, providing a snapshot of their history of discovery, taxonomy, biology (breeding, behaviour, diet) and conservation. These are themes that we return to in more detail later in the book. We also provide an appendix listing all species with their common and scientific names and family relationships. This will be a handy reference to consult when carnivorous marsupials are named in later chapters.

2

GUIDE TO CARNIVOROUS MARSUPIALS

In the accounts of genera in this chapter, we refer to:

1. 'Size', which equates to the average adult body length, including the head, body and tail, and range of body weights (in brackets).
2. The 'IUCN (International Union for Conservation of Nature) Red List' (see also Chapter 11), which provides a comprehensive and objective global approach for evaluating conservation status including, in increasing level of extinction risk: non-threatened species categories of Least Concern and Near Threatened; threatened species categories of Vulnerable, Endangered and Critically Endangered; and two extinction categories, Extinct in the Wild and Extinct.

Carnivorous marsupials are classified as part of:

Kingdom Animalia

Phylum Chordata

Class Mammalia

Infraclass Marsupialia

Fig. 2.1. The largest living carnivorous marsupial, the Tasmanian Devil (*Sarcophilus harrisii*), can weigh up to an impressive 14 kg – similar to a medium-sized dog. The primary prey are kangaroos, wallabies, possums and wombats, which it kills by ambush or relentlessly running them to death. Once exhausted beyond endurance, the prey are simply torn limb from limb and devoured. Source: Jiri Lochman.

Australian fauna (two orders, three families, 15 genera, 61 endemic species)

Order Dasyuromorphia; Family Dasyuridae (13 genera, 58 species)

Genus *Antechinomys* (Kultarr or Jerboa-marsupial, 1 species)

Distribution: Semi-arid and arid Australia

Habitat: Desert plains; stony and sandy areas where small bushes and grasses predominate; scrub land; clay pans

Size: 17–25 cm (20–30 g)

The Kultarr was named by British naturalist John Gould in 1856. He depicted the animal on a tree branch, but it is in fact active only on the ground. Kultarrs were first considered the marsupial equivalent of the hopping-mouse (jerboa), but in 1867 the Kultarr was given its own genus, *Antechinomys*. The Kultarr's relationships with other Australian marsupials remain uncertain even to the present day. From the 1970s, the Kultarr was recognised as being

Fig. 2.2. The Kultarr (*Antechinomys laniger*). Note the hugely elongated hind feet, which the animal uses in concert with the hands to bound about with astonishing agility. Source: Jiri Lochman.

distinctive morphologically (i.e. in body and skull form), although bearing similarity to the dunnarts (genus *Sminthopsis*). Several DNA studies suggest that the dunnarts are not monophyletic (i.e. more closely related to each other than they are to anything else). In phylogenetic 'trees of life' based on DNA, the Kultarr is nested within the dunnart group. Indeed, one study using both DNA and morphology (body characteristics such as fur colour, measures of external and internal (skull) features), has shown that Kultarrs are most closely related to Long-tailed Dunnarts (*Sminthopsis longicaudata*), excluding the rest of the dunnarts. Two subspecies of Kultarr are recognised, which together possess a wide distribution across arid central Australia.

Kultarrs are small carnivorous marsupials with fawn–sandy brown fur above and white fur on the chest and belly. They have dark fur down the mid-line of the face and around the eye. Their ears are very large; the eyes protrude. They have long, thin hind feet. A long tail ends in a sparse brush of dark hairs. These animals are active at night, spending much time in search of food. They are known to enter torpor (i.e. a period of inactivity; a mini-hibernation) for up to 16 hours. Contrary to popular belief, these animals do not hop, but bound rapidly using hands and feet. This gives the animal great agility and an ability to rapidly change direction, which is useful to evade predators and catch prey. Kultarrs mostly eat invertebrates, including spiders, centipedes, crickets and cockroaches. They have a long breeding season and may mate several times throughout the year. Breeding timing varies depending on location and is likely related to day length. Exact length of gestation (i.e. pregnancy) has not been determined, but is more than 12 days. Females have six to eight teats and there is no discrete pouch, only folds of skin that protect the young during early stages of suckling. Almost nothing is known about their movement patterns. The species is adapted to life in open country and appears to undergo changes in population size throughout the year. Kultarrs are rare and scattered. They are notoriously difficult to catch using standard Elliott (aluminium box) traps, and capture rates in alternative types of trap, such as pitfall traps (where holes are dug in the ground), are usually also very low.

This species is classified as Least Concern on the IUCN Red List. Nevertheless, some populations may

be extinct, victim to intensified land use by pastoralists and introduced predators such as the European Red Fox (*Vulpes vulpes*) and feral House Cat (*Felis catus*).

Genus *Antechinus* (antechinuses, 15 species)

Distribution: Eastern, south-western and northern Australia, mostly in coastal or near-coastal regions; one species can be found in semi-arid mulga

Habitat: Open to closed forest and rainforest, but including heaths, sedges and grassland in some species

Size: 12–31 cm (16–178 g)

The first antechinus was captured on Waterhouse Island off the north-east coast of Tasmania. It was named by French naturalist Étienne Geoffroy Saint-Hilaire more than 200 years ago, in 1803. The Frenchman originally classified the beast as a new species of quoll (genus *Dasyurus*). In 1840, another species was discovered in Tasmania and named by the redoubtable George Waterhouse, then Keeper at the British Museum. He nominated the animal as a new species of *Phascogale*. The genus *Antechinus* was formally recognised by William Sharp Macleay when he nominated a third species in this carnivorous marsupial group captured near Sydney Harbour, New South Wales. Macleay was from a family of keen naturalists, which included his father, Alexander and cousin, William. The Macleays' primary focus was on insects, with broader interests that included vertebrates. In 1837, Irish artist and naturalist James Stuart, then working as Colonial Assistant Surgeon, had discovered a little marsupial near Sydney Harbour and passed it on to his friend William Sharp Macleay. Macleay named the new species after Stuart, raising the new genus *Antechinus* at the same time, in 1841. He was just in time for Stuart to recognise the honour: a year later, Stuart was dead after a third bout of typhus contracted during his duties tending the sick on incoming disease-ridden ships. Later, there followed the naming of two further new species of *Antechinus*, by British taxonomist Oldfield Thomas in 1904 and 1923. No other species of *Antechinus* was named until Australian taxonomist Steve Van Dyck's Cinnamon Antechinus (*A. leo*), in 1980. A range of genetic studies in the 1980s–1990s tested relationships among various families and genera of Australian mammals, including dasyurids. This work prompted description of other antechinus species. When Van Dyck conducted his comprehensive review of antechinuses in 2002, he recognised 10 living species. Since 2012, using DNA and morphology, five new species have been discovered, bringing the total to 15 species in the genus (see also Chapter 4, vignette). A further species most likely needs to be split in two, and this taxonomic work is in progress.

Antechinuses are small- to medium-sized carnivorous marsupials that are generally brownish to greyish in colour. The tails are thin and tapering, ranging from somewhat shorter to slightly longer than the head–body length. The fur is dense and generally soft. Species inhabiting colder areas tend to have a thicker, shaggier coat. The heads are conical in shape and ears are small to medium in size. Hands and feet are moderate in size and claws can be long in a couple of species that are adept diggers. Some species have relatively long, narrow snouts that give them a shrew-like appearance. Antechinuses are generalist predators, consuming mostly invertebrates such as beetles, cockroaches, spiders, grasshoppers, bugs, moths/butterflies, millipedes, scorpions, ants, and the like. They will also take a range of vertebrates, including skinks and frogs. The largest species regularly eat small birds and mammals. They are ferocious predators, taking on prey sometimes almost as large as themselves. In captivity, if unwary House Mice (*Mus musculus*) enter their cages or traps, most antechinus species will tear the heads from their hapless prey before quickly devouring the remainder.

Antechinuses are perhaps best known for their semelparous, so-called 'suicidal' reproduction. No male antechinus lives beyond the breeding season, which occurs annually across 1–3 weeks. Breeding is stressful – males and females mate promiscuously in sessions lasting up to 14 hours at a time. The annual male die-off is an inevitable result of surges in male testosterone that ensure a failure in the stress hormone (cortisol) cut-off switch. Excess cortisol causes systemic 'poisoning' and males suffer from internal bleeding. Organ malfunction followed by death results inevitably from immune system failure. This ensures that no male is alive by the time the first babies are born. Gestation is typically about a month long. Females will have four to 14 young, depending on the species. The 3–4 mm young attach themselves to nipples on the mother's pouch-less abdomen. Sunken walls and skin folds afford some protection

Fig. 2.3. The Agile Antechinus (*Antechinus agilis*). Many antechinuses spend as much time in trees as they do on the ground. Some species have been implicated in pollination of various plant species, such as the *Banksia* depicted here. Source: Jiri Lochman.

for the young while the mother moves about. The young remain attached to the nipples for ~6 weeks. They will spend a further 6 weeks in a spherical leaf/grass/twig nest, hidden in a tree trunk, fallen log, crevice or disused burrow. Once weaned, they leave the nest as juveniles after several experimental hunting forays with their mother. The general pattern is for antechinuses to breed in winter and give birth to young in the spring, then disperse in summer. In any given species at a certain location, reproduction is typically strongly synchronised. It will occur at close to the same time every year, depending in large part on day length and the rate at which the day length is increasing. A few species are mostly ground-dwelling, but the rest are as comfortable in trees as they are on the ground. Antechinuses are exceptionally fast-moving, exhibiting short, sharp, staccato/jerky movements. They are extremely agile and can leap a metre from a crouch position. In captivity, most species readily use rat running wheels, but they run on the outside of the wheel, upside down, rather than using it in the traditional manner! Most species are hostile if handled. Larger species will hiss and bite readily, especially males during the breeding season.

Until recently, no antechinus was listed on the IUCN Red List, but two species are now listed (Vulnerable and Near Threatened) and a number are currently under consideration for listing, including three of the five most recently named. Two of these new species apparently have among the smallest distributions of any Australian mammal. Antechinuses generally require forested areas for feeding and nesting, so land clearing, which has been marked and ongoing in eastern and south-western Australia, is a threat. Antechinuses fall prey to a range of feral predators such as cats and foxes. Pigs (*Sus scrofa*), Cattle (*Bos taurus*) and Horses (*Equus caballus*), which are ubiquitous throughout Australia, even in protected areas, trample their habitat. Fires, both planned and accidental, will cause local antechinus numbers to crash. It will take anywhere from 1 to 20 years for populations to re-establish, provided they have been able to take refuge in adjacent unburned areas. Climate change threatens several high-altitude species.