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Unexpected Captures of Hopping Mice in Tree-Mounted Phascogale Traps in Western Australia

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Abstract

Hopping mice are omnivorous rodents known for their burrowing habits and are not typically found in trees. We provide a record of an unusually high number of hopping mice caught in tree-mounted Elliott traps targeting red-tailed phascogales (*Phascogale calura*) at a multi-species reintroduction site in Western Australia. In 2024, 43 captures of hopping mice, representing two extant *Notomys* spp. (spinifex hopping mouse *N. alexis* and Mitchell's hopping mouse *N. mitchellii*), were unexpectedly captured in Elliott traps positioned >1.5 m off the ground, including three instances where two hopping mice were captured in a single trap. These captures provide evidence of previously unrecorded climbing behaviour by foraging hopping mice.

INTRODUCTION

Hopping mice (*Notomys* spp.) are gregarious, nocturnal, omnivorous rodents that construct elaborate burrows of interconnected vertical shafts with 'pop-holes' at the surface (Bradley 2009; Diete et al. 2014, 2016; Watts and Aslin 1981). Hopping mice are most often captured using pitfall traps (buckets dug into the ground) or Elliott traps, small aluminium box traps triggered by a treadle (Bradley 2009; Breed 1992; Breed and Leigh 2011; Diete et al. 2016). Given what is known about the semi-fossorial habits of *Notomys* spp. (see Watts and Aslin 1981), their mode of locomotion (Dawson 1976) and general preference for foraging in more open habitats across multiple species (Diete et al. 2016; Murray and Dickman 1994; Spencer et al. 2014), traps are typically deployed at ground level.

Mt Gibson Wildlife Sanctuary (Mt Gibson), a 131,812 ha conservation property on Badimia Country owned and managed by Australian Wildlife Conservancy (AWC) in mid-west Western Australia, is home to at least 16 extant terrestrial mammal species, including two hopping mouse species: spinifex hopping mouse *N. alexis* and Mitchell's hopping mouse *N. mitchellii.* Both species are widespread throughout much of arid and semi-arid Australia (Bradley 2009; Dickman et al. 2010; Smith et al. 2024; Van Dyck and Strahan 2008; Watts and Aslin 1981). Consistent with common practice elsewhere, hopping mice are monitored at Mt Gibson via a periodic standardised live trapping survey using a combination of pitfall traps and ground-deployed Elliott traps (Hungerford and Kark 2024). Between 2001 and 2020, AWC staff recorded 384 captures of *Notomys* sp. in a mixture of pitfall and Elliott traps (*N. alexis* = 13, *N. mitchellii* = 365, species not recorded = 6; Hungerford and Kark 2024).

Mt Gibson is also the site of an ambitious rewilding program involving translocations of ten regionally extinct mammal species (Kanowski et al. 2018; Ruykys and Carter 2019; Smith et al. 2020), largely into a 7,832 ha feral predator-free fenced exclosure completed in 2015 (Ruykys and Carter 2019). Red-tailed phascogales (*Phascogale calura*), reintroduced into the exclosure in 2017-2019 (Pierson et al. 2023; Ruykys et al. 2017), are monitored via a standardised live trapping survey involving tree-mounted Elliott traps (Anderson et al. 2024). Hopping mice are not a target species in these surveys and captures of large numbers of hopping mice are not expected. While *N. alexis* have been observed interacting with a number of habitat enrichment features in captivity, including artificial burrows, mazes, water crossings, pipes, branches and mounds (Bradley 2009; Dennis and Fowler 2008), and has been observed in largely bipedal kangaroo rats (*Dipodomys* spp.; Bartholomew and Caswell 1951), we could not find any records of *Notomys* spp. climbing.

Here, we describe a series of hopping mouse captures in tree-mounted traps targeting red-tailed phascogales. The observations provide evidence of climbing and offer insight into the range of foraging behaviours available to hopping mice. We discuss the factors that may contribute to this unexpected behaviour at Mt Gibson.

METHODS AND RESULTS

Arboreal trapping for red-tailed phascogales was conducted in 2021, 2022, 2024 and 2025, between late January and early April. Rainfall in the year prior to each trapping event was 308 mm, 496 mm, 147 mm and 401 mm respectively (BOM 2025; onsite station #10075; mean 1983-2024: 328 mm). Average daily maximum temperature (°C) during each survey was 28, 39, 27 and 40 respectively, while average daily minimum temperature was 20, 22, 16 and 25 respectively (BOM 2025, nearby station #007139). Elliott traps, attached to wooden platforms using cable ties, wire or bungee cords and mounted directly onto horizontal tree branches 1–2 m from the ground (Anderson et al. 2024), were lured with small balls of universal bait (one part quick cooking oats, four parts peanut butter, two parts sardines in oil). Preluring occurred for up to three weeks (Anderson et al. 2024). Coopex Residual Insecticide Spray was sprayed around traps if ant activity was observed during pre-luring, and traps were not opened if heavily overrun with ants. Twenty traps were deployed at each of six sites and trapped for four consecutive nights (n = 480 trap nights per survey), except for 2025 where only one night of trapping was conducted due to weather interruptions.

Hopping mice are captured incidentally in ground-deployed Sheffield wire-mesh cage traps (22 cm x 22 cm x 56 cm with treadle trigger) during reintroduced species monitoring, and are regularly detected on a standardised annual camera survey (Anderson et al. 2024; Sinclair et al. 2024). Sheffield traps were half-covered with a hessian bag and baited with universal bait or chopped apple and sweet potato (Smith et al. 2020). The camera survey involved two lured, downward-facing infrared cameras at each of 70 sites across the exclosure, strat-

Figure 1. Two examples of tree-mounted Elliott traps at Mt Gibson Wildlife Sanctuary, Western Australia.

ified by habitat type, for three weeks each summer (Anderson et al. 2024), and detection data were used to calculate naïve occupancy (detection/ trap nights). Reconyx PC900 HyperFire Professional Infrared remote cameras were used, set to record three images per trigger with no quiet period. A one-minute window of independence was used to reduce multiple counts of the same individuals. Hopping mouse species cannot be differentiated on the camera images.

A single *N. alexis* was captured in a tree-mounted Elliott trap in 2021, an oddity but not investigated further. In 2024, however, 43 hopping mice captures were recorded in tree-mounted traps over a single week (*N. alexis* = 11, *N. mitchellii* = 20, species not recorded = 12), similar to the total number of red-tailed phascogale captures, the target species, in that year (n= 68; Anderson et al. 2024). Captures included three instances where two mice were found in the same trap (one occasion for each species, species not recorded for the third; Figure 2). A further five captures (*N. alexis* = 3, *N. mitchellii* = 2) were recorded during one night of trapping in 2025.

Notomys spp. were captured incidentally in ground-deployed cage traps during ten monitoring events (Sinclair et al. 2024; n = 7 standardised surveys, n = 3 non-standardised trapping efforts for health checks or translocations of other species) within the Mt Gibson exclosure between 2020 and 2024 (n = 207; *N. alexis* = 105, *N. mitchellii* = 87, species not recorded = 15; Table 1). Incidental captures of *Notomys* spp. in ground-deployed cage traps, and naïve occupancy, were highest in 2023 and 2024 and lowest in 2020 and 2021 (Table 1).

DISCUSSION

Increased *Notomys* population densities due to favourable environmental conditions and/ or the impacts of feral predator exclusion could explain our novel observations of hopping mouse captures in arboreal traps. Additionally, or alternatively, specific environmental conditions before and during arboreal trapping in 2024 and 2025 may explain the unexpected behaviour. Arid ecosystem dynamics in Australia are largely driven by temperature extremes and variation in water availability, with animal populations additionally influenced by predation risk and availability of food (Newsome and Corbett 1975; Rymer et al. 2016; Woinarski et al. 2014). Several long-term ecological studies on *N. alexis* show that population densities oscillate from periods of high abundance during 'boom' years, undergoing massive eruptions at times, to rarity during drought (Dickman et al. 2010; Finlayson 1941; Letnic et al. 2004; Masters 1993; Newsome and Corbett 1975; Predavec 1994; Southgate and Masters 1996). *N. mitchellii* is known to exhibit similar patterns (Bradley 2009; Breed 2014). Boom conditions in 2021 could have resulted in increased population size, and thus higher densities and higher detectability, in subsequent years.

Feral predators have caused the extinction of many Australian mammal species and driven large declines in many more (Doherty et al. 2016; Woinarski et al. 2015). Cat- and fox-free islands and exclosures have helped to avoid further extinctions (Legge et al. 2018) and increase the size of populations protected within them (Moseby et al. 2011; Smith et al. 2020). Extant small vertebrates have benefitted, with higher density populations recorded inside exclosures compared to adjacent areas for small dasyurids (Roshier et al. 2020), native mice (Moseby et al. 2009, 2020) and some reptiles (Stokeld et al. 2018; although see Moseby et al. 2020; Hungerford and Kark 2024). In these examples, population densities in exclosures increased rapidly following removal of introduced predators (Stokeld et al. 2018) and were sustained over time (Moseby et al. 2020). Release from predation following the completion of Mt Gibson's exclosure in 2015 could have resulted in increased population size, and thus higher densities and higher detectability, in subsequent years.

Finally, animal behaviour is influenced by environmental conditions, with resource limitation a potentially strong driver. Hungry animals are more likely to engage in risky exploratory behaviours as they search for food (Found 2022; Hall and Bradshaw 1998; Moran et al. 2021; Smith and Grueter 2021). Starving aardvarks (*Orycteropus afer*) shifted from nocturnal to diurnal activity following a dry and hot summer (Rey et al. 2017), cats (*Felis catus*) are more likely to consume poisoned baits when less preferred prey is available (Algar et al. 2007) and hungry graybelly salamanders (*Eurycea multiplicata griseogaster*) are more willing to hunt in the presence of predator cues than satiated salamanders (Whitham and Mathis 2000). Hunger may increase the effort an animal is willing to put into searching for food and decrease neophobic responses to novel objects in the environment, such as traps (Bisi et al. 2011; Gragg et al. 2007; Short et al. 2002). Mt Gibson experienced a severe drought in 2023 and into early 2024 (Fontaine et al., 2024). Annual rainfall in 2023 was the lowest on record and the 2023-2024 summer was unusually hot (Mastrantonis and Bourne 2025; Sinclair et al. 2024). Temperatures were also exceptionally high in January 2025, with the single night of trapping preceded by eight

Figure 2. Hopping mice caught in tree-mounted Elliott traps at Mt Gibson Wildlife Sanctuary, Western Australia, including *Notomys mitchellii* (Mitchells' hopping mouse; left) and two *Notomys alexis* in the same trap (spinifex hopping mouse; right).

Table 1. Incidental captures of hopping mice within the exclosure at Mt Gibson during arboreal trapping and all other live trapping surveys combined and naïve occupancy from the standardised camera survey. Arboreal trapping used tree-mounted Elliott traps; other live trapping survey types use ground-deployed Sheffield traps with treadle trigger. Total rainfall in the previous calendar year is most informative for arboreal trapping (conducted in the austral summer). As the arboreal survey for phascogales was the first survey in 2025, no data were available for the other survey types for 2025 at the time of writing.

	2018	2019	2020	2021	2022	2023	2024	2025
Rainfall (mm)	353	154	308	496	290	147	401	
Notomys alexis								
Arboreal trapping			*NA*	1	0	*NA*	11	3
Ground-based trapping			8	0	3	37	57	
Notomys mitchellii								
Arboreal trapping			*NA*	0	0	*NA*	20	2
Ground-based trapping			10	3	1	53	20	
Notomys spp.								
Arboreal trapping			*NA*	0	0	*NA*	12	0
Ground-based trapping			0	0	0	5	10	
Naïve occupancy	0.73	0.69	0.39	0.36	0.66	0.83	0.84	

days approaching or exceeding 40°C. High numbers of *Notomys* captures in early 2024 and 2025 may be explained by higher than usual motivation to find food during a severely resource-restricted time.

We consider the last factor most likely to explain the high numbers of unexpected hopping mouse captures during routine arboreal trapping in 2024. If impacts of boom conditions on population density were the primary driver, we would have expected higher detections rates in 2021 and 2022 following years of higher-than-average rainfall. Instead, *Notomys* captures and occupancy tended to be lowest in these years (Table 1). Additionally, several *Notomys* were captured in ground-deployed traps in 2020 (Table 1), prior to the heavy rains in 2021, and population densities of many other species at Mt Gibson declined rather than increased in 2023 (Sinclair et al. 2024). Similarly, if release from predation pressure was the primary factor, we would have expected a sustained increase in captures over time (Moseby et al. 2020) rather than the observed drop in ground-deployed trap captures in 2020-2022. We therefore conclude that hungry hopping mice were likely highly motivated to access bait balls in tree-mounted traps in 2024 and 2025 due to severe resource limitation during the historic 2023-24 drought and heat waves in early 2025. High incidental captures in ground-deployed traps, and high naïve occupancy at lured camera sites in 2023 and 2024 support this hypothesis – hungry hopping mice were likely drawn to the food lures. It is also possible that high food motivation could be driven by an interaction between increasing population size before the drought and reduced resources that followed.

Our observations offer unique insight into the range of foraging behaviours available to hopping mice. Previously, *Notomys* spp. have not been recorded climbing or foraging in trees. Prior to 43 captures in arboreal traps in 2024, we had only recorded one *Notomys* capture in an arboreal trap at Mt Gibson. These captures provide evidence that *Notomys* spp. can, and do, climb trees to search for food. Approaching food lures in traps or in front of cameras in larger numbers overall, and specifically the unexpected arboreal captures, was likely motivated by hunger during extreme conditions. Unanswered but potentially interesting questions emerging from these observations include (1) whether hopping mice ordinarily forage in trees in the absence of lured traps, and if so, what do they eat, or (2) whether the documented behaviours constitute a novel behavioural response to extreme weather and/ or climate change.

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