

Indian palm squirrel

Funambulus spp.



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Government

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Front cover: Indian palm squirrel

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Summary

This study assessed the potential for five species of *Funambulus*, known as ‘Indian palm squirrels’, to become invasive pests in Queensland. It used an “evidence-based” approach to pest risk assessment, where published information on a species’ biology, ecology and history as a pest elsewhere was used to make reasonable predictions of potential impact and probability of naturalisation in Queensland.

This study presents evidence that two species, *Funambulus pennantii* (Five-striped palm squirrel) and *F. palmarum* (Three-striped palm squirrel), are high-risk species with major pest potential in Queensland. Both species are well adapted to climate types in Queensland, have broad opportunistic diets and tolerate a diverse range of habitats. *F. pennantii* is a serious pest of fruit crops in India including mangoes, apples, grapes, sugarcane and nuts. It also consumes bird’s eggs. It has successfully naturalised in Perth, Western Australia, (and at one point in time Sydney, New South Wales). *F. palmarum* has very similar biology and ecology. *F. pennantii* and *F. palmarum* are highly commensal and could become abundant in urban areas, especially Brisbane, Queensland, which appears to offer ideal habitat.

The other three species in the genus are more specialised in terms of their diet and habitat, preferring tropical rainforests, but are still considered to pose a moderate risk in Queensland, particularly Queensland’s wet tropics.

The risk of introduction into the state is very high for *F. pennantii* since it has been sold as a pet in New South Wales for at least 20 years.

In any forest environment, the arboreal and highly agile nature of palm squirrels could make eradication very difficult, if not impossible. As such, prevention, in the form of exclusion (preventing entry into Queensland and preventing sale and/or private possession) may be the only defence.

Identity and taxonomy

Species identity:

This risk assessment reviewed the pest potential of all species in the genus *Funambulus*. The genus is in the Sciuridae family (Order Rodentia).

Various common names are loosely applied to multiple species including Indian palm squirrels, 'Asian palm squirrels' and 'Asiatic striped squirrels'. There is considerable confusion as to the correct identity of the various species within the online literature.

According to Nowak (1999), *Funambulus* comprises five species:

1. *Funambulus pennantii* (often misspelled as *F. pennanti*)—common names include 'Five-striped palm squirrel' and 'Northern palm squirrel'. According to ZipCode Zoo (undated) subspecies include *argentescens* and *pennanti*
2. *Funambulus palmarum*—common names include Three-striped palm squirrel and according to ZipCode Zoo (undated) subspecies include *bellaricus*, *kelaarti* and *palmarum*
3. *F. tristriatus*—common name is 'Jungle striped squirrel' and according to ZipCode Zoo (undated) there is a subspecies *tristriatus*
4. *F. layardi*—common names include 'Layard's palm squirrel' and 'Flame-striped jungle squirrel'. According to ZipCode Zoo (undated) subspecies include *dravidianus* and *layardi*
5. *F. sublineartis*—common names include 'Dusky palm squirrel' and 'Dusky-striped jungle squirrel' and according to ZipCode Zoo (undated) there is a subspecies *obscurus*.

F. pennantii was recognised as a distinct species around the beginning of the twentieth century but prior to that was lumped with *F. palmarum* as the 'Common Palm Squirrel' (Sathasivam undated).

Palm squirrels derived their name from an association with the Palmyrah Palm (*Borassus flabelli*) (Jayawardene 2006).

Description

Body size, weight and colour vary across the five species of palm squirrels. However, all can be described as small mammals with general morphology similar to a range of other more widely recognised squirrel species.

The two most abundant and best-known species, *F. palmarum* and *F. pennantii*, range in size from 225–400 mm total length (including 110–120 mm long tail) and weigh 60–200 g (Wright 1972, Watts and Aslin 1981, Long 2003). Many online references say palm squirrels are “about the size of rats”. However, *F. sublineartus* is smaller and “more mouse-like” (Jayawardene 2006). Key diagnostic features of palm squirrels are their bushy tails and (usually) conspicuous stripes running along their bodies (Figure 1) (*F. sublineartus* has paler stripes).



Figure 1. *Funambulus pennantii* (Five-striped palm squirrel)

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All species have at least three stripes running along their bodies, but *F. pennantii* has two additional paler stripes on its sides, running between hind and forelegs (Figure 2). Most species have whitish stripes, but *F. layardi* has three orange stripes. Fur colour is generally grey-brown with some species being a little more reddish (rarely black). The belly is creamy white or brownish (except *F. layardi*, which has a reddish belly). The tail is covered with interspersed long black and white hairs. The ears are small and triangular. Like other species in the Order Rodentia, palm squirrels have chisel-sharp incisor teeth that grow constantly (Seebeck 1989).



Figure 2. *Funambulus pennantii* (Five-striped palm squirrel) in India.

Photo: Yann—reproduced from Wikimedia Commons with permission granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation, http://commons.wikimedia.org/wiki/File:Funambulus_pennantii,_Squirrel,_Jaura,_M.P.,_India.jpg.

Biology and ecology

Diet

Diet varies depending on species but the two most widespread species *F. pennantii* and *F. palmarum* have broad, opportunistic diets, consuming a range of foods that vary depending on season. All palm squirrels are essentially herbivores but the diet of the latter two species is known to include a range of seeds, leaves and soft fruit and certain animal matter such as birds' eggs/chicks and insects, especially locusts (Seebeck 1989, Stalder and Lundrigan 2009). Stalder and Lundrigan (2009) commented that, in India, *F. pennantii* has “a special liking for the nectar of silky oaks (*Grevillea robusta*)”, a tree native to Australia. Long (2003) noted that their diet includes citrus and stone fruits. Other crops damaged by palm squirrels include pineapple, mango, pomegranate, apples, guava, blackberries, grapes, sugarcane and groundnuts (Barnett and Prakash 1975, Prakash and Ghosh 1992, Chakravarthy 2004).

In urban areas, *F. pennantii* is known to feed extensively on food scraps, especially bread (Sedgwick 1968, Scanlen et al. 1978). In the Perth Zoo, *F. pennantii* has been observed to consume plant buds, grass, insects, animal food, fruit of *Phoenix* (palms), *Ficus* (figs), *Morus* and *Melia* and seeds from *Brachychiton*, *Araucaria* and *Pinus* (Wright 1972).



Figure 3. *Funambulus palmarum* (Three-striped palm squirrel) feeding on small fruits in India (Photo: JM Garg—reproduced from Wikimedia Commons with permission granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation.), [http://commons.wikimedia.org/wiki/File:Three-Striped_Palm_Squirrel_\(Funambulus_palmarum\)_feeding_on_Lannea_coromandelica_fruits_W_IMG_7816.jpg](http://commons.wikimedia.org/wiki/File:Three-Striped_Palm_Squirrel_(Funambulus_palmarum)_feeding_on_Lannea_coromandelica_fruits_W_IMG_7816.jpg)

Reproduction and longevity

In Perth, naturalised *F. pennantii* breed from August to May with peaks in October and April (Seebeck 1989). Gestation period is about 42 days (Seebeck 1989). Litter size varies from one to five young (average 2–3) and females can have two litters per year (fecundity varies depending on weather and the availability of food). Young are born in grass nests, usually constructed in a tree, but sometimes in a wall or roof. *F. palmarum* has been noted to build nests out of “anything that they can find” and “in urban areas it takes material from curtains etc” (Jayawardene 2006). Other species build their nests inside tree hollows. The young are weaned after about 10 weeks and are sexually mature at nine months. Juvenile mortality of 30% was recorded for *F. pennantii* in Perth (Wright 1972).

In captivity, palm squirrels (generally *F. pennantii*) have been described as “extremely flighty” and only have a five to six year life span (Thorington and Hoffmann 2005). In the wild (India), they live for at least 18 months (Chaudry and Beg 1977).

Behaviour

Palm squirrels are diurnal (active during the day). While not strictly territorial, they sometimes defend their nest and roost sites. While generally arboreal (tree-climbing) they will forage on the ground at times, much like other squirrels. They have sharp, curved, non-retractable claws that help them to climb and sometimes feed in groups. Palm squirrels are highly mobile, agile and quite vocal, with an alarm call that sounds like “chip chip chip”. In India, home range for *F. pennantii* varies from 0.2 ha for males and 0.15 ha for females, with partial sharing of ranges between sexes (Prakash et al. 1968). Home ranges can be smaller in urban areas, with ranges of 0.02–0.26 ha recorded in Perth Zoo (range length 50–135 m) (Wright 1972). They sometimes live in groups of up to 10 individuals and build communal nests (Long 2003).

Palm squirrels can be readily domesticated and trained to accept food from people. While naturally active, their activity is said to reach “frenzied levels” during the mating season, when males chase and fight each other and bite the tails of females (Seebeck 1989). Some people who have kept palm squirrels as pets describe them as “a hyperactive rat”.

Preferred habitat

With the exception of *F. pennantii*, palm squirrels are best adapted to tropical areas, as most occur naturally in areas of India that lie south of 23°N (latitudinally, this corresponds to the area north of Rockhampton, Central Queensland). *F. pennantii* is best adapted to climates experienced north of 23°N in India, which can be described as subtropical, but still seasonally hot and arid.

Preferred habitat varies widely between species (Nowack 1999). *F. pennantii* and *F. palmatum* are common in a wide range of seasonally dry tropical (hot) habitats, especially around villages and orchards. Long (2003) stated that the habitat of *F. pennanti* includes “open palm growths, forest and scrub, gardens, parks and schools”. Within its native range, *F. pennantii* is said to be “widespread and flexible” in its habitat preferences (Stalder and Lundrigan 2009). Habitats are typically below 4000 m and include “grasslands, scrublands, plantations, and tropical to subtropical dry deciduous forests” (Nameer and Molur 2008, Nowak 1999, in Stalder and Lundrigan 2009). *F. pennantii* “has a tendency to live in plantations and around farm lands” (Nowak 1999). Moore (1960) describes the species as being “arid-adapted” and suggests that wet forest is unsuitable and geographically restricting.

The range of *F. pennantii* extends into the deserts of northwest India, mainly in rocky and ruderal habitats. While uncommon in arid areas, it survives by seeking shelter in thick foliage of gardens and orchards (Ghosh 1975, Prakash 1975).

In Perth, *F. pennantii* is highly commensal, sheltering in gardens and buildings and relying on a range of introduced garden plants and scraps for food. At the Como High School in Perth, palm squirrel abundance declined during school holidays when food scraps became unavailable (Scanlan et al. 1978). WADAF (unpublished) commented that “it seems that palm squirrels do not favour native eucalypts, and prefer gardens with exotic trees, particularly palms.”

In contrast to *F. pennantii* and *F. palmarum*, the literature suggests that the three other species, *F. tristriatus*, *F. layardi* and *F. sublineartia*, are adapted to wetter (mesic) forest habitats (in tropical areas). While their preferred habitat is poorly described in the published literature, Jayawardene (2006) commented that *F. layardi* is found in “lowland and upland jungles” (rainforest) of Sri Lanka. The same author also described the habitat of *F. sublineartia* in Sri Lanka as “mountain forests and open, wild terrain”. Similarly, Prater (1980) (in Sathasivam undated) states that this species inhabits the south Indian hill ranges where it is “shy and secretive” keeping to damp gullies in dense forest where it is difficult to detect among tangled creepers and dense undergrowth, which are its hunting ground (it is said to feed largely on the fruit of *Rubus* species). It is recorded from the dense woods of the Nilgiris and “at considerable elevations” in Wynaad and Coorg (Sathasivam undated). It is also known from “Shernelly, Cochin”, Kodaikanal, the mountains of Travancore and from Newera-Eliya and other localities in Sri Lanka. In Travancore, the species was noted as common in bamboo-jungle and very common in other areas (Sathasivam undated). Sathasivam (undated) wrote that *F. tristriatus* lives in “jungle, evergreen forest and coffee estates” and is said to “frequent houses rarely and only where the Palm Squirrel does not occur”.

Predators and disease

Natural predators include varanid lizards, but natural predation is relatively low (Seebeck 1989). Parasites include mites and various internal parasites such as coccidiosis. Viruses including foot and mouth disease, leptospirosis and mange have been recorded to affect other species of squirrels (Tittensor 1977).

Origin and distribution

Nowack (1999) lists the species' native range as:

- *Funambulus palmarum* (Three-striped palm squirrel)–central and southern India (south of the Vindhya Range, which is at 23°N) and Sri Lanka
- *F. tristriatus*–southwestern India
- *F. layardi*–extreme southern India and Sri Lanka
- *F. sublineartia*–extreme southern India and southern Sri Lanka
- *F. pennantii* (Five-striped palm squirrel)–extreme southwestern Iran, Pakistan, India and Nepal.

In India, the range of *F. pennantii* partly overlaps with *F. palmarum*. *F. pennantii* is found in the Andaman Islands, Nicobar Islands (introduced), India (in Andhra Pradesh, Assam, Bihar, Chattisgarh, Delhi, Uttaranchal, Punjab, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Sikkim, Uttar Pradesh and West Bengal), Nepal, Bangladesh, Pakistan and Iran. Two subspecies *F. pennantii* subsp. *argentescens* and subsp. *lutescens* were suggested by Wroughton (1905) in addition to the nominate race. However, more recent workers do not make this distinction (Ellerman 1961, Srinivasula et al. 2008).

In India, the southern boundary is not clearly identified and recent records suggest that the southern boundary of the species may extend as far as Madanapalli (Srinivasulu et al 2008).

Sathasivam (undated) states that *F. pennantii* is almost entirely a northern (India) species and “is found in north India and Pakistan, and in a narrow range along the west of the peninsula down to about 16°N.”

According to Jayawardene (2006), Sri Lanka has three species of palm squirrels: *F. layardi*, *F. palmarum* and *F. sublineatus*. Of these, *F. palmarum* is the most common. In Sri Lanka the latter has four subspecies, each with its own range: one inhabits “the hill country”; one in the “wet zone”; and the other two in the “dry zone—north and south”. *F. layardi* is the rarest species of palm squirrel in Sri Lanka (Jayawardene 2006).

Sathasivam (undated) wrote that *F. tristriatus* is found in the Western Ghats alone, north to Bombay.

Status in Australia and Queensland

There is currently no evidence that palm squirrels have naturalised in Queensland.

The Five-striped palm squirrel (*F. pennantii*) is occasionally kept as a pet and several seizures have occurred over the past 20 years in Queensland and interstate. For example, eight specimens were seized in an aviary near Cairns, north Queensland, in November 1990 and two specimens (believed to be Five-striped) were seized at Stanthorpe, South East Queensland, in 1992 (after being purchased from a dealer in New South Wales) (Biosecurity Queensland file records).

In 1997, seven wild specimens were trapped and destroyed in Kew, Melbourne. Prior to this, one person had been selling the animals for \$700–\$1500 per pair. Investigations suggest at least 150 breeding pairs were sold in Victoria. Five-striped palm squirrels are currently kept and sold (as desexed specimens) in New South Wales. Palm squirrels have been sold as pets in New South Wales since at least 1992 (Biosecurity Queensland file records). There is unconfirmed anecdotal evidence that some people trap the animals in Perth (where there is a wild population) and transport them to other states for sale as pets. Palm squirrels are relatively easy to trap using possum cage traps.

In about 1898, Lieutenant-Colonel EA Le Souef released *F. pennantii* into the grounds of the Perth Zoological Gardens, Western Australia (Andrew unpublished). A wild population established and subsequently spread into nearby suburbs. The population has been subject to control action over the years and at one stage had spread over an estimated 30 km² (Western Australian Agricultural Protection Board, undated). The scrub and sand plain surrounding Perth may have prevented population expansion to date, however recent expansion of residential suburbs and gardens may allow them to eventually spread throughout the Perth metropolitan area (Lever 1985).

In 1942, *F. pennantii* was also released into the grounds of Taronga Zoo, Sydney, and established a small wild population that soon spread into nearby Ashton Park and as far as Clifton Gardens, a kilometre away. The population died out in the 1970s and its failure is attributed to a rat baiting campaign undertaken in 1976, as many squirrels took the bait (Andrew unpublished).

History as a pest elsewhere

The Five-striped palm squirrel (*Funambulus pennantii*) has naturalised in Perth, where it damages citrus, stone fruits, ornamental garden plants and electrical wiring in the roofs of houses, posing a fire risk (WAAPB undated, Long 2003). While damage is generally considered minor in Perth, the squirrels are probably persisting outside their preferred range and, as such, this population may not be providing a full insight into the species' pest potential in tropical and subtropical areas.

F. pennantii is a significant pest of orchards and nurseries in India where it causes serious damage to fruits and vegetables (Barnett and Prakash 1975, Prakash and Ghosh 1992, Parshad 1999, Idris 2009). Damaged fruit crops include pineapple, mango, pomegranate, apples, guava, blackberries and grapes, from the flowering to the ripening stage (Barnett and Prakash 1975, Prakash and Ghosh 1992, Chakravarthy 2004). Palm squirrels consume the flowers and ripe fruit and also nibble and drop unripe fruit (Barnett and Prakash 1975). Damage to sugarcane and groundnut crops has also been reported in India (Prakash and Ghosh 1992). Wheat, millet and sorghum have been used as poison baits for controlling this species in orchards and gardens (Barnett and Prakash 1975).

In India, *F. pennantii* “has a tendency to live on plantations and around farm lands, so they can be a pest when it comes to eating buds and seeds of food producing plants. They are also known to eat cocoa pods and can damage twigs of important plants” (Nowak 1999).

Nine species of ‘tree squirrels’ have naturalised elsewhere (Long 2003) including the Mexican red-bellied squirrel (*Sciurus aureogaster*); which naturalised in Biscayne National Park, Florida (Palmer et al. 2007); and the belly-banded squirrel (*Callosciurus flavimanus*), which escaped from zoological gardens in Oshima, Japan, in the 1930s or 1940s and by 1950 reached a population size of 20,000 (Long 2003).

Risk of introduction

This study suggests that the risk of introducing *F. pennantii* into Queensland is very high, based on the following evidence:

- *F. pennantii* is being kept and sold as a pet in New South Wales
- people moving from Perth could bring pet palm squirrels with them into Queensland
- small numbers of *F. pennantii* have been detected and seized on two occasions in Queensland already.

The risk of introducing the remaining four species is considerably lower.

Pest potential in Queensland

Bomford (2008) suggests three attributes are most often associated with invasive mammals:

- a history of invasion success elsewhere
- “climate match” (i.e. climate in an introduced range is similar to the species’ native range)
- a relatively broad natural geographic range.

Invasive mammals also tend to have broad (generalist) diets, although this attribute is a less reliable predictor of invasion success. Bomford suggests that these attributes are perhaps the best predictors of invasion success and can be used to assess risk of establishment.

Two species of Palm squirrels, *F. pennantii* and *F. palmarum*, have four attributes considered to confer pest potential in Queensland, viz.

1. They have broad “generalist” diets and would have little difficulty finding food once naturalised in suitable habitat (refer to section on Diet for more detail).
2. *F. pennantii* has naturalised elsewhere (i.e. Perth and at one point in time Sydney).
3. Climatically they are well suited to semi-arid and seasonally dry tropical and subtropical areas of Queensland. *F. pennantii* is best suited to subtropical areas and *F. palmarum* tropical areas (refer to section on Preferred habitat for more detail).
4. Both species are common and widespread in India, especially *F. pennantii*, which is found across northern India and into adjacent regions.

Hence, based on these attributes alone, there is a strong probability that these species could naturalise and become invasive pests in suitable parts of Queensland.

The potential impact of *F. pennantii* and *F. palmarum* populations in Queensland is difficult to predict with accuracy. However, based on the species’ diet in their native range, it seems reasonable to predict that they will eat fruit and also the eggs and chicks of native birds. *F. pennantii* is a serious pest of fruit crops in India, where it damages pineapple, mango, pomegranate, apples, guava, blackberries, grapes, sugarcane and groundnut crops. Hence, it could have similar impacts in Queensland. Mangoes, pineapples and sugarcane are valuable crops in Queensland.

Experience in Perth shows *F. pennantii* can damage garden plants and damage electrical wiring, creating fire risk. If it became abundant, its impact on native bird populations might be significant.

For *F. palmarum*, habitats most at risk are probably some of the semi-arid and seasonally dry parts of north Queensland, with suitable habitats including seasonally dry monsoon forest, tropical savannah and riparian areas within Cape York and the Gulf.

F. pennantii and *F. palmarum* are unlikely to persist in closed rainforests of north Queensland. However, they may do well in cleared areas with fruit crops and gardens along the coast, especially *F. palmarum*, which has a subspecies native to the wetter areas of Sri Lanka.

The three remaining species in the genus, *F. tristriatus* (Jungle Striped Squirrel), *F. layardi* (Flame-striped jungle squirrel) and *F. sublineartis* (Dusky-striped jungle squirrel) appear well suited to rainforests of the wet tropics of north Queensland and perhaps marginally suited to rainforests in southeast Queensland. *F. sublineartis* occurs naturally in upland rainforests in tropical parts of Sri Lanka, so it may be climatically suited to subtropical lowland rainforests.

Using CLIMEX (climate-modelling software), areas of Australia where climate is similar to climate experienced across the native range of three species *Funambulus palmarum*, *F. pennantii* and *F. sublineartis* was mapped (Figures 4, 5 and 6).

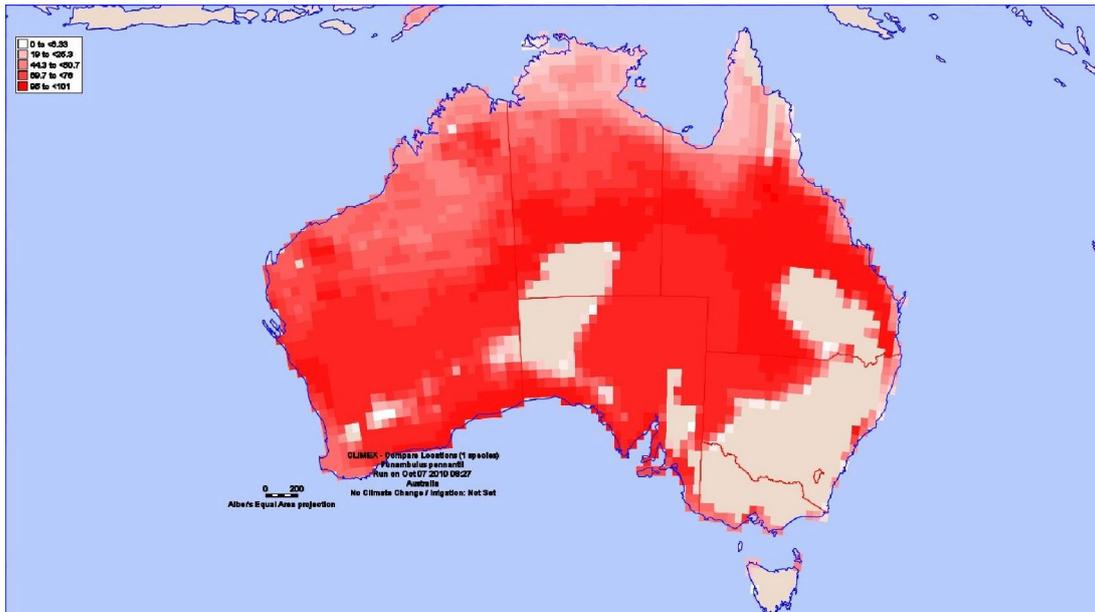


Figure 4. Area of Australia where climate appears most suitable for *Funambulus pennantii* (Five-striped palm squirrel). The dark red indicates areas where climate is most suitable; light red marginally suitable; and the remaining areas are unsuitable.

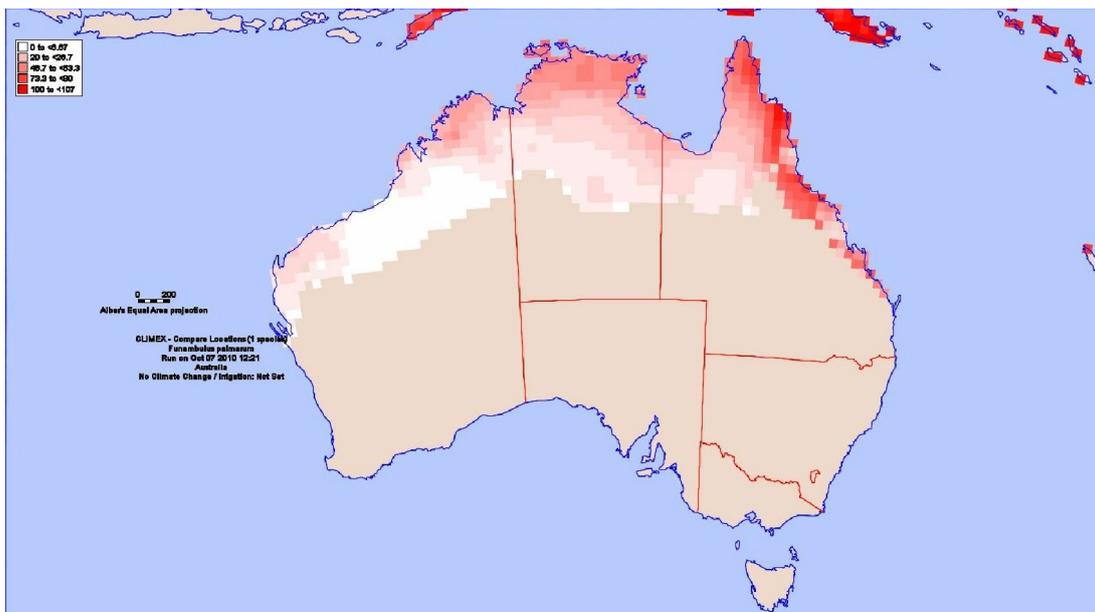


Figure 5. Area of Australia where climate appears most suitable for *Funambulus palmarum* (Three-striped palm squirrel). The dark red areas indicate where climate is most suitable; light red marginally suitable; and the remaining areas are unsuitable.

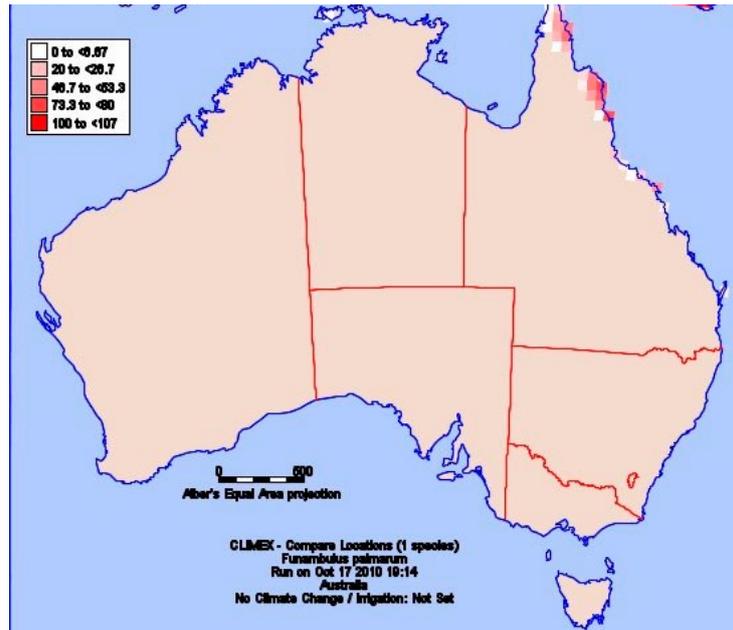


Figure 6. Areas of Australia where climate appears most suitable for *Funambulus sublineartis* (Dusky or Jungle striped palm squirrel) is indicated by dark and light green colours.

While these predictions are based on information on the species' natural range and habitats in India, two other facts are relevant: (1) one species of palm squirrel has naturalised in Perth and Sydney, outside its optimal climate zone; and (2) invasive mammals are well known for successfully naturalising outside their preferred climate zones. For these reasons, most of Queensland could be considered at risk.

Using the 'Bomford risk assessment protocol' (Bomford 2008), the Western Australian Department of Agriculture completed a risk assessment of *F. pennantii* and concluded that it posed an "extreme" risk to Australia (WADAF unpublished).

Eradication

Worldwide, there are few examples of successful eradication of naturalised mammal populations on mainland areas. Exception to this generalisation are more than 20 examples of successful eradication of rodents on small islands, where aerial application of rodenticide is practical and where the total population can be treated in a short period of time (Martins et al. 2006, Csurhes unpublished).

If detected at a very early stage of population development, when the population is small and confined to a manageable area, eradication may be viable, provided the species is not cryptic, arboreal or highly mobile. Once widespread, populations become highly resilient.

If a small wild population of palm squirrels was detected in Queensland, eradication could be attempted using baited cage traps. Palm squirrels have been trapped successfully elsewhere using drum traps with a funnel entrance, baited with bread and apples (Wright 1972). The latter technique, using 30 traps, caught more than 270 animals in three to four days. A small naturalised population at Taronga Zoo, Sydney, was eliminated by rat poison. If established over a large area, trapping and poisoning become less practical. In a forest environment, the arboreal and highly agile nature of palm squirrels would make eradication very difficult, if not impossible. Eradication in the 'wet tropics' rainforests of northern Queensland is predicted to be impossible. As such, prevention, in the form of exclusion (preventing entry into Queensland and preventing sale and/or private possession) may be the only defence.

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