

**PESTS**SMART

Michelle Christy

# Indicative 10 Project National Resource Material

## Pacific Rat (*Rattus exulans*)

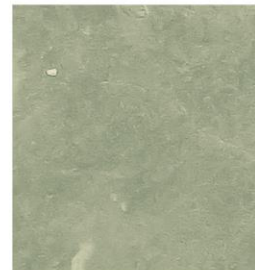
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2017

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*An Invasive Animals CRC Project*

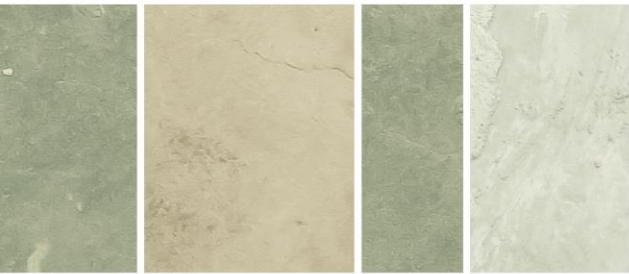






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## Summary

Summaries based on assessments carried out in (García-Díaz 2014a, b, c).

Species on VPC List 2007?	No
Species on the live import list (EPBC Act 1999)?	No
Risk of establishment:	Moderate (Bomford 2008)
Pathways:	Unintentional (stowaway)

## Key Messages

**Introduction pathway** - introduced to many Pacific islands including Hawaii and New Zealand by early Polynesian colonists, either as accidental stowaways or deliberately as a food source. In recent times, accidental stowaways on vessels have been identified as a pathway for introductions to Australia. *R. exulans*, *R. rattus* and *R. norvegicus* are considered to be the most widely introduced vertebrates to accompany people globally (Drake and Hunt 2009)

**Impact to Economy** - major pest of primary production by damaging a range of agriculture grain and fruit crops, and spreading disease

**Impact to Environment** - moderate pest risk of predation on susceptible native plants and animals, and spread of disease

**Identification** - may be mistaken for other introduced and native rodents

## Classification

*Rattus exulans* (Peale, 1848)

Class:	Mammalia
Order:	Rodentia
Family:	Muridae
Subfamily	Murinae
Genus:	<i>Rattus</i>
Species:	<i>exulans</i>



Figure 1. *Rattus exulans* Photo: Scot Nelson (CC BY-NC-SA 2.0)

## Common Names

Pacific rat, Kiore, Polynesian rat, Maori rat



## Biology and Ecology

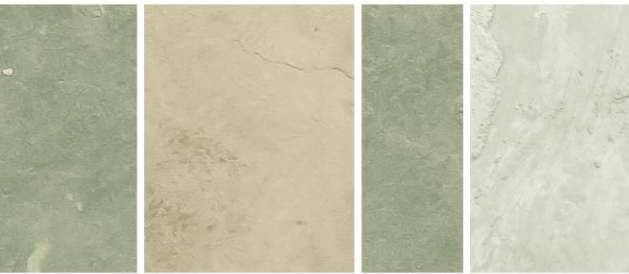
### Identification

The Pacific rat is the smallest rat species of the genus *Rattus* (Motokawa et al. 2004), being substantially smaller in size than the two other species associated with humans - the black or ship Rat (*R. rattus*) and the Norway or brown rat (*R. norvegicus*). It is a small mammal weighing 30 to 100 g. It has a head and body length of 80 to 140 mm, but with some animals measuring up to 180 mm (King 2005). The rat has a pointed nose and naked ears with dark grey skin (CABI 2017; ISSG 2017b; Figure 2 and 3). The body fur is reddish-brown to grey-brown, has translucent bristles buried in the fur and projecting black guard hairs on the back and sides; the fur feels somewhat harsh to touch (Tobin 1994). The belly fur is dark grey with white or pale grey tips. The thin, dark tail has narrow rings of scales, and short hairs on the upper surface. The tail length is variable, often as long as or slightly longer than the body, but it can also be shorter. The upper surface of each hind foot is marked with a triangle of dark reddish-brown hairs, extending from the ankle to part way down the foot. The toes are pale. Female Pacific rats have eight nipples (ISSG 2017b; King 2005; Long 2003; Medway 1969; Tobin 1994).



Figure 2: *Rattus exulans*. Photo Dean Foster (USDA NWRC)

The Pacific rat may be mistaken for other rodents (Kirkpatrick 2011). However it can be distinguished from the closely related black and brown rats (Table 1). Juveniles are similar to house mice (*Mus musculus*) apart from the tail colour (rat dark; mouse grey-brown) and feet. The feet of a juvenile Pacific rat are






proportionally longer and broader than those of an equivalent-sized mouse. Pacific rats also have an elongated fleshy pad on the under surface of the feet whereas the pad is round-shaped in mice (Kirkpatrick 2011).

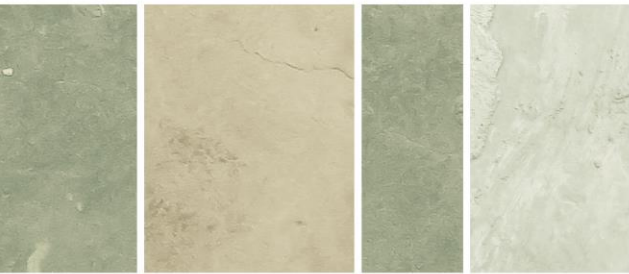


Figure 3. *Rattus exulans*. Photo Dean Foster (USDA NWRC)



Table 1: Basic morphometric comparisons between Pacific rat (*R. exulans*), and the black (*R. rattus*) and brown rat (*R. norvegicus*). Information from (GISD 2010; ISSG 2017b; Tobin 1994; Williams 1973),

Species	Morphometrics
<p>Pacific rat <i>Rattus exulans</i></p>  <p>Dean Foster Public Domain - US</p>	<p>Weight 30 to 100 g            Snout vent length to 180 mm            Ear 15.5 to 20.5 mm            Tail 125 to 135 mm            No. nipples 8</p> <p><b>Key features:</b></p> <ul style="list-style-type: none"> <li>• dark hair on the outside of the hind feet</li> <li>• ears are smaller than the black rat</li> <li>• ears can cover the eyes when pulled forward</li> <li>• tail is roughly the same length as the body</li> </ul>
<p>Black rat <i>Rattus rattus</i></p>  <p>Susannah Anderson CC BY-NC-ND 2.0</p>	<p>Weight 85 to 350 g            Snout vent length to 500 mm            Ear 19.0 to 26.0 mm            Tail 185 to 245 mm            No. nipples 10 to 12</p> <p><b>Key features:</b></p> <ul style="list-style-type: none"> <li>• ears can cover the eyes when pulled forward</li> <li>• tail is generally longer than the body</li> </ul>
<p>Brown rat <i>Rattus norvegicus</i></p>  <p>Richard Place CC BY-NC 2.0</p>	<p>Weight 120 to 580 g            Snout vent length to 510 mm            Ear 14.0 to 22.0 mm            Tail 150 to 215 mm            No. nipples 12</p> <p><b>Key features:</b></p> <ul style="list-style-type: none"> <li>• small ears that do not cover the eyes when pulled forward</li> <li>• tail is generally shorter than the body</li> </ul>



## Behaviours and Traits

The Pacific rat is nocturnal, but active during the day when population densities are high (Long 2003; Tobin 1994). It lives on the ground but readily climbs tall grasses, low trees and the walls and roofs of buildings (Tobin 1994; Williams 1973). It is a poor swimmer, only able to swim an average of 65 m (in comparison to black rats that can swim 300 m).

Species of the genus *Rattus* show site fidelity and usually disperse relatively short distances, often less than 500 m from their home range (e.g., Gardner-Santana et al. 2009; ISSG 2017a; Madsen and Shine 1999). Like the black and brown rats, Pacific rats are almost always found associated with human settlements (Howald et al. 2007a; ISSG 2017a; Miller and Miller 1995; Russell and Clout 2004).

## Food and Foraging

The Pacific rat eats seeds, flowers, fruits and foliage, as well as snails, insects, larvae, earthworms, small lizards, birds (including chicks) and eggs (Fall et al. 1971; Sugihara 1997). Ground-nesting adult birds may also be gnawed. To provide the Pacific rat with shelter and protection from predators while feeding, food is often carried by the rats to small husking stations, located amongst tree roots and rock piles, within cracks in tree trunks at ground level, and occasionally up in trees (Campbell et al. 1984).

## Reproduction and Lifecycle

Breeding occurs throughout the year with three litters produced per year (Miller and Miller 1995). Litter size is typically four, but can vary from one to nine (Sherley 2000). The neat, spherical nest is usually built about 20 cm off the ground among debris, often near the base of trees, in and under logs and sometimes in trees and buildings. Nests can also be suspended in 'tussock' grasses including rice plants and cane grass (Williams 1973).

## Habitat

In Asia, the Pacific rat lives close to villages, in huts or houses, cultivated fields, rice paddies, coconut plantations and canefields (Williams 1973). When black rats are present, Pacific rats are displaced from villages to the forest and may be absent altogether when there is a high density of black rats (Harper et al. 2005). The Pacific rat will also inhabit cleared areas with good cover, grassland, bush, scrub and secondary forest (Harper et al. 2005; Williams 1973). On Adele Island (Australia) it lives in spinifex hummock grassland.





## Global Range

The Pacific rat is the third most widespread rat species behind the brown and black rats (Williams 1973). It originated in Southeast Asia and has become widespread; natural and introduced range is estimated at 3.5 million km<sup>2</sup> (Kirkpatrick et al. 2010), from eastern Bangladesh, Andaman Islands, Myanmar, Thailand, Vietnam, south to Sumatra, Java, Sulawesi and east to Sumbawa, Flores, Timor, Sumba, Bali, Lombok, Papua New Guinea (including the Bismarck Archipelago), Philippines, Solomon Islands, New Zealand and many of the islands of Micronesia and Polynesia (Long 2003; Medway 1969).

The species was transported by early settlers in Pacific region over 1600 years ago (e.g., Kirch 1982), and its widespread and introduced range throughout the region occurred in association with human movement (Anderson 2009; Cowan 2004; Matisoo-Smith and Robins 2009; Rauzon 2007; Roberts 1991). The Pacific rat is introduced to American Samoa, Australia, Chile, Cook Islands, Hawaii, Fiji, French Polynesia, Guam, India, Indonesia, Taiwan and Miyakojima Island (Motokawa et al. 2001), Kiribati, Malaysia, Marshall Islands, Federated States of Micronesia (FSM), Nauru, New Caledonia, New Zealand, Niue, Northern Mariana Islands, Palau, Pitcairn, Solomon Islands, Samoa, Wallis and Futuna islands, Vanuatu, Taiwan, Tokelau, Tonga, Tuvalu, United States of America (Pribilof Island, Hawaii, and Howland and Wake islands of Minor Outlying Islands) (GISD 2010; Kirch 1982; Sugihara 1997; Figure 4).

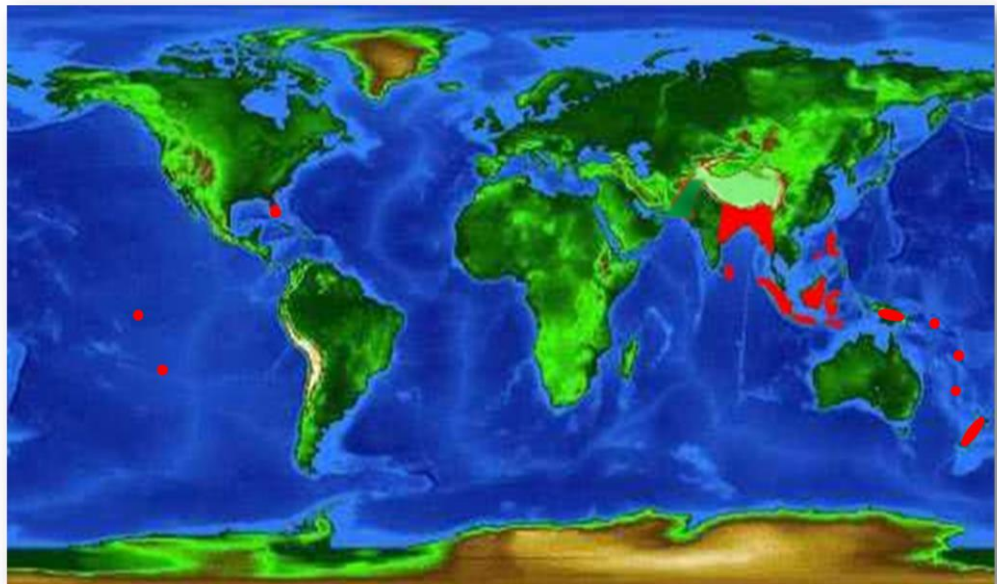
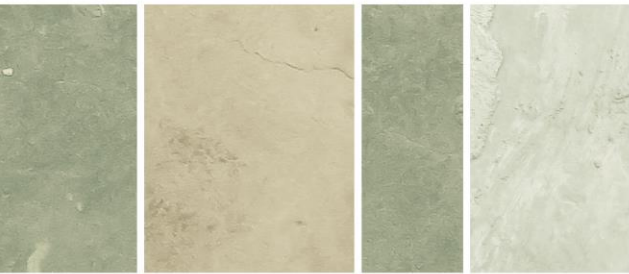


Figure 4. Map showing the current range of *Rattus exulans*. Image adapted from CABI (<https://www.cabi.org/isc/datasheet/46834>) August 2017.



New Zealand is the closest established population to Australia, and perhaps the highest risk of incursion. The Pacific rat was most likely introduced to New Zealand around 800 years ago and possibly as far back as 2000 years ago (King 2005; Lever 1985). It was once widespread in all suitable habitats on the three main islands, offshore islands and several outer islands. Today it occurs on numerous offshore islands and on the mainland in parts of Fiordland, Southland and south Westland (King 2005). Its decline on the mainland is attributed to it being largely displaced by the arrival of the black rat and brown rat with the first Europeans, as well as the spread of mice (Aplin et al. 2003; King 2005).

The earliest records of the Pacific rat in Australia is from Adele Island (northern Western Australia) in 1891 (Tate 1951; Taylor and Horner 1973) and the Murray Islands (east of Torres Strait) in 1888-89 (Watts and Kemper 1989). It has also been recorded on Sunday Island (Western Australia) and Norfolk Island, and possibly Christmas Island (Department of the Environment Water Heritage and the Arts 2009); (Long 2003; van Dyck and Strahan 2008; Watts and Aslin 1981). The species may have been eradicated from Adele Island (R. Palmer, personal communication reported in García-Díaz 2014d). Pacific rats are not known to be present on the Australian mainland (Department of the Environment Water Heritage and the Arts 2009; Long 2003; van Dyck and Strahan 2008) and have never been recorded on the Australian mainland (ALA 2017; CABI 2017; Watts and Aslin 1981; Watts and Kemper 1989).

## Potential for Introduction

The Pacific rat is prohibited from import into Australia but it could arrive here accidentally. For example, in addition to New Zealand, Pacific rats are established in Papua New Guinea (Long 2003) and there is the likelihood of the rat being transported through the Torres Strait to Australia (García-Díaz 2014c). To prevent the rat from establishing populations, it is essential that all those involved in importing cargo into Australia ensure that rodents do not board ships and transport barges at the point of departure. Management strategies should be in place at likely entry points to detect, contain and eradicate rats. Any animals found on board should be eliminated to ensure they do not disembark in Australia.

Although not known to be established in Australia, individuals or incipient populations may be present and mistaken for other rodents.

All non-native rodents detected in Australia have been transported as stowaways (Henderson et al. 2011). Although inspections by customs and biosecurity agencies provide support for the prevention of a Pacific rat incursion, the increasing transportation of people and commodities presents a high risk for the introduction of the Pacific rat.

Csurhes (2012) suggested that competition with other non-native species of rodents such as mice and rats negatively impact the probability of establishment of *R. exulans* in Australia. Russell and Clout (2004) found the presence of other rats negatively impacted the presence of Pacific rats in offshore islands as well as mainland New Zealand.



## Potential for Eradication

Although there is substantial evidence that eradication of the species is possible on islands (e.g., Harris et al. 2012; Howald et al. 2007a; Keitt et al. 2011; Long 2003; van Dyck and Strahan 2008), eradication of a population on the Australian mainland is not considered feasible (Csurhes 2012), despite the species' relatively strong site fidelity and association with human settlements. Based on the low detection probability of other non-native rats using intensive trapping (e.g., Adams et al. 2011; Pickerell et al. 2014; Watkins et al. 2010), detection of *R. exulans* at low densities will likely be difficult (García-Díaz 2014c).

Records from the “Database of Island Invasive Species” indicate a 60% success rate of eradications (DIISE 2015). The most frequent control method used for rodents is baiting using toxins, although trapping is often employed as a complementary technique (as reported in García-Díaz 2014d). Of the 284 islands where Pacific rat eradication programs occurred, 71% of the programs used brodifacoum (Howald et al. 2007b). Other toxins used include 1080 (although not considered effective in New Zealand), bromadiolone and diphacinone (Csurhes 2012; Harris et al. 2012; Howald et al. 2007a; Miller and Miller 1995). These toxins (and others) are currently registered to control rodents in Australia (DAWR 2017; Mcleod and Saunders 2013) and have proven effective at eradicating *R. exulans* from offshore islands (Keitt et al. 2011).

Monitor lizards (genus *Varanus*) and mongoose have been trialed as biocontrol agents on some Pacific islands in early but unsuccessful attempts to control Pacific rats (ISSG 2017b).

Early detection is a better strategy than eradication. However, eliminating a single invading rat can be difficult because of their secretive and atypical behaviour in the absence of conspecifics (GISD 2010; Russell et al. 2005; Weihong et al. 1999; Wiewel et al. 2009). Even if rats have been successfully eradicated, further incursions are likely. Ongoing surveillance is necessary to detect invading rats early, so that mitigation responses can occur (Russell et al. 2008).

## Impacts

### Economic

The Pacific rat is a major pest of agriculture in south-eastern Asia, Melanesia and throughout the Pacific region. The greatest damage occurs to rice, sugarcane and tuber crops; other effected crops include banana, cacao, coconut, maize, passionfruit, pawpaw, pineapple and root crops (ISSG 2017b; Long 2003; Tobin 1994). Damage occurs when flowers, pollen, fruit and seeds are eaten and stalks and other plant parts gnawed. In addition, the Pacific rat can impact people by entering houses, eating food and biting people and pets (Pacific Islands Cooperative Islands Initiative 2009).



## Environmental

The Pacific rat is known to exert high predation pressure on ground nesting birds, roosting bats, lizards and invertebrates in its natural range (e.g., Atkinson and Towns 2001; Jones et al. 2008; Long 2003; Sherley 2000; Whitaker 1973). Similar impacts have been reported from other locations where the species has been introduced (Jones et al. 2008; Long 2003; Wiewel et al. 2009).

Predation by the Pacific rat has been directly linked to the decline of the greater short-tailed bat (*Mystacina robusta*; (CABI 2017; Harris 2009). On the Mokohinau island group, lizard populations declined substantially after Pacific rat colonisation (McCallum 1986). Although the rats were subsequently removed, the altered remaining lizard assemblage suggests that some species are more susceptible to rat predation than others. Video surveillance showed predation of eggs of small seabirds, the effects of which have been confirmed by studies of chick survival before and after Pacific rat eradications (Towns et al. 2006). Fatal attacks by Pacific rats on adult Laysan albatross (*Phoebastria immutabilis*) appear associated with reduced fruiting of food plants after storms (Atkinson and Atkinson 2000). On Henderson Island (Pitcairn Islands), intense predation by Pacific rats on newly hatched chicks of three petrel species (*Pterodroma neglecta*, *P. heraldica* and *P. ultima*) was observed (de L Brook 1995; Scott 1993).

Large, flightless invertebrates are also at risk of predation by Pacific rats (Gibbs 2009). On Lady Alice Island (New Zealand), two large land snails (*Amborhytida tarangensis* and *Placostylus hongii*) are thought to be extinct following the introduction of the Pacific rat (Brook 1999). On Molokai, Hawaii, predation by Pacific rats has contributed to a substantial decline in populations of the native arboreal snail *Partulina redfieldi* (Hadfield and Saufler 2009). After Pacific rats were removed from Korapuki Island (New Zealand), nine previously unreported species of large invertebrates appeared, including native cockroaches and earwigs; these species have since become abundant (Towns et al. 1997) as cited in King (2005).

Pacific rats inhabit ecological niches similar to those of some Australian rodents and marsupials. These native animals could be at risk from competition for food, nesting sites and suitable habitat.

Impacts by the Pacific rat are not limited to animals. Pacific rats forage intensively on native vegetation, reducing seedling recruitment and damaging plant structures (Athens 2009; Campbell and Atkinson 1999, 2002; Jones et al. 2008).

## Social

Rodents are reservoirs of infectious disease which may be transmitted to people or domestic animals (Caughley et al. 1998). The Pacific rat occurs in close association with humans and is considered a public health risk. The rat can be a vector of hazardous diseases such as leptospirosis (Biosecurity Australia. 2000), rickettsial diseases (Kuo et al. 2011; Stevenson and Hughes 1988), such as scrub (*Rickettsia tsutsugamushi*) in northern Australia (Currie et al. 1996; Faa et al. 2003; Ralph et al. 2004) and murine typhus (*R. typhus*) in Western Australia,



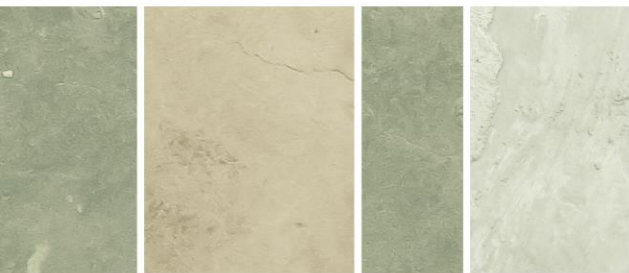
Queensland, South Australia and Victoria (Jones et al. 2004), toxoplasmosis (Atkinson and Towns 2001; CABI 2017), plague, lungworm, and other pathogens and parasites (King 2005; Singleton and Petch 1994).

## Legislation

The high risk and potential pest status of the Pacific rat is recognised throughout Australia, as indicated in Table 2.

Table 2: Current status of the Pacific rat under jurisdictional legislation

Jurisdiction	Legislation	Status
Australia	Biosecurity Act 2015	included
Australia	List of specimens taken to be suitable for live import	not listed
Western Australia	Biosecurity and Agriculture Management Act 2007	prohibited
South Australia	Natural Resources Management Act 2004	prohibited
New South Wales	Non-Indigenous Animals Regulation	high risk
Queensland	Land Protection (Pest and Stock Route Management) Act 2002	Class 1 declared animal
Victoria	Catchment and Land Protection Act 1994	prohibited



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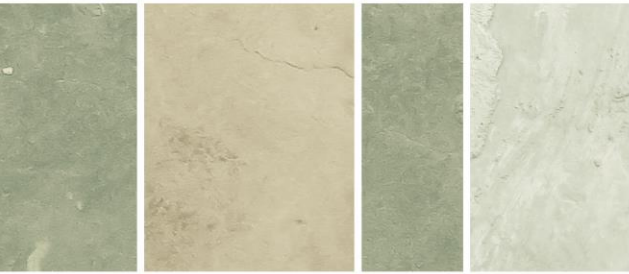
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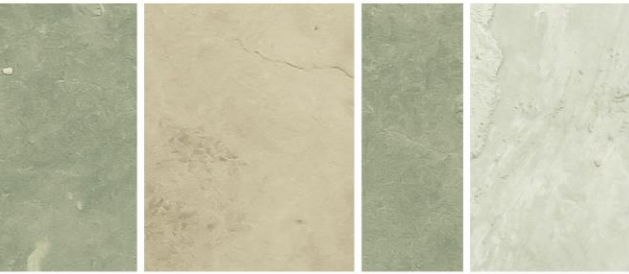








## Image Library - Pacific rat (*Rattus exulans*)





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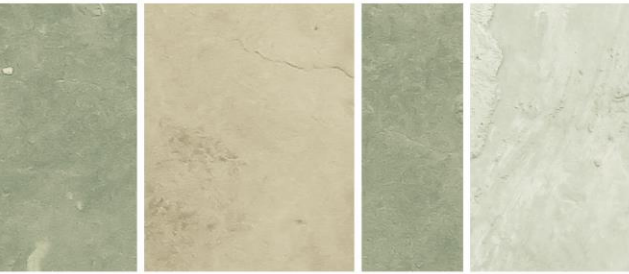
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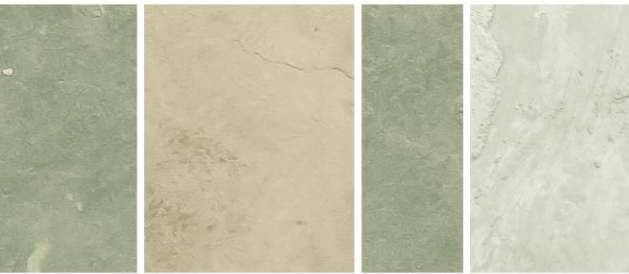
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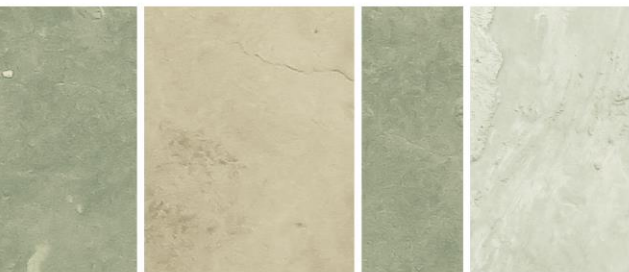
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## References

- Adams AAY, Stanford JW, Wiewel AS, Rodda GH. 2011. Modelling detectability of kiore (*rattus exulans*) on aguiguan, mariana islands, to inform possible eradication and monitoring efforts. *New Zealand journal of ecology*:145-152.
- ALA, (Atlas of Living Australia) 2017. Atlas of living australia website National Collaborative Research Infrastructure Strategy (NCRIS), Commonwealth Scientific and Industrial Research Organisation (CSIRO), and Global Biodiversity Infrastructure Facility (GBIF). <http://www.ala.org.au>.
- Anderson A. 2009. The rat and the octopus: Initial human colonization and the prehistoric introduction of domestic animals to remote oecania. *Biological Invasions* 11:1503-1519.
- Aplin KP, Brown PB, Jacob J, Krebs CJ, Singleton GR. 2003. Field methods for rodent studies in asia and the indo-pacific: Australian Centre for International Agricultural Research. Canberra.
- Athens JS. 2009. *Rattus exulans* and the catastrophic disappearance of hawaii's native lowland forest. *Biological Invasions* 11:1489.
- Atkinson I, Towns D. 2001. Advances in new zealand mammalogy 1990-2000: Pacific rat. *Journal of the Royal Society of New Zealand* 31:99-109.
- Atkinson IAE, Atkinson TJ. 2000. Land vertebrates as invasive species on islands served by the south pacific regional environment programme. In: Sherley G, editor. *Invasive species in the pacific: A technical review and draft regional strategy*. South Pacific Regional Environment Programme. Samoa. pp 19-84.
- Biosecurity Australia. 2000. A scientific review of leptospirosis and implications for quarantine policy. Department of Agriculture Fisheries and Forestry, Australia Canberra. 108 pp.
- Bomford M. 2008. Risk assessment models for establishment of exotic vertebrates in australia and new zealand: Invasive Animals Cooperative Research Centre Canberra, ACT.
- Brook FJ. 1999. Changes in the landsnail fauna of lady alice island, northeastern new zealand. *Journal of the Royal Society of New Zealand* 29:135-157.
- CABI, (The Centre for Agriculture and Bioscience International). 2017. Invasive species compendium. The Centre for Agriculture and Bioscience International. Oxfordshire, UK. <http://www.cabi.org/isc/>.
- Campbell D, Atkinson I. 1999. Effects of kiore (*rattus exulans* peale) on recruitment of indigenous coastal trees on northern offshore islands of new zealand. *Journal of the Royal Society of New Zealand* 29:265-290.
- Campbell D, Atkinson I. 2002. Depression of tree recruitment by the pacific rat (*rattus exulans* peale) on new zealand's northern offshore islands. *Biological Conservation* 107:19-35.
- Campbell DJ, Moller H, Ramsay GW, Wait JC. 1984. Observations on foods of kiore (*rattus exulans*) found in husking stations on northern offshore islands of new zealand. *New Zealand journal of ecology* 7:131-138.
- Caughley J, Bomford M, Parker B, Sinclair R, Kelley D. 1998. Managing vertebrate pests: Rodents: Bureau of Resource Sciences and Grains Research and Development Corporation. Canberra. 130 pp.

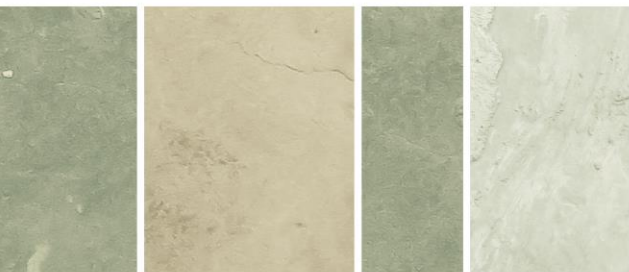
- Cowan P. Invasive rodent research priorities in new zealand; 2004; Fort Collins. National Wildlife Research Centre.
- Csurhes S. 2012. Invasive animal risk assessment - pacific rat *rattus exulans*. Brisbane, QLD. 14 pp.
- Currie B, Lo D, Marks P, Lum G, Whelan P, Krause V. 1996. Fatal scrub typhus from litchfield park, northern territory. Communicable Diseases Intelligence 20:420-421.
- DAWR, (Department of Agriculture and Water Resources). 2017. Australian pesticides and veterinary medicines authority. Department of Agriculture and Water Resources. Canberra, ACT.  
<http://www.agriculture.gov.au/ag-farm-food/ag-vet-chemicals/regulation>.
- de L Brook M. 1995. The breeding biology of the gadfly petrels pterodroma spp. Of the pitcairn islands: Characteristics, population sizes and controls. In: Benton TG, Spencer T, editors. Biological journal of the linnean society - the pitcairn islands: Biogeography, ecology and prehistory. pp 213-231. Department of the Environment Water Heritage and the Arts. 2009. Background document for the threat abatement plan to reduce the impacts on biodiversity on australian offshore islands of less than 100 000 hectares.  
<http://www.environment.gov.au/biodiversity/threatened/publications/tap/reduce-impacts-exotic-rodents-biodiversity-australian-offshore>.
- DIISE DoIISE. 2015. The database of island invasive species eradications Island Conservation, Coastal Conservation Action Laboratory UCSC, IUCN SSC Invasive Species Specialist Group, University of Auckland and Landcare Research New Zealand. Santa Cruz, CA.  
<http://diise.islandconservation.org>.
- Drake D, Hunt T. 2009. Invasive rodents on islands: Integrating historical and contemporary ecology. Biological Invasions 11:1483-1487.
- Faa AG, McBride WJH, Garstone G, Thompson RE, Holt P. 2003. Scrub typhus in the torres strait islands of north queensland, australia. Emerging Infectious Diseases 9:480-482.
- Fall MW, Medina AB, Jackson WB. 1971. Feeding patterns of *rattus rattus* and *rattus exulans* on eniwetok atoll, marshall islands. Journal of mammalogy 52:69-76.
- García-Díaz P. 2014a. Evaluation of potential impacts of species proposed for category 1 list. Invasive Animals and Plants Committee. Adelaide, SA. 32 pp.
- García-Díaz P. 2014b. Pathways of incursion of species proposed for category 1 list. Invasive Animals and Plants Committee. Adelaide, SA 4pp.
- García-Díaz P. 2014c. Preliminary feasibility analysis. Mammals: Pacific rat (*rattus exulans*). Invasive Animals and Plants Committee. Adelaide, SA. 6 pp.
- García-Díaz P. 2014d. Preliminary feasibility analysis. Reptiles: Pacific rat (*rattus exulans*) Invasive Animals and Plants Committee. Adelaide, SA. 6 pp.
- Gardner-Santana L, Norris D, Fornadel C, Hinson E, Klein S, Glass G. 2009. Commensal ecology, urban landscapes, and their influence on the genetic characteristics of city-dwelling norway rats (*rattus norvegicus*). Molecular ecology 18:2766-2778.



- Gibbs G. 2009. The end of an 80-million year experiment: A review of evidence describing the impact of introduced rodents on new zealand's 'mammal-free' invertebrate fauna. *Biological Invasions* 11:1587-1593.
- GISD, (Global Invasive Species Database). 2010. *Rattus exulans*. Invasive Species Specialist Group.  
<http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=rattus+exulans&rn=&hci=-1&ei=-1&lang=EN&Image1.x=15&Image1.y=16>  
11 September 2009.
- Hadfield M, Saufler J. 2009. The demographics of destruction: Isolated populations of arboreal snails and sustained predation by rats on the island of moloka'i 1982-2006. *Biological Invasions* 11:1595-1609.
- Harper GA, Dickinson KJ, Seddon PJ. 2005. Habitat use by three rat species (*rattus* spp.) on stewart island/rakiura, new zealand. *New Zealand journal of ecology* 29:251-260.
- Harris D, Gregory SD, Bull L, Courchamp F. 2012. Island prioritization for invasive rodent eradications with an emphasis on reinvasion risk. *Biological Invasions* 14:1251-1263.
- Harris DB. 2009. Review of negative effects of introduced rodents on small mammals on islands. *Biological Invasions* 11:1611-1630.
- Henderson W, Bomford M, Cassey P. 2011. Managing the risk of exotic vertebrate incursions in australia. *Wildlife Research* 38:501-508.
- Howald G, Donlan C, Galván JP, Russell JC, Parkes J, Samaniego A, Wang Y, Veitch D, Genovesi P, Pascal M. 2007a. Invasive rodent eradication on islands. *Conservation Biology* 21:1258-1268.
- Howald G, Donlan CJ, Galvin JP, Russell JC, Parkes J, Samaniego A, Wang Y, Veitch D, Genovesi P, Pascal M and others. 2007b. Invasive rodent eradication on islands. *Conservation Biology* 21:1258-1268.
- ISSG, (Invasive Species Specialist Group) 2017a. Global invasive species database. International Union for Conservation of Nature (IUCN).  
<http://www.iucngisd.org/gisd/>.
- ISSG, (Invasive Species Specialist Group) 2017b. Global invasive species database - *rattus exulans* International Union for Conservation of Nature (IUCN).  
<http://193.206.192.138/gisd/speciesname/Rattus+exulans>.
- Jones HP, Tershy BR, Zavaleta ES, Croll DA, Keitt BS, Finkelstein ME, Howald GR. 2008. Severity of the effects of invasive rats on seabirds: A global review. *Conservation Biology* 22:16-26.
- Jones SL, Athan E, O'Brien D, Graves SR, Nguyen C, Stenos J. 2004. Murine typhus: The first reported case from victoria. *Medical Journal of Australia* 180:482.
- Keitt B, Campbell K, Saunders A, Clout M, Wang Y, Heinz R, Newton K, Tershy B. 2011. The global islands invasive vertebrate eradication database: A tool to improve and facilitate restoration of island ecosystems. In: Veitch C, Clout M, Towns D, editors. *Island invasives: Eradication and management*. IUCN. Gland, Switzerland. pp 74-77.
- King CM, editor. 2005. *The handbook of new zealand mammals*. 2nd ed. Oxford University Press. Auckland. 600 pp.
- Kirch PV. 1982. The impact of the prehistoric polynesians on the hawaiian ecosystem. *Pacific Science* 36:1-14.
- Kirkpatrick W, Massam M, Page A. 2010. Risk assessment for australia of pacific rat *rattus exulans*. Western Australia. 20 pp.



- Kirkpatrick WE, Massam, M. M. 2011. Pacific rat. National animal pest alert no 10/11. Department of Agriculture and Food, Western Australia.
- Kuo CC, Wang HC, Huang CL. 2011. The potential effect of exotic pacific rats *rattus exulans* on vectors of scrub typhus. *Journal of Applied Ecology* 48:192-198.
- Lever C. 1985. *Naturalised mammals of the world*: Longman. London.
- Long JL. 2003. *Introduced mammals of the world: Their history, distribution and influence*: CSIRO Publishing. Melbourne, VIC.
- Madsen T, Shine R. 1999. Rainfall and rats: Climatically-driven dynamics of a tropical rodent population. *Australian Journal of Ecology* 24:80-89.
- Matisoo-Smith E, Robins J. 2009. Mitochondrial DNA evidence for the spread of pacific rats through oecania. *Biological Invasions* 11:1521-1527.
- McCallum J. 1986. Evidence of predation by kiore upon lizards from the mokohinau islands. *New Zealand journal of ecology* 9:83-87.
- Mcleod L, Saunders G. 2013. *Pesticides used in the management of vertebrate pests in australia: A review*. NSW Department of Primary Industries. Orange, NSW 176 pp.
- Medway L. 1969. *The wild mammals of malaya and offshore islands including singapore*: Oxford University Press. London. 127 pp.
- Miller C, Miller T. 1995. Population dynamics and diet of rodents on rangitoto island, new zealand, including the effect of a 1080 poison operation. *New Zealand journal of ecology* 19:19-27.
- Motokawa M, Lin L-K, Lu K-H, Harada M. 2004. Geographic variation in cranial features of the polynesian rat *rattus exulans* (peale, 1848) (mammalia: Rodentia: Muridae). *The Raffles Bulletin of Zoology* 52:653-663.
- Motokawa M, Lu K-H, Harada M, Lin L-K. 2001. New records of the polynesian rat *rattus exulans* (mammalia: Rodentia) from taiwan and the ryukyus. *Zoological Studies* 40:299-304
- Pacific Islands Cooperative Islands Initiative. 2009. Fiji: Viwi island - pacific rat (*rattus exulans*).ISSG. <http://www.issg.org/cii/PII/demo/viwa.html>.
- Pickerell GA, O'Donnell CF, Wilson DJ, Seddon PJ. 2014. How can we detect introduced mammalian predators in non-forest habitats? A comparison of techniques. *New Zealand journal of ecology* 38:86-102.
- Ralph A, Raines M, Whelan P, Currie BJ. 2004. Scrub typhus in the northern territory: Exceeding the boundaries of litchfield national park. *Communicable Diseases Intelligence* 28:267-269.
- Rauzon MJ. 2007. Island restoration: Exploring the past, anticipating the future. *Marine Ornithology* 35:97-107.
- Roberts M. 1991. Origin, dispersal routes, and geographic distribution of *rattus exulans*, with special reference to new zealand. *Pacific Science* 45:123-130.
- Russell J, Beaven B, MacKay J, Towns D, Clout M. 2008. Testing island biosecurity systems for invasive rats. *Wildlife Research* 35:215-221.
- Russell JC, Clout MN. 2004. Modelling the distribution and interaction of introduced rodents on new zealand offshore islands. *Global Ecology and Biogeography* 13:497-507.
- Russell JC, Towns DR, Anderson SH, Clout MN. 2005. Intercepting the first rat ashore. *Nature* 437.



- Scott DA, editor. 1993. A directory of wetlands in oceania. International Waterfowl and Wetlands Research Bureau Slimbridge, UK and Asian Wetland Bureau Kuala Lumpur, Malaysia
- Sherley G. 2000. Invasive species in the pacific: Samoa: South Pacific Regional Environment Programme, 2000.
- Singleton GR, Petch DA. 1994. A review of the biology and management of rodent pests in southeast asia. Canberra. Australian Centre for International Agricultural Research.
- Stevenson WJ, Hughes K. 1988. Synopsis of zoonoses in australia: Government Publishing Service. Canberra, ACT.
- Sugihara RT. 1997. Abundance and diets of rats in two native hawaiian forests. Pacific Science 51:189-198.
- Tate GHH. 1951. Results of the archbold expeditions no 65 - rodents of australia and new guinea. Bulletin American Museum Natural History 94:183-430.
- Taylor MJ, Horner EB. 1973. Results of the archbold expeditions no 98. Systematics of native australian *rattus* (rodentia, muridae). Bulletin American Museum Natural History 150:1-130.
- Tobin ME. 1994. Polynesian rats. Digital Commons at University of Nebraska. Lincoln, NE.  
[http://digitalcommons.unl.edu/icwdmhandbook/7/?utm\\_source=digitalcommons.unl.edu%2Ficwdmhandbook%2F7&utm\\_medium=PDF&utm\\_campaign=PDFCoverPages](http://digitalcommons.unl.edu/icwdmhandbook/7/?utm_source=digitalcommons.unl.edu%2Ficwdmhandbook%2F7&utm_medium=PDF&utm_campaign=PDFCoverPages).
- Towns D, Atkinson I, Daugherty C. 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biological Invasions 8:863-891.
- Towns DR, Simberloff D, Atkinson IAE. 1997. Restoration of new zealand islands: Redressing the effects of introduced species. Pacific Conservation Biology 3:99-124.
- van Dyck S, Strahan R. 2008. The mammals of australia: New Holland Publishers. Sydney, NSW.
- Watkins AF, McWhirter JL, King CM. 2010. Variable detectability in long-term population surveys of small mammals. European Journal of Wildlife Research 56:261-274.
- Watts CHS, Aslin HJ. 1981. The rodents of australia: Angus & Robertson Publishers. Sydney.
- Watts CHS, Kemper CM. 1989. Muridae. In: Walton DW, Richardson BJ, editors. Fauna of australia. AGPS Canberra. pp 35.
- Weihong JI, Veitch CR, Craig JL. 1999. An evaluation of the efficiency of rodent trapping methods: The effect of trap arrangement, cover type, and bait. New Zealand journal of ecology 23:45-51.
- Whitaker A. 1973. Lizard populations on islands with and without polynesian rats, *rattus exulans* (peale). Proceedings of the New Zealand Ecological Society 20:121-130.
- Wiewel AS, Yackel Adams AA, Rodda GH. 2009. Distribution, density, and biomass of introduced small mammals in the southern mariana islands. Pacific Science 63:205-222.
- Williams JM. 1973. The ecology of *rattus exulans* (peale) reviewed. Pacific Science 27:120-127.

