New Zealand peripatus/ ngaokeoke

Current knowledge, conservation and future research needs

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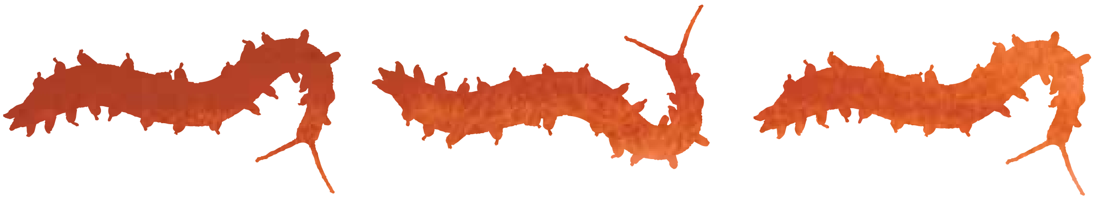

Cover: *Peripatoides novaezealandiae*. Photo: Rod Morris

ISBN 978-0-478-15009-4

Published by: Department of Conservation, Ōtepoti/Dunedin Office,
PO Box 5244, Dunedin 9058, New Zealand.

Editing and design: Publishing Team, DOC National Office

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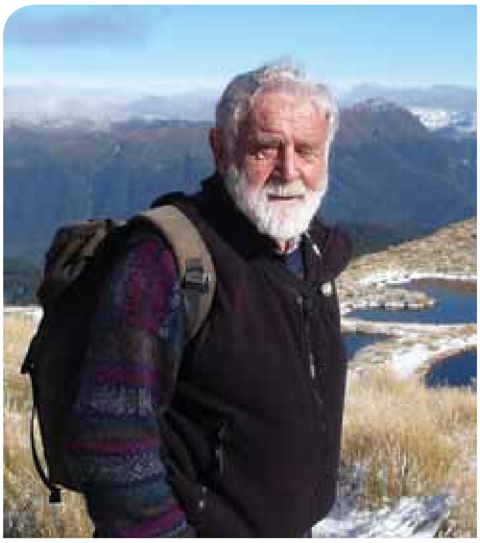
Caversham peripatus showing underside and mouthparts. *Photo: Rod Morris*.

Preface



A general acceptance of the importance of peripatus led to provision being made for the sustainability of one species as part of a highway realignment project that occurred adjacent to its habitat in Dunedin's Caversham Valley. This comprehensive review of the taxonomic status and habitat requirements of this group of invertebrates at a regional, national and global level has resulted from this mitigation process. I compliment the authors on the production of this working document, which provides an excellent basis not only for proceeding with management of peripatus through continued research at Caversham Valley, but also for obtaining overdue legal protection for this group—at least in New Zealand, but perhaps at all known locations, as is surely our formal obligation under the International Convention on Biological Diversity, to which New Zealand is a signatory. We have evidently made considerable progress since, as a member of the Otago Conservation Board and a Forest and Bird Dunedin Branch committee member, I joined ranks with several other local conservationists to prevail on the Dunedin City Council and used a seeding grant from the Branch to purchase the Caversham Valley property as a city asset for conservation purposes. The future for peripatus at this site should now be assured.

Sir Alan Mark FRSNZ, KNZM, Emeritus Professor, University of Otago—8 April 2013

Introduction

Peripatus are invertebrates that superficially resemble caterpillars. They range in length from 2 to 15 cm (Fig. 1). The name peripatus has been given to one particular genus, so they are more accurately referred to by their phylum name Onychophora (Greek for 'claw bearers'). They are also known as velvet worms and by their Māori name ngaokeoke.

In New Zealand, nine species of peripatus belonging to two genera have been described to date. However, it has been suggested that there may be 20–30 more species awaiting formal description (Pripnow & Ruhberg 2003). In 1983, the IUCN Red List of Threatened Species listed all Onychophora as Vulnerable (Wells et al. 1983). However, it currently lists only 11 species as Vulnerable, including two New Zealand species: *Peripatoides indigo* and *P. suteri* (IUCN 2012). The equivalent threat classification system in New Zealand listed *P. indigo* and *Ooperipatellus viridimaculatus* as Category I (Insufficient Information) in 1992 and 1994 (Molloy and Davis 1992; Molloy et al. 1994), respectively, while the most recent listing in 2012 included *O. nanus* (Naturally Uncommon) and *P. indigo* (Data Deficient) (Buckley et al. 2012). Once there is formal clarification of peripatus taxonomy in New Zealand, the status of these and any newly described species will need to be reviewed.

Figure 1. *Ooperipatellus* sp., Sinbad Valley, Fiordland. *Photo: Rod Morris.*

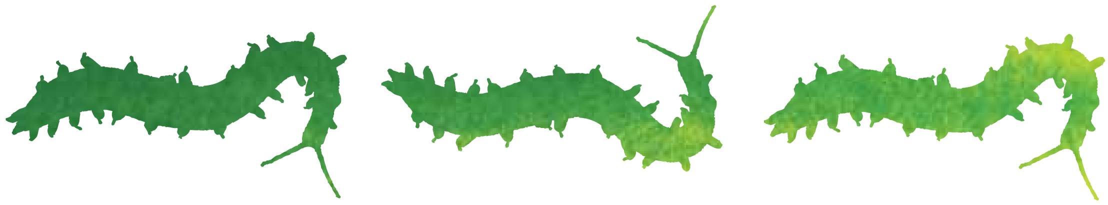
In late 2012, work began to widen and realign State Highway 1 Caversham between Barnes Drive and Lookout Point, Dunedin, which involved the clearance of a 40-m-wide strip of land (Fig. 2). The northern edge of this section of SH1 included forest in two Dunedin City Council reserves—Lookout Point Reserve (0.5 ha) and Caversham Valley Forest Reserve (3.4 ha), between which are two private properties (2.8 ha). Caversham Valley Forest Reserve was identified in the Council's District Plan as an Area of Significant Conservation Value because peripatus are found there. Although this is not an official reserve under the Reserves Act 1977, it is managed as though it is.

Figure 2. Road widening and realignment work at Caversham. *Photo: M. Wakelin.*

In developing plans for the road works, the New Zealand Transport Agency (NZTA) recognised the significance of Caversham Valley peripatus and worked with the Department of Conservation (DOC), Dunedin City Council, the University of Otago and private landowners to plan for the translocation of peripatus affected by the land clearance, along with monitoring, management and habitat enhancement of the adjacent bush area into which they were moved. The project has been an example of cooperative adaptive management, and has been very valuable for increasing awareness and advocating for the protection of peripatus.

The original aim of this document was to provide information about peripatus in the Caversham Valley, South Dunedin, to further increase awareness of this species. However, the scope was broadened to provide an overview of all peripatus species in New Zealand and to present our current knowledge of these species in a global context. It is intended that this will provide a useful resource for informing on, advocating for and stimulating interest in the management of peripatus and their habitat, whether on private or public land. It is also hoped that future management plans, not only in Dunedin but also in similar situations elsewhere in New Zealand, may be guided by the issues and concepts highlighted here.

The report begins by providing an overview of the taxonomy and distribution of peripatus across the globe, but with a particular focus on New Zealand. The biology and ecology of New Zealand species are then outlined, to improve our understanding of the species' requirements and vulnerability. In the sections that follow, the main threats to New Zealand species are discussed, followed by the types of conservation initiatives that can be carried out to help protect them. Finally, areas for further research are highlighted. Additional resources, including useful contacts, websites and publications, and funding sources, are listed in Appendix 1.



What are peripatus?

Taxonomy

Peripatus are invertebrates belonging to the phylum Onychophora, within which there are two families: Peripatidae and Peripatopsidae.

Peripatus were once referred to as a 'missing link' as they were thought to connect the heritage of segmented, legless invertebrates (such as worms) and the jointed-legged arthropods (such as insects), bearing structural characteristics of both. Worm-like features include a thin cuticle rather than a hard exoskeleton, unstriated muscles, numerous unsegmented legs, a simple excretory system and the lack of a distinct head. Insect-like features are a blood circulatory system, dorsal tube-like heart, unbranched tracheal breathing system and the form of the mouthparts. This group of invertebrates is currently placed in its own phylum within the arthropod evolutionary line.

The first peripatus was described from St Vincent, Trinidad, in 1826, and the first New Zealand species from Wellington by Hutton in 1876. Peripatus taxonomy has become confused due to species being defined based on somewhat ambiguous characteristics. For example, skin colour pattern, and the number of leg pairs, jaw denticles and spinous pads can be quite variable between some individuals within a species and yet similar between some species (Oliveira et al. 2012b). More recent genetic studies have revealed numerous complexes of cryptic species that visually appear the same. For example, what were thought to be five South African species were found to be 18 (Daniels et al. 2009; Daniels & Ruhberg 2010; Daniels 2011), one species became four in Brazil (Oliveira et al. 2011) and more than 70 previously undescribed species were discovered in Australia (Briscoe & Tait 1995). However, even with the aid of genetic techniques, defining species and genera can be an arbitrary decision. Worldwide, there are presently about 200 species described in ten genera (Oliveira et al. 2012b).

The current distribution and relationships between the Peripatopsidae can be explained by a common ancestor having been present on Gondwana. The species seen today thus evolved as each land mass split off from Gondwana—Africa c. 130 million years ago (mya), New Zealand c. 85 mya, and South America and Australia detached from either side of Antarctica c. 35 mya. Grouping of related species puts nearly all mainland Australian species together, with the exception of one which appears in a group with Tasmanian and New Zealand species (Gleeson et al. 1998). The high sea level c. 30 mya left very little, if any, of the New Zealand land mass above water. Therefore, it is possible that Onychophora dispersed to New Zealand after this event (Trewick 2000).

In New Zealand, nine species of Peripatopsidae belonging to two genera have been described, but it has been suggested that 20–30 more species may await formal description (Pripnow & Ruhberg 2003). The length of time that species have been separated can be estimated from the number of differences in their genes (although this is not always accurate). Based on this, the two genera in New Zealand are thought to have diverged from some Australian and Tasmanian genera c. 75 mya. However, divergence of the New Zealand genus *Ooperipatellus* from the Australian species *O. insignis* has been estimated at c. 42 mya (Allwood et al. 2010). Species radiation within the New Zealand genus *Peripatoides* may have occurred between 7 and 15 mya (Trewick 2000). Figure 3 shows a giant peripatus from Tasmania.

Figure 3. Giant peripatus, *Tasmanipatus barretti*, Tasmania. *Photo: Rod Morris.*

New Zealand species

Peripatoides novaezealandiae (Hutton, 1876)
Live bearing (ovoviviparous), 15 legs, up to 12 cm long; Wellington region. This species was considered widespread but is now known to be a species complex that includes at least six morphospecies from other areas (Pripnow & Ruhberg 2003), four of which (*P. aurorbis, P. kawekaensis, P. morgani* and *P. sympatrica*) have now been described (Trewick 2000; see below). Consequently, its current status is unclear (Oliveira et al. 2012b).

There are other undescribed species within the *P. novaezealandiae* complex (Tait & Briscoe 1995), and there are distinct morphs at Kapiti Island, Paengaroa, Moncton, Woodville, Mohi Bush, Boundary Stream (Pripnow & Ruhberg 2003), Dunedin, The Catlins and Piano Flat.

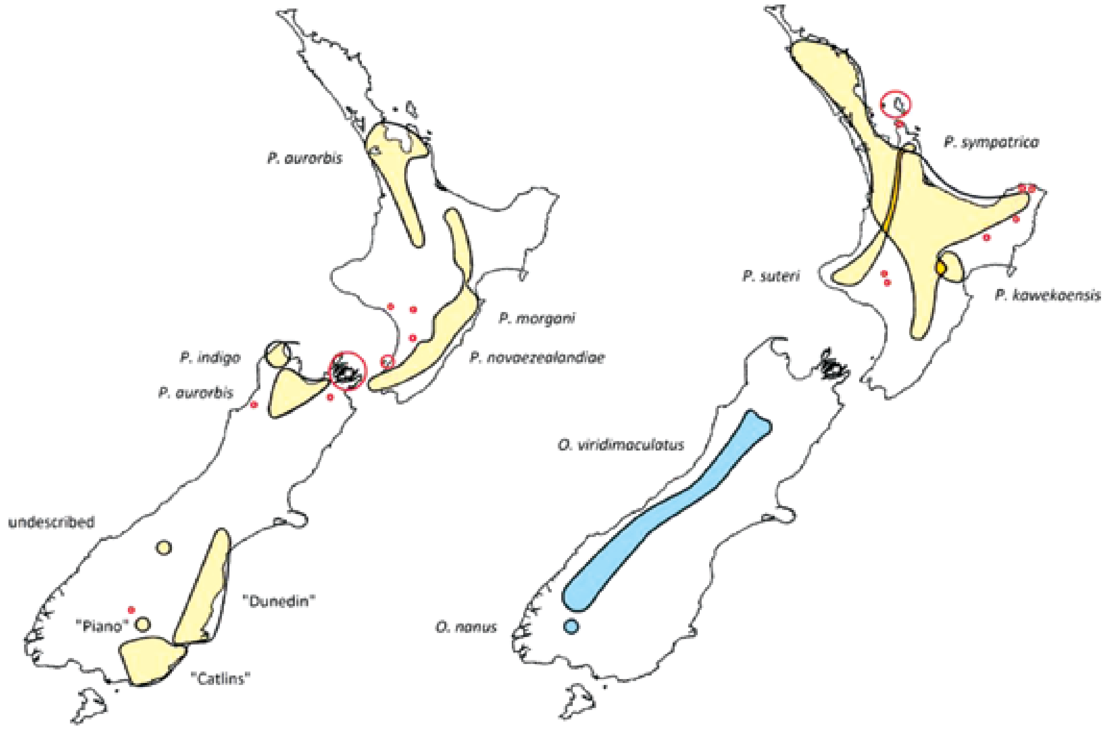


Figure 4. Distribution of New Zealand's *Peripatoides* and *Ooperipatellus* species (after Trewick 2000) Red spots and circles = additional records of uncertain species.

(Trewick 1999; Fig. 4). The Dunedin species is relatively consistent genetically from Outram to Peel Forest (Fig. 5) (Trewick 1998), and yet, some people consider specimens from Leith and Caversham Valleys (Fig. 6) to be sufficiently genetically distinct that they belong in a different genus that may have diverged from other lineages c. 95 mya, prior to the separation of Australia and New Zealand (Tait & Briscoe 1995; Gleeson 1996). The density of the Caversham Valley peripatus population is higher than is usually found elsewhere in Dunedin or New Zealand. There has also been a bright green form found in beech forest in the Aoraki/Mount Cook – Lake Ohau area (Harris 1991).

Figure 5. *Peripatoides* sp. 'Mt Peel'. *Photo: Rod Morris.*

Figure 6. *Peripatoides* sp. adult and young, Caversham Valley. *Photo: Rod Morris.*

Figure 7. *Peripatoides indigo. Photo: Rod Morris.*

Figure 8. *Ooperipatellus viridimaculatus. Photo: Rod Morris.*

Peripatoides suteri (Dendy, 1894)
Ovoviviparous; 16 legs, 9 cm long; Taranaki and Coromandel Range. Possibly a variant of *P. novaezealandiae* (Buckley et al. 2012); questionable status (Oliveira et al. 2012b). More closely related to *P. aurorbis* and undescribed South Island species than other *Peripatoides* spp. (Trewick 1998).

Peripatoides aurorbis Trewick, 1998
Ovoviviparous; Auckland, Coromandel and Nelson. More closely related to *P. suteri* and undescribed South Island species than other *Peripatoides* spp. (Trewick 1998).

Peripatoides kawekaensis Trewick, 1998
Ovoviviparous; Hawke's Bay.

Peripatoides morgani Trewick, 1998
Ovoviviparous; eastern North Island. Very close genetically to *P. novaezealandiae*; may still be in the process of speciation (Trewick 2000).

Peripatoides sympatrica Trewick, 1998
Ovoviviparous; Northland, Coromandel, Waikato, East Cape and Hawke's Bay. Shares sites with at least three other species (Trewick 1998).

Peripatoides indigo (Ruhberg, 1985)
Ovoviviparous; 14 legs, 6–7 cm long, deep blue colour (Fig. 7); Northwest Nelson.

Ooperipatellus viridimaculatus (Dendy, 1900)
Egg laying (oviparous); 14 legs, 3–5 cm long (Figs 1 & 8); western South Island in subalpine beech forest and under rocks in the alpine zone, between 300 and 1650 m above sea level. Lays eggs with ovipositor. Distinct from *O. insignis* of Australia (Tait & Briscoe 1995).

Ooperipatellus nanus (Ruhberg, 1985)
Oviparous; 13 legs; Takitimu Mountains.

An undescribed species of *Ooperipatellus* exists in the Waitakere Ranges, and on Tiritiri Matangi Island and Motuora Island.

Where are they found?

Distribution

Worldwide

As well as being considered a missing link, peripatus are often called 'living fossils' because they look remarkably similar to their marine ancestors that are seen in fossils from the Cambrian period, 500 mya (Fig. 9). More recent (c. 40 mya) amber fossils from the Baltic region and Myanmar show that they once had a wider terrestrial distribution than is seen today. Members of the family Peripatidae are currently found in southern Mexico, the Caribbean, central and northern South America, West Africa, and parts of Southeast Asia. By contrast, Peripatopsidae are found in South Africa, Chile, New Guinea, Australia and New Zealand.

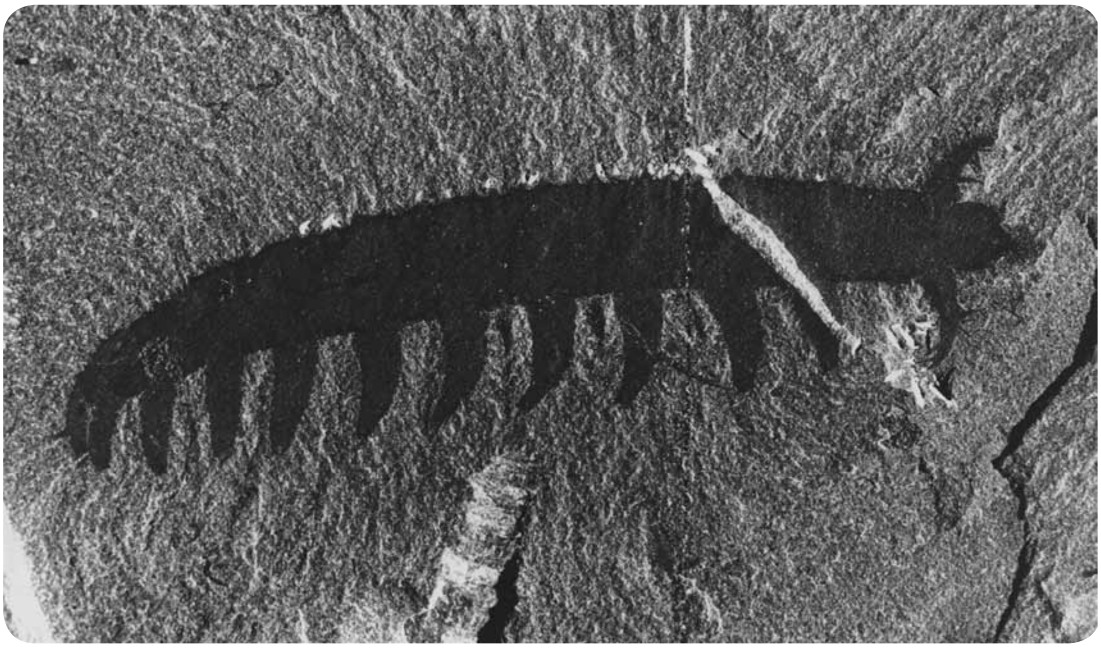


Figure 9. Fossil of *Aysheaia pedunculata,* from the Burgess Shale, British Colombia, Canada.
Courtesy of the Smithsonian Institute.

New Zealand

It is thought that the ancestor of peripatus came with the land that broke away from eastern Australia 85 mya. As the land moved and the landscape changed to become New Zealand, peripatus evolved and diverged with it. Peripatus have been found in most regions of the North Island, South Island and Stewart Island/Rakiura of New Zealand, and on many offshore islands, including 27 000-ha Great Barrier Island (Aotea Island) 16 km off the Coromandel Peninsula and 7-ha Birch Island about 20 m from the banks of the Clutha River/Mata-Au. They are not known from the Chatham or subantarctic islands, however.

Peripatus might be found patchily throughout New Zealand's main islands where the conditions are suitable—and more than one species occurs in some areas. A list of localities where peripatus have been found is given in Appendix 2.

Habitat

Peripatus are unable to close the spiracles leading to their tracheal breathing tubes, which means that moisture loss is an issue for these animals, but they can drown if immersed in water. Consequently, they are generally restricted to damp environments within and beneath logs and leaf litter. Peripatus in Dunedin were less likely to be present beneath cover objects that experienced lower humidities or extremes of relative water content (Barrett 2013). A South African species has been shown to prefer a relative humidity of c. 98% at 25.5°C (Bursell & Ewer 1950). Peripatus are found in caves elsewhere in the world; however, although there are records of peripatus from caves in Nelson and Waikato, these are thought to be occasional animals (trogloxenes) rather than permanent populations.

One study showed that an Australian species was more likely to be present in bigger, moister, more degraded logs on southeast-facing slopes that had more prey and shrub cover (Barclay et al. 2000a). The sexes were found to be evenly distributed in logs and litter, while for another species in the same area, males predominantly occurred in litter while females tended to occupy logs (Tutt et al. 2002).

In Dunedin, peripatus presence was also found to be associated with the presence of tree fuchsia (*Fuchsia excorticata*; Fig. 10) and small arachnids (< 2 cm), slightly acidic conditions, an increase in the number, size and degradation of logs, and the relative water content of cover objects, canopy density and air humidity (Barrett 2013). In an urban landscape, peripatus presence increased with the presence and area to edge ratio of forest, reduced housing density, and increased garden size. No relationship was found between peripatus presence and temperature, the amount of sun, type of cover object, the amount of short shrub cover, distance from edge and main vegetation type (Barrett 2013).

In Caversham Valley, peripatus have been found within stumps and logs of various native and exotic species (Fig. 11), and amongst deep leaf litter, bark chips and wood piles. Where tree canopy provides cover and detritus, peripatus have also been found in piles of dumped rubbish, brick and rubble, foam, rubber, plastic, and cracks

Figure 10. *Fuchsia excorticata,* Caversham Valley, Dunedin. *Photo: Rod Morris.*

Figure 11. Peripatus habitat amonst dense aluminium weed, Caversham Valley, Dunedin. *Photo: Rod Morris.*

Figure 12. Dave Randle and a trial artificial refuge, Caversham Valley, Dunedin. *Photo: Rod Morris.*

and crevices of stone walls, quarries, and rocks (Fig. 12). They tend to be found in moderate numbers within the forest, but are much more numerous around the more disturbed fringes (D. Randle, Dunedin, pers. comm.).

The habitat requirements of peripatus may be flexible, as they can also be found in 'non-typical' and apparently marginal habitat, such as logs without tree cover, in tussock grassland, beneath rocks beside a glacier and in exotic plantations (Hamer et al. 1997; Trewick 2000; Pawson et al. 2010). It is unclear, however, whether such habitat is preferred or used as a last refuge.

Biology

Few studies have been conducted on New Zealand peripatus. The following sections summarise what is currently known and provide general information about Onychophora and relevant species of Peripatopsidae.

Morphology

All Onychophora have the same general external appearance (Hamer et al. 1997), with body segments that are not visible externally, but each of which bears a pair of stumpy 'legs' with two claws. The number of segments, and thus the number of pairs of legs, varies from 14 to 44 between species, but is thought to be consistent within a species. New Zealand species have 13–16 pairs of legs. The eyes are small and sight is poor, so they mostly rely on touch, using their short antennae and sensory spines on the numerous papillae, which project from the cuticle giving it a velvety appearance. Like Arthropods (e.g. insects, spiders, centipedes), peripatus breathe through pores (spiracles) in the skin; however, they are unable to close these. Consequently, they need to inhabit a damp environment but avoid extremely wet habitats where they may drown. Humidity receptors on the body surface mediate movement towards the wet, while receptors on the antennae mediate movement towards the dry (Bursell & Ewer 1950); these receptors probably function via water evaporation. A diagram of peripatus anatomy is provided in Fig. 13.

Although species can be quite similar in appearance, their life history and physical characteristics such as body size, breeding period, method of sperm transfer, brood size, inter-moult period and habitat preference can be quite varied (Leishman & Eldridge 1990).

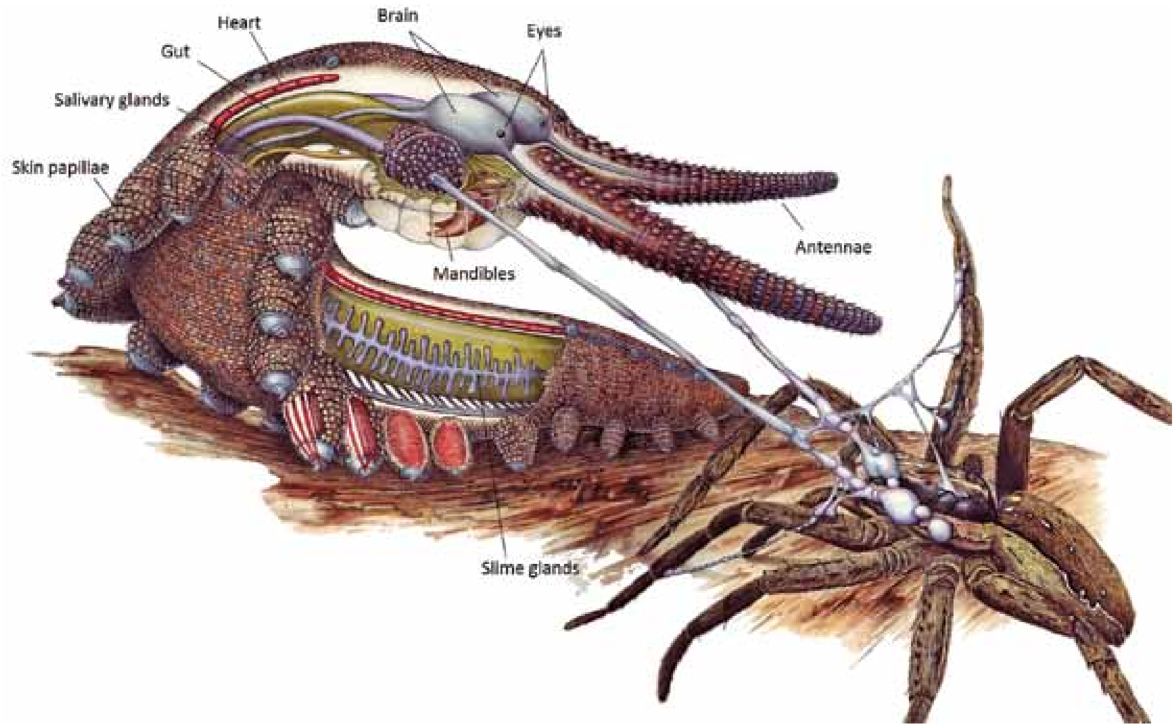


Figure 13. Anatomy of Onychophora. Image courtesy of Andrew Lack and Angela Harland, *New Zealand Geographic*.

Activity

Peripatus are relatively cautious, slow moving and nocturnal, emerging from their shelter deep within logs and leaf litter at night to prey on other invertebrates. Their victims are trapped with jets of viscous fluid that are shot from a pair of oral papillae; they are then chewed and injected with saliva before the partially digested juices are sucked out (Fig. 13). The fluid is also used to defend individuals from predators, probably making an unpleasant mouthful should attack occur. Some species in Tasmania (Bryant & Jackson 1999) and South Africa (Hamer et al. 1997) also curl into a tight ball when disturbed, but this has not been reported in New Zealand peripatus.

Dispersal in suitable habitat has been estimated at 20 m per year (Fox et al. 2004b). Females appear to carry out only limited dispersal (Daniels 2011). Males of an Australian species initially disperse to and colonise new habitat, following which they secrete a pheromone to attract females (Barclay et al. 2000b). This means that females do not need to expend as much energy or take as much risk searching for food and shelter, which may explain why they are often larger (Leishman & Eldridge 1990) and more common (Barclay et al. 2000b) than males—although this may also be due to their earlier maturation and longer lifespan (Scott & Rowell 1991; Daniels 2011). In New Zealand, logs containing single females have been found, however, which suggests that males may not always initiate dispersal (Tutt et al. 2002).

Interactions have been recorded for the Australian species *E. rowelli*, which aggregate in groups of mixed age and sex around a dominant female, and show aggression towards members of other groups (Reinhard & Rowell 2005). After dispersing from their natal sites, loose aggregations are formed that include multiple reproductive females (Daniels 2011). It is unclear whether such a social structure is normal, however. New Zealand peripatus are more commonly found as individuals or occasionally in clusters (Fig. 14), but have been observed to form nurseries, shelter in mixed age groups, and hunt and feed in groups in captivity. A notable exception is the Caversham Valley peripatus, which have been recorded in large clusters (Harris 1991) estimated at up to 2000 individuals, with only scattered individuals in between (D. Randle, pers. comm.). These colonies can be of mixed age, but some all-adult and some distinct nursery groups have been found.

Figure 14. Group of peripatus feeding, Trotters Gorge. *Photo: Rod Morris.*

Life history and reproduction

With the exception of one parthenogenic species, peripatus have both males and females. In *P. novaezealandiae*, males can be distinguished from females by the orange papillae in front and to either side of the anus (Trewick 1998), which are present before sexual maturity is reached. Males reach sexual maturity at c. 43 mg weight or 25 mm length, while females mature at a similar length but twice the weight. Males grow to a maximum length of 45 mm, while females can reach 60 mm. Larger females are more fecund but less common (Tutt et al. 2002). For peripatus generally, maturity is thought to occur at about 1 year of age and the average lifespan is c. 5–7 years (Hamer et al. 1997; Fox et al. 2004b).

Mating is rarely observed, but males may place packages of sperm (spermatophores) either internally or on the female's cuticle, from where they are absorbed. This latter mechanism is likely to occur in *P. novaezealandiae* (Tutt et al. 2002). Mating probably occurs throughout a female's life (Tutt et al. 2002), but sperm can also be stored in spermathecae for several years. Males produce sperm and females store sperm throughout the year (Tutt et al. 2002).

Females have two uteri and can have multiple embryos at different stages developing at the same time. Some species, including those of *Ooperipatellus*, lay eggs via an ovipositor located between the last pair of legs. Others, like *Peripatoides*, retain the eggs internally and give birth to live offspring. Members of the *P. novaezealandiae* group appear to be able to defer release of their embryos or to fertilise eggs using stored sperm and are iteroparous breeders (have offspring repeatedly rather than in one end-of-life event) (Pripnow & Ruhberg 2003). Gestation is thought to take c. 6 months (Sunnocks et al. 2000), while females in captivity in the absence of males gave birth after 24 months (Pripnow & Ruhberg 2003). Most females appear to give birth in November to December (Sunnucks et al. 2000). The average brood size in *P. novaezealandiae* was 12 with a maximum of 28 (Tutt et al. 2002).

The offspring resemble small, white adults (Fig. 6). They are able to fend for themselves, and moult before birth and then every few weeks throughout life. In some species, young can be sexed after 2 months (Pripnow & Ruhberg 2003). The sex ratio of offspring is thought to be close to 1:1. However, in a study involving different morphs of the *P. novaezealandiae* group that had been collected from eight sites and were being held in captivity, it was found to vary from 13 all female, to 5 all male, to 10 male : 7 female (Pripnow & Ruhberg 2003).

Threats

The IUCN Red List of Threatened Species lists two New Zealand species (*P. indigo* and *P. suteri*) as Vulnerable (IUCN 2012), while the New Zealand Threat Classification System lists *O. nanus* as Naturally Uncommon and *P. indigo* as Data Deficient (Buckley et al. 2012). Therefore, it is important that we understand the various threats to New Zealand peripatus to enable us to better manage and protect them.

The main currently identified threats to peripatus are listed below. However, it should be noted that none of these threats alone seems critical to peripatus survival, except if a species is particularly vulnerable due to a small population size and limited distribution or location.

Habitat loss

Figure 15. Remnant logs in fragmented habitat that can harbour peripatus. *Photo: M. Wakelin.*

The discontinuous distribution of some species of peripatus that is seen today may indicate that there was once a widespread population that has been reduced (Wells et al. 1983). The major cause of peripatus decline is likely to be permanent loss of habitat. Habitat destruction is continuing, largely as a result of forest clearance for development, agriculture and forestry, but also due to fire, floods and chemical spills (Wells et al. 1983; Bryant & Jackson 1999). For species of peripatus that cannot survive in plantation forest, population decline has been shown to be proportional to the percentage of habitat converted (Fox et al. 2004b). However, some species can tolerate habitat disturbance such as selective felling, mining and some fires right up to the habitat edge (Mesibov & Ruhberg 1991) (Fig. 15). Various scenarios of mixed native harvesting and plantation conversion of up to 50–60% of a forest were predicted to result in a population reduction of a maximum of 10% at some point in the next 100 years (Fox et al. 2004b).

On a finer habitat scale, peripatus require deep leaf litter and logs, which are vulnerable to disturbance or destruction by grazing stock and wild pigs and deer. Logs can require at least 45 years of decay to build large populations of peripatus (Barclay et al. 2000a). The work associated with the Caversham Valley road widening project (discussed later in this report) provides an example of efforts to mitigate the effects of habitat destruction.

Climate change

Peripatus have adapted to climatic changes over millions of years. However, in a modern, fragmented landscape, a rapid change in climate, particularly towards drier conditions, might be a problem for such humidity-dependent invertebrates; and their permanently open spiracles means that they are also likely to be prone to drowning. More frequent and extreme climatic events may also change an ecosystem's vegetation cover and habitat.

Predators

The nocturnal activity, and cryptic behaviour and colour of peripatus may help them to avoid predators such as native birds, lizards, bats and large invertebrates. The viscous fluid they produce could also make peripatus an unpalatable meal. It is generally difficult to detect soft-bodied prey in diet analyses, but peripatus have been shown to be eaten by North Island robins (*Petroica australis longipes*) and weka (*Gallirallus australis*) (Carroll 1963). If predation is a threat to peripatus populations, it would most likely be by introduced animals, such as birds or wasps and especially nocturnal hunters such as hedgehogs (*Erinaceus europaeus*) and rodents.

Collectors

Although curiosity about these animals seems to be quite high, collection and trading of peripatus represents a relatively small market and the demand is low. This is likely due to their nocturnal, secretive, slow-moving and climate-sensitive behaviour, as well as the fact that New Zealand species are smaller and less colourful than those found elsewhere. Comments on an online pet forum mentioned the difficulty in caring for New Zealand specimens, and the sale regulations and high cost of South American species. Collecting is only considered to be a major threat to small populations of peripatus (Wells et al. 1983), but demand could be satisfied by captive breeding of more common species. However, should collecting become more of a threat in the future, the legal protection of peripatus may need to be increased. Captive breeding is not seen as necessary for other species (New 1995; Hamer et al. 1997) where habitat loss is the main threat.

Disease

Peripatus persist in modified habitats and also seem to survive (if not thrive) in captivity. Therefore, they do not appear to be overly susceptible to toxins or pathogens under stress. Scratches to the skin are prone to bacterial infections but no other information on potential diseases is currently available. However, their similarities to the damp-dwelling, sensitive-skinned native frogs do suggest that there may be the potential for a chytrid-like fungus to seriously affect them.

Animal control operations

Broadcast poison operations could potentially affect peripatus. Contact with pest control toxins such as 1080 or crop and pasture sprays would probably be lethal. Since peripatus are predators, they are unlikely to come into direct contact with these chemicals. However, secondary poisoning by eating invertebrates that contain the poisons could have an impact. Although factors such as broadcast rate, probability of encounter, proportion of population affected and bait toxicity would influence the impact on peripatus, any such impact is likely to be low.

Conservation

There are three general approaches by which peripatus could be protected: legislation, reserves and management. The latter has rarely applied, however, due to our lack of knowledge about their behavioural ecology.

Legislation

In New Zealand and Australia, legislation protects those invertebrates that are listed in the relevant Acts. Being listed offers direct protection against collection or any action that may harm the species.

The Wildlife Act 1953 protects nearly all native or introduced species of vertebrate wildlife, unless the species is listed in the schedules of unprotected wildlife or game species. Protection under the Act means that it is illegal to collect, possess or keep in captivity specimens without a permit issued by DOC (permits are not required for dead specimens collected before they became protected and it is not an offence to accidentally kill a protected animal). However, invertebrates are not included in this Act unless they are declared as 'animals' and individually listed. A review in 2006 recommended that all Onychophora be included in the Act. However, none have been added to date and, therefore, New Zealand peripatus are not currently protected.

Although collectors do not seem to be a major threat to peripatus (Daniels 2011), full legal protection of all Onychophora and collection by permit only, as is the case in South Africa, would increase their protection considerably (Wells et al. 1983; Hamer et al. 1997), and would require planners and developers to consider the conservation of these species and their habitat. Listing taxa of which not enough is known may mean including some that are not threatened, but it seems reasonable to act conservatively and assume that some will surely be threatened.

Another means of protection for peripatus is via legislation for reserves, as it is illegal to remove or destroy plants or animals within reserves without specific authority (Bryant & Jackson 1999; Threatened Species Section 2005; Daniels 2011).

Photo: M. Henderson.

Reserves

The creation of reserves is currently the major means of protection for peripatus in both New Zealand and other countries (Wells et al. 1983). These are mainly in the form of national parks, forest parks and conservation parks, as well as nature, scientific, scenic, recreational and ecological reserves and covenants (see below). Reserves are not necessarily safe from development or resource exploitation—for example, the protection of cave habitat in South Africa did not prevent peripatus from being disturbed or collected (Hamer et al. 1997). However, in a reserve, the large-scale habitat such as forest canopy and small-scale habitat such as dead wood can be maintained, and habitat can also be

enhanced by fencing areas to prevent stock damage, storing old vegetation and adding logs. Pest control programmes may also be beneficial.

Some reserves might not suit peripatus due to a lack of suitable habitat. Some are disturbed and modified sites with introduced plants, which may harbour peripatus populations, but are unlikely to contain threatened species, as these tend to be less tolerant of disturbance (Hamer et al. 1997). Suitable reserves should include damp slopes with abundant logs and incorporate 10-m-wide riparian strips as buffers and corridors (Bryant & Jackson 1999; Threatened Species Section 2005; Daniels 2011). It is important that there are sufficient links in the habitat to enable dispersing young to maintain genetic flow between populations (Daniels 2011). It is also important to take into account species' distributions and behavioural differences (Hamer et al. 1997). Prioritisation of areas that are species rich and endemic hotspots (perhaps Coromandel, Waikato, Hawke's Bay) will maximise the benefit. Therefore, this process requires accurate and up-to-date distributional knowledge (Hamer et al. 1997).

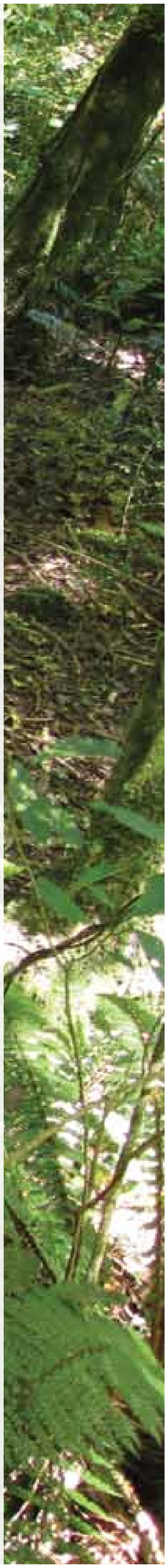
Peripatus can also benefit from the management of private land, by restricting new plantations, advising on the best practice for existing logging operations and implementing a fire management regime (Bryant & Jackson 1999; Threatened Species Section 2005; Daniels 2011). The forestry industry in Tasmania protected 'wildlife priority areas' of prime Onychophora habitat from wood production and fire (Mesibov & Ruhberg 1991), and managed native forest conversion, guided by a population viability assessment of peripatus (Fox et al. 2004a). Ecological enhancement and reserve creation can be used to offset or mitigate the impact of activities and to gain planning approval.

Covenants

Private land can be sold, gifted or exchanged to create reserves. However, land that is retained in private ownership can also have formal reserve protection. Commonly, this is through the creation of covenants, which is a means of legal protection that is recorded on the title usually in perpetuity and that is binding on future owners. A covenant is an agreement between the landowner and an agency such as the Queen Elizabeth II (QEII) National Trust, DOC, or the local city or regional council. Their production can be assisted through rates relief, and special grants for survey, legal and fencing costs, as well as management advice. Other possible habitat protection arrangements with DOC include a Protected Private Land Agreement, which is recorded on the title by gazette notice, and a more interim DOC Management Agreement under section 29 of the Conservation Act, which is not recorded on the title and not binding on future owners. The edges of subdivisions can also have voluntary protection through DOC or the council as 'Esplanade Reserves' under the Reserves Act. Owners of Māori land can place areas under Ngā Whenua Rāhui kawenata.

Peripatus reserves

In the past, the production of reserves has been justified by the presence of peripatus, even if they have not been specifically created for peripatus. For example, in 2006, 12-year-old Kahn Coleman discovered peripatus in a patch of bush near Wimbledon in the Tararua district. He then worked with the landowner to have the land protected with a QEII covenant.



The Caversham Valley Forest Reserve was purchased in 1994 by Dunedin City Council, using a seeding grant from the Royal Forest and Bird Protection Society's Dunedin Branch, with the main purpose of protecting the peripatus and the forest habitat necessary for its survival (but also with other community goals, particularly indigenous forest restoration at the southern end of Dunedin's Town Belt). Although this is not an official reserve under the Reserves Act 1977, it is managed as though it is.

Management

Work to enhance the habitat for peripatus in Caversham Valley, Dunedin, has been ongoing over three decades. A 1996 management plan for the Caversham Valley Forest Reserve (Dunedin City Council 1996) included invertebrate monitoring and forest restoration, which involved planting locally sourced seedlings, creating native forest corridors for invertebrates, and retaining branches, logs and some large exotic trees to facilitate regeneration of native plants and habitat for invertebrates. In 1999, a 'development plan for the restoration and enhancement of the habitat' for peripatus was produced. Following this, small logs were cut into 1–1.5-m lengths, large trees were felled for firewood, logs were chipped or removed, and areas were planted and weeded.

Recommendations informed by that work are currently in preparation (D. Randle, pers. comm.). While the actions may be specific to the Caversham Valley site, the practices and techniques used might be relevant to other areas. Therefore, these are outlined below.


Tree fuchsia. *Photo: DOC.*

Revegetating

At the start of a revegetation project, consideration should be given to any requirements for vehicular (or other) access, storm water disposal and natural water courses. As much as possible, all inorganic rubbish should be removed. Planting should spread outwards from existing forest patches or sheltered areas, with an aim of connecting fragments, and increasing the forest to edge ratio and canopy density. Fast-growing or colonising species such as tree fuchsia and tree lucerne should be used. These can also act as a food source for native birds such as kererū which, in turn, will promote revegetation through natural seed dispersal. Tree fuchsia was found to be an important habitat for peripatus in Dunedin (Barrett 2013). Plants that produce shallow, dry leaf litter or smothering vines should be avoided. When working in an area of established vegetation, it is important that there is no significant disturbance and no large trees felled. Any fallen trees should remain in the area, with suspended fallen trees made safe by undercutting (to bring the logs down to the ground). Regeneration will be accelerated if light wells are planted.

Weed control

Weed control may be needed in some areas to help plantings to establish. However, the use of broadcast sprays should be avoided, and woody noxious plants should be base cut and stump poisoned. Mulches and other organic materials that could potentially act as peripatus habitat should be left on site. In areas with no subcanopy, ground weeds such as aluminium plant should be left to retain moisture in the forest floor. Some plants such as blackberry, gorse, broom and grasses will require only short-term control, as the plantings will eventually out-compete them. Where a native subcanopy exists, large trees should only be removed a few at a time, to allow succession to occur.

Provision of logs

Prior to revegetation, as many logs as practical should be distributed throughout the area to provide habitat for peripatus and their food. Since peripatus show no 'edge effect', suitable logs can also be placed up to the edge of the area. Logs from a variety of different plant species can be used to provide continuity of invertebrate habitat.

Peripatoides novaezealandiae. Photo: D. Veitch.

It can take many years for logs to decay sufficiently to provide habitat suitable for peripatus. Therefore, interim shelter and forage habitat is also required. Coarse pine bark chips can be piled to a height of 150 mm or more around potential logs, to provide both shelter and forage habitat within 2 years. This habitat can then be further enhanced by a tree canopy, which will supply both shade and organic material. Logs can also be treated to accelerate their decomposition (and thus make the conditions more suitable for peripatus). Such treatments include the removal of bark, and cutting the upper log surface to flatten it (so water can collect) and cutting down into the log to allow water to penetrate. The introduction of fungal spores to the damaged areas of logs will also accelerate fungal decomposition.

Searching and monitoring

It is notoriously difficult to survey peripatus populations (Hamer et al. 1997). Marking individuals for monitoring does not seem possible as the skin is shed (and eaten) every few weeks. Searching generally involves focusing on likely locations that contain their preferred habitat and then turning over and breaking apart rotting logs. However, this not only disturbs individuals, but can also destroy their habitat. Even careful inspection appears to alter the microhabitat such that any individuals present will have relocated upon subsequent inspections (Harris 1991). Therefore, monitoring via repeat searches would clearly be unreliable.

The search technique could potentially be refined by using any available information on peripatus behaviour, such as looking for them on humid nights in summer. Peripatus have been caught in pit fall traps, on tree trunks 1.5 m above ground, using trunk traps (Moeed & Meads 1983), in foam sleeves used for lizards (Bell 2009) and in wētā apartments (Trewick & Morgan-Richards 2000). However, capture rates have been too low for any of these to represent viable survey methods. Peripatus' evident tolerance of artificial substrates suggests that the use of artificial cover objects could be a feasible low-impact and non-invasive monitoring approach. This concept was tested by D. Randle in the Caversham Valley: black plastic bags with holes in the bottom were partially filled with decaying vegetative material and folded over at the top; these were then placed on the ground next to possible peripatus shelter. Peripatus were found underneath and inside these bags within months where site conditions and decay rates were favourable.

Since peripatus are generalist predators whose prey tends to be reasonably abundant, there is no obvious lure that could be used to increase trapping success or cover occupancy. However, since pheromones may be used in dispersal (Barclay et al. 2000b) and mating (Trewick 2000) in some species, the use of pheromone traps could be successful and is worthy of investigation in the future—although the crural glands that secrete pheremones are not present in *Peripatoides* species.

Research that includes an assessment of available search and monitoring techniques is currently in progress for the Caversham Valley species (D. Randle and R. MacGibbon, Opus, Hamilton, pers. comm.).

Captivity

A website for exotic pets suggests that peripatus can be kept in a soil-filled container with holes in the bottom, which is stood in a tray of water to keep the substrate damp and cool. Bark and sphagnum moss can be placed on top of the soil to provide shelter. The ideal temperature for peripatus is between 16°C and 20°C. It is recommended that they are fed a couple of times per week with small, live crickets or hoppers, and that offspring are housed in a separate container. Keeping and breeding peripatus in captivity is considered difficult, however, due to their sensitivity, and the trade of New Zealand species (fortunately) seems to be hampered by their care requirements.

Adult *P. novaezealandiae* from six North Island sites have been successfully held in captivity for up to 24 months (Pripnow & Ruhberg 2003). In this study, two to five adults were housed on layers of moist tissue and compressed turf in special containers with perforated lids, and were disturbed as little as possible. Some individuals produced offspring while in captivity, which must have involved fertilisation using stored sperm from matings prior to capture, as not all females were kept with males. Most peripatus stop producing young after 9 months in captivity, which suggests that it is difficult to provide suitable conditions for mating. Therefore, captive breeding is not likely to be a viable option for the purpose of maintaining a long-term, self-sustaining population.

Translocations

Since it is possible to capture peripatus and maintain them in captivity, it seems plausible that they could also survive being moved into new areas of suitable habitat. If such a move was successful, then their ability to produce offspring from stored sperm would mean that a new population could be established. In the Galapagos Islands, peripatus were accidentally introduced to Santa Cruz via a shipment of bananas from South America and subsequently spread throughout the whole 98 000 ha island over a period of 20 years.

Before any translocations are carried out, the specific habitat needs of the target species should be considered, along with the genetic consequences of the number and diversity of individuals and the distance over which they are moved. Translocations to areas outside a population's known range should not be considered until their taxonomy is clarified.

A translocation and monitoring plan was prepared for the Caversham Valley peripatus when road widening prompted their removal from a 40-m-wide strip and their release into the adjoining bush (MacGibbon 2011).

Peripatoides novaezealandiae. Photo: D. Gleeson.

Future research

There are four main obstacles to improving our knowledge of Onychophora (New 1995):

1. A lack of consistent features for identifying species or even genera
2. Low population densities, which makes sampling them difficult
3. Their nocturnal and light-avoiding behaviour and susceptibility to desiccation, which makes studying them difficult
4. A lack of knowledge about the influence of weather and seasonal and changes on the activity of individuals

To secure the survival of onychophorans, research into their taxonomy, ecology and behaviour is a high priority (Pripnow & Ruhberg 2003). Such research needs to include mapping their distribution, assessing population trends, investigating rates of decline and the reasons for them, and determining suitable monitoring (Daniels 2011), habitat management (Wells et al. 1983; New 1995; Hamer et al. 1997; McGuinness 2001) and captive breeding techniques. The particularly dense population of peripatus in Caversham Valley, Dunedin, combined with an excellent zoology department at the nearby University of Otago, provides an excellent opportunity for research into peripatus ecology and management techniques (such as translocation, monitoring, habitat restoration, artificial refugia and pheromone traps).

Although species of peripatus appear very similar physically, they have high genetic diversity. Species of Peripatoides are more diverse than some insects (Trewick 2000), and two populations of an Australian species that were separated by less than 10 km were found to have genetic divergence as great as that seen between a bee and a fly (Fox et al. 2004b). This suggests that the relationship between morphology, genetics and taxonomy for peripatus might not be conventional. International research on Peripatidae has highlighted some morphological, molecular and chromosomal techniques for taxonomic and phylogenetic studies that might be useful for people studying New Zealand's Peripatopsidae (Oliveira et al. 2012a). Although taxonomic opinions can vary, resulting in the 'lumping' or 'splitting' of species groups, these tend to resolve into stable species descriptions over time. In New Zealand, the current nine described species need much more attention to determine how many species really are present, and this needs to be resolved before any decisions can be made on the management of species.

Some research into the taxonomy of onychophorans is currently underway. Emily Koot, a Master's student at Massey University, is investigating the genetics of all New Zealand Peripatoides species, and further work on approximately seven potential species belonging to the North Island *P. novaezealandiae* complex is planned in the next few years (H. Ruhberg, University of Hamburg, and S. Trewick, Massey University, pers. comm.). Work is also underway to sequence the genome of an Australian species as part of the 'Genome 10k' project (Georg Mayer, Leipzig University), which should help to place onychophoran genetics into a wider context.

Once the taxonomy of the Onychophora becomes clearer, research will be needed on the biology of each species to determine differences in their distributions, habitat requirements, population dynamics and threats. It is of vital importance that as much detail be recorded as possible, as the significance of any such information may only become apparent later. Research on habitat selection and distribution (Barrett 2013) and translocation and monitoring (D. Randle and R. MacGibbon, pers. comm.) has been carried out in Dunedin.

Since conservation requires the commitment of the general public and local communities, it would also be helpful to investigate the best methods for getting people educated and involved in peripatus conservation (Daniels 2011). Although there is no particular mention of peripatus in Māori lore and they are not included as a taonga species in the Ngāi Tahu Deed of Settlement, any work with peripatus also needs to recognise the mana whenua of iwi.

Future protection—management, conservation and recovery planning

The objective of management, conservation and recovery would be to maintain and restore viable populations of peripatus across their natural range, and to maintain their genetic diversity. Unfortunately, the level of knowledge that would be required for recovery planning is not currently available for New Zealand peripatus. However, the likelihood of peripatus continuing to survive is increased by the fact that fertilisation can occur years after mating, they persist in modified, disturbed and marginal habitats, and that one-third of New Zealand is protected in reserves.

There are three key requirements for peripatus protection:

1. Formal legal protection (of current species)
2. Habitat protection—reserves and/or covenants
3. Completion of taxonomic work to identify species

This list is really a continuous cycle, as the identification of new species as a result of item 3 will feed back into item 1.

There also need to be contingency plans against threats to the short-term safety of high-risk peripatus species, and advocacy plans to raise community awareness and support for peripatus conservation.

Protecting peripatus by reserving their habitat would see them become 'umbrella species', whereby the protection of their habitat would also benefit many less-conspicuous animals that have similar environmental requirements (Pripnow & Ruhberg 2003). They may also be seen as 'flagship species' that help to raise awareness of broad issues affecting invertebrate conservation.

Acknowledgements

The following people were involved in and assisted with preparing this report: David Agnew, Michael Wakelin, Dave Randle, Rod Morris, Dolina Lee, Hoani Langsbury, Janet Ledingham, Beatrice Lee, Sir Alan Mark, Dan Barrett, Steve Trewick, Hilke Ruhberg. The funding provided by the New Zealand Transport Agency to produce this document, and the assistance provided by Simon Underwood in particular, is greatly appreciated.

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Glossary

Aluminium plant—*Lamium galeobdolon* 'variegatum' (also known as artillery plant and *Galeobdolon luteum* and *Galeobdolon argentatum*)

Arthropoda—The phylum of jointed-legged invertebrate animals such as crustaceans, insects, spiders and millipedes.

Cuticle—The tough external exoskeleton of invertebrates.

Divergence—The evolution of dissimilar features in descendants of a common ancestor.

Exoskeleton—The tough outer covering of arthropods such as insects and crustaceans.

Gondwana—The supercontinent that broke apart to form present-day southern hemisphere lands.

Invertebrates—Animals that do not have an internal bony skeleton.

Iteroparous—Animals that are capable of breeding more than once during their lifetime.

Kererū—New Zealand pigeon, *Hemiphaga novaeseelandiae*

Morphology—The physical form and structure of animals.

Morphospecies—Species or species groups that can be distinguished by their appearance but have not yet been formally described.

Ngaokeoke—The Māori name for peripatus, which means 'to crawl'.

Onychophora—The phylum to which all peripatus belong.

Oviparous—Animals that lay eggs.

Ovipositor—A tube through which eggs are laid.

Ovoviviparous—Animals that retain the eggs inside the female until after hatching and then give birth to live young.

Papillae—Small lumps in the skin that have specialised functions.

Parthenogenic—A form of asexual reproduction whereby an embryo is produced in the absence of fertilisation.

Peripatidae—The more northerly distributed of the two onychophoran families.

Peripatopsidae—The more southerly distributed of the two onychophoran families.

Phylogenetic—The evolutionary relationships in the development of an organism.

Sympatric—Species that are found in the same geographical area.

Spermathecae—Sacs in which sperm from another individual are stored.

Spiracle—The external opening of the respiratory system in the cuticle of invertebrates.

Tracheae—The main air tubes that make up the invertebrate respiratory system.

Tree fuchsia—kotukutuku, *Fuchsia excorticata*.

Tree lucerne—tagasaste, *Chamaecytisus palmensis*

Appendix 1

Additional resources

A1.1 Contacts

Key agencies

Department of Conservation
77 Stuart Street, Dunedin 9016
Phone: 03 477 0677
www.doc.govt.nz

Dunedin City Council
50 The Octagon, PO Box 5045, Dunedin 9058
Phone: 03 477 4000
www.dunedin.govt.nz

Otago Museum
419 Great King Street, Dunedin 9016
Phone: 03 474 7474
www.otagomuseum.govt.nz

Otago University
547 Castle Street, Dunedin 9016
Phone: 03 479 1100
www.otago.ac.nz

Forest and Bird Society, Dunedin Branch
PO Box 6230, Dunedin 9054
www.forestandbird.org.nz

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A1.2 Websites and publications

General information on peripatus

www.onychophora.com/

General information on New Zealand peripatus

www.teara.govt.nz/en/peripatus/1
www.landcareresearch.co.nz/science/plants-animals-fungi/animals/invertebrates/systematics/onchyphora [sic]
www.peripatus.gen.nz/Taxa/Arthropoda/Onychophora.html
http://evolves.massey.ac.nz/peripatus.htm
New Zealand Geographic, Issue 46, April–June 2000

Checklist of described species

www.pensoft.net/journals/zookeys/article/3463/a-world-checklist-of-onychophora-velvet-worms-with-notes-on-nomenclature-and-status-of-names

Extensive bibliography

www.onychophora.com/
www.landcareresearch.co.nz/science/portfolios/defining-land-biota/invertebrates/systematics/onchyphora [sic]
research.calacademy.org/redirect?url=http://researcharchive.calacademy.org/research/izg/izgresearch.htm

A1.3 Potential funding sources

DOC
Oversees Biodiversity Condition Fund
Biodiversity Advice Fund
Nature Heritage Fund
Nga Whenua Rahui
For more information, see http://www.doc.govt.nz/getting-involved/volunteer-join-or-start-a-project/start-or-fund-a-project/

Ministry for the Environment
Community Environment Fund (replaces the Sustainable Management Fund)

QEII Trust
Covenants: www.openspace.org.nz/Site/Home/default.aspx

Lotteries Environment and Heritage grants
www.communitymatters.govt.nz/Funding-and-grants---Lottery-grants---Lottery-Environment-and-Heritage

Fish and Game Council
NZ Game Bird Habitat Trust
www.fishandgame.org.nz/new-zealand-game-bird-habitat-trust

World Wildlife Fund
Habitat Protection Fund
Conservation Innovation Fund
Environmental Education Action Fund
www.wwf.org.nz/what_we_do/community_funding/

Otago Museum
Linneaus Taxonomy Fellowship—for studying the taxonomy of Otago organisms

Dunedin City Council
Biodiversity Fund
www.dunedin.govt.nz/services/dcc-funding/biodiversity-funding

Transpower Community Care Fund
www.transpower.co.nz/community-initiatives/communitycare-fund

AirNZ Environmental Trust
Kids Restore NZ
airnzenvironmenttrust.org.nz

ASB Community Trust
www.asbcommunitytrust.org.nz/

Honda TreeFund
www.honda.co.nz/environment/treefund)

Pacific Development and Conservation Trust
www.dia.govt.nz/diawebsite.nsf/wpg_URL/Services-Trust-&-Fellowship-Grants-The-Pacific-Development-and-Conservation-Trust?OpenDocument

Note: Additional funding is also provided by groups that individuals may need to apply to, such as the New Zealand Native Forests Restoration Trust, New Zealand Landcare Trust and New Zealand Ecological Restoration Network.

Appendix 2

Localities at which peripatus have been found

Key to probable species present:

1. *Perpatoides sympatrica*
2. *P. aurorbis*
3. *P. suteri*
4. *P. morgani*
5. *P. indigo*
6. *P. kawekaensis*
7. *P. novaezealandiae*
8. *Perpatoides* “Dunedin”
9. *Perpatoides* “Catlins”
10. *Perpatoides* “Piano”
11. *Perpatoides* sp.
12. *Ooperipatellus nanus*
13. *O. viridimaculatus*
14. *Ooperipatellus* sp.

Northland: Kaitaia Walkway (1); Mangamuka (1); Russell Forest (1); Herekino (1); Puketi (1); Ngaiotonga (1); Trounson Kauri Park (1); Waima (1); Waipoua Forest (1); Bream Head (1); Hen & Chickens Islands (1).

Auckland: Leigh (1); Mt Auckland (1); Kawau Island (1); Dome Valley (1); Tiritiri Matangi Island (1, 2, 14); Titirangi (1, 2); Kauri Park, Birkenhead (1, 2); Rangitoto Island (2); Motuora Island (14); Lynfield (1, 2); Mt William (1, 2); Waitakeres (1, 2, 14); Bethells Beach (1, 2); Huia (2).

Coromandel: Great Barrier Island (2); Little Barrier Island (2); Mt Moehau (2); Coromandel Range (2); Wentworth River gorge (2); Titan Rocks (2); Waiwawa (2, 3); Kauaeranga Valley (1); Forthbranch (1); Kirikiri Saddle (1, 2).

Waikato: Raglan (1, 2); Pirongia (1); Silverhope (1); Braithwaite Park (1), Hamilton (1); Hammond Park (1), Hamilton (1); Kakaho (1); Otorohanga (1); Te Kauri Park (1); Waitomo Caves (1); Mt Te Aroha (1).

Bay of Plenty: Mamakus (1); Rotorua area (1); Okere Falls, Rotorua (1); Lake Tikitapu (4); Cape Runaway (1); Hicks Bay (1); Papatea (1).

East Cape: East Cape (1); Mt Hikurangi (1); Mangatutara (1); Pohutu (1); Te Koau (1); Kopuapounamu, Ureweras (1); Waikaremoana (1).

Hawke’s Bay: Opepe (1); Balls Clearing (1, 6); Boundary Stream (1); Hutchinsons (6); Mohi Bush (4); Oueroa (4); Tangoio (6); Rangataiki (4, 6); Norsewood (1, 4); Dannevirke (Ngapaeruru) (7).

Taupo: Kaimanawa Ranges (1); Pureora Forest (1); Lake Rotopounamu (1); Opepe Bush (1); Horopito (1); Whakapapa (1, 3); Ohakune (1); Rangataua (1); Rangitikei (1).

Taranaki: Mt Messenger (3, 7); Mt Taranaki (3, 7); Dawson Falls (3, 7); New Plymouth area (3, 7); Lake Rotokare (3, 7).

Wanganui: Gordon’s Bush, Wanganui (1); Kitchener Park, Feilding (1).

Rangateiki: Monckton (4); Paengaroa (1, 7); Ruahine Range (1, 7); Hunterville (1); Bruce Park, Marton (1).

Wellington: Miller (7); Bideford (4, 7); Perry's (7); Kahuterawa Valley, Linton (7); Waiopehu Reserve, Levin (7); Kapiti Island (7); Waikanae (7); Nga Manu (7); Mana Island (7); Akatarawera (7); Transmission Gully (7); Porirua (7); Silverstream (7); Keith George Park (7); Melling (7); Orongorongo Valley (7); Days Bay (7); Khandallah (7); Ngaio (7); Otari (7); Zealandia (7); Horokiwi Valley (7); Karori (7); Gollans Valley (7).

Wairarapa: Woodville Gorge (7); Pahiatua (Mt Bruce) (7); Wimbledon (7); Waiohine (7); Carterton (7); Gladstone (7); Turanganui River (7).

Marlborough Sounds: Titirangi Bay (2); Stephens Island (2); D'Urville Island (2); Pickersgill Island (2); Maud Island (2); Arapawa Island (2).

Marlborough: Port Underwood Saddle (2); Onamalutu Scenic Reserve (2).

Nelson: Pelorus Bridge (2); Dun Track (2); Matai Valley (2); Twin Forks Cave, Patarau (5); Aorere Valley (5); Perry Saddle Hut, Heaphy Track (5); Kahurangi National Park (5); Harwoods Hole (2); Canaan (2); Pyramid (2); Cobb (2); Mt Arthur tableland (2); Gordons Knob (2); Owen Valley (2); Lake Rotoroa (2); Lake Rotoiti (2).

Buller: Buller Gorge (2); Shenandoah Saddle (13); Mt Misery (13); Victoria Forest Park (13).

West Coast: Duffy Creek Saddle (13); Lewis Pass (13); Hope River (13); Callaghans Ridge, Ahaura (13); Charming Creek, Seddonville (13); Denniston Plateau (13); Fox Glacier (13); Haast (13).

Canterbury: Lake Sumner (13); Arthur's Pass (13); Rocky Ridge, Geraldine (8); Kakahu Bush (8); Peel Forest (8); Gunns Bush, Waimate (8).

Otago: Aoraki/Mt Cook – Lake Ohau area (11, 13); Te Anau (13); Earnslaw Burn (?7); Danseys Pass (8); Kakanui Mountains (8); Birch Island (9); Black Gully (9); Blue Mountains (9); Black Umbrella Range (10); Balclutha (9); Kaka Point Reserve (9); Waikaia Forest (10); Nevis Valley (10); Piano Flat (10).

Dunedin: Trotters Gorge (8); Herbert Forest (8); The Silverpeaks (8); Truby King Memorial Park Seacliff (8); Blueskin Bay (8); Grahams Bush (8); Leith Valley (8); Queens Drive Town Belt (8); Dunedin Botanic Garden (8); Caversham Valley (8); Frasers Gully (8); Portobello (8); Boulder Beach (8); Andersons Bay (8); Tomahawk Lagoon (8); Saddle Hill (8); Whare Flat (8); Maungatua (8); Waipori Falls (8); Outram (8); Taieri Mouth (9); Matai Falls (9).

Southland: Mores Reserve, Riverton (14); Haldane (9); Hokonui (9); Takitimu Mountains (12).

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Kaunihera-a-rohe o Otepoti

Te Rūnanga o NGĀI TAHU

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