Parasitoids and predators of the endemic defoliator *Pseudocoremia suavis* (Butler) (Lepidoptera: Geometridae: Ennominae)

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Abstract

Pseudocoremia suavis is an endemic looper with a history of damaging outbreaks in exotic plantation forests in New Zealand. Little is known of the natural enemies of this pest, or what role they might play in the regulation of populations. Here we compile a list of parasitoids and predators of this species, including the results of recent collections of larval parasitoids at Eyrewell Forest, a pine plantation in North Canterbury. Thirteen primary parasitoids, two hyperparasitoids and 11 predators are recorded. The dominant parasitoid reared from larval collections made at Eyrewell Forest in this study was *Aleiodes declanae*. This species was also dominant during *P. suavis* outbreaks at Eyrewell Forest during the 1950s and 1960s, along with the pupal parasitoids *Aucklandella conspirata, A. pyrastis*, and *Zealachertus longus*. Previously unpublished information on the biology of the parasitoids and predators gathered during this study and during previous outbreaks of *P. suavis* is included.

Keywords: Hymenoptera, hyperparasitoid, natural enemy, plantation forest.

Introduction

The endemic forest looper *Pseudocoremia suavis* (Butler) (Lepidoptera: Geometridae: Ennominae), previously known as *Selidosema suavis* (Butler), is common throughout New Zealand. Its larvae are polyphagous defoliators of a wide range of native and exotic trees and shrubs, including *Nothofagus* spp., podocarps, and exotic conifers (Zondag 1956, Dugdale 1958). Both adults and larvae are present throughout the year (Zondag 1956). Two or three generations of *P. suavis* occur per year, and reports vary as to whether or not these are well synchronised (Kay 1982, Berndt *et al*. 2004). A recent pheromone analysis suggests that *P. suavis* may include several subspecies, but these appear to be similar in terms of seasonal phenology and susceptibility to parasitism (Gibb *et al*. 2006).

Serious outbreaks of *P. suavis* have occurred in plantations of *Pinus* spp. in Canterbury during the 1950s and 1960s (White 1974), and Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) in the central North Island in the 1970s (Kay 1982, 1983). It is not known whether similar outbreaks have occurred in native forests. According to a study of the central North Island outbreaks, population growth is triggered by low rainfall in months when eggs and young larvae are present (Kay 1982, 1983). This low rainfall may reduce rain-induced mortality of eggs or young larvae, or reduce disease spread (Kay 1982). When these weather conditions occur on trees under stress, from poor silviculture for example, populations can reach outbreak levels (Kay 1983). Another study, based on the outbreaks of *P. suavis* in Canterbury, also proposed that outbreaks occur when trees are stressed (e.g., in periods of drought) which increases the amount of nitrogen available to young larvae, thus increasing survival (White 1974).

Little is known about the natural enemy complex attacking *P. suavis,* or its role in the population dynamics of this pest. Alma (1977) stated that *P. suavis* populations are usually kept in balance by parasitoids, predators and pathogens, but provided no supporting evidence. Previous records list six parasitoids (Gauld 1980, Valentine & Walker 1991, van Achterberg *et al*. 2004) and eight predators (Zondag 1956) of *P. suavis*. A polyhedral viral disease and a fungal disease caused the collapse of outbreak populations after

3-4 epidemic generations during the Canterbury outbreaks (Dugdale 1964). Most information on natural enemies comes from extensive studies in exotic plantation forests (Zondag 1956, White 1974, Kay 1983, Berndt *et al*. 2004). No studies have been published of natural enemies of *P. suavis* in its native habitat.

Here we present an updated and annotated list of parasitoids and predators of *P. suavis*. This includes new information from recent collections from a non-outbreak *P. suavis* population and previously unpublished biological observations made during the outbreaks by entomologists from the Forest Research Institute (now Scion).

Materials and Methods

Pseudocoremia suavis larvae were collected between 28 November 2002 and 12 March 2003 from Eyrewell Forest, a 7000 ha pine plantation in North Canterbury. Sampling was conducted over the summer months because larvae were rare in the field at other times although they were reported to be present year-round during outbreaks (Berndt *et al*. 2004, and unpublished data). Eyrewell Forest was one of two plantations in Canterbury to suffer *P. suavis* outbreaks in the 1950s and 1960s (White 1974). Lepidoptera larvae were beaten from young and mature pine (*Pinus radiata* D.Don) (1280 and 87 samples respectively), kanuka (*Kunzea ericoides* Burgan) (243 samples) and gorse (*Ulex europaeus* L.) (85 samples) within the plantation, as described in Berndt *et al*. (2004). Larvae were identified on collection, and the identification checked throughout larval development, by L. A. Berndt using diagrams and descriptions in Anon. (1959), and specimens previously identified by W. Faulds (Ensis). Larval identifications were checked against those of adults moths that emerged, specimens of which were identified by J. S. Dugdale. Larvae were reared individually to completion in pottles on foliage of the host plant from which they were collected. Parasitoids were sorted to species by L. A. Berndt, vouchers were identified by J. A. Berry, and specimens were deposited in the National Forest Insect Collection (FRNZ, housed at Scion, Rotorua). Egg and pupal stages of *P. suavis* were too rare in the field to be sampled, so that only larval parasitoids could be assessed. Disease was not assessed in larvae collected in this study, but no virulent diseases were found in three summer seasons of collecting and rearing *P. suavis* in the laboratory (Berndt *et al*. 2004).

The FRNZ collection was searched for parasitoids reared from *P. suavis*. This collection was established as part of the Forest Biology Survey Lepidoptera sampling programme (1956 – 1966), in which defoliating larvae from exotic forests (mostly of *Pinus radiata* and *Pseudotsuga menziesii*) throughout New Zealand were collected and reared. Most of the specimens collected at this time were identified by W. Faulds. The collection has been added to ever since and is a comprehensive collection of insects of New Zealand's native and exotic forests. Additional information on the identity and biology of *P. suavis* parasitoids and predators was obtained from unpublished reports (Scion/Forest Research Institute File 50/2/5, *Selidosema suavis*, correspondence for the period 18 Dec 1951-12 Mar 1954, and for the period 14 Nov 1954-31 Dec 1982, hereafter referred to as FRI files), other references, and personal communications as specified. The New Zealand Arthropod Collection (NZAC) was also searched for parasitoids of *P. suavis*.

Results and Discussion

Parasitoids

A total of 391 Lepidoptera larvae from 10 identified species were collected in beating samples in Eyrewell Forest during the 2002-03 season (Table 1). One hundred and thirty four larvae were identified as *P. suavis*, and of these, 105 were successfully reared to either parasitoid or adult. The overall parasitism rate of *P. suavis* was 12.4%, and three species of larval parasitoid were reared from these larvae: eight *Aleiodes declanae* van Achterberg, four *Mesochorus* sp. (a hyperparasitoid of *P. suavis* via *A. declanae*), and one *Meteorus pulchricornis* (Wesmael). One specimen of *Gelis tenellus* (Say) was reared from an *A. declanae* cocoon collected during the sampling. The primary host cadaver appeared to be *P. suavis*, but could also have been *Declana flocossa* Walker (Geometridae: Ennominae). As this identity could not be confirmed, this species has not been included in the parasitoid species list (Table 2).

Table 1: Lepidopteran larvae and their parasitoids collected in 1695 beating samples on *Pinus radiata, Kunzea ericoides* and *Ulex europaeus* at Eyrewell Forest, November 2002 to March 2003.

Family	Species	Number collected	Host plants (this study)	Parasitoids (this study)
Geometridae	*Chloroclystis filata* Guenée	1	Pine	nil
	Declana floccosa Walker	47	Pine, gorse, kanuka	*Aleiodes declanae, Meteorus pulchricornis*
	Poecilasthena schistaria Walker	81	Kanuka, pine	*Habronyx* sp
	Pseudocoremia suavis (Butler)	134	Pine, gorse, kanuka	*A. declanae, M. pulchricornis, Mesochorus* sp. (via *A. declanae*)
	Unidentified Geometridae	9	Pine, gorse, kanuka	*Mesochorus* sp. (via *A. declanae*)
Psychidae	*Liothula* sp.	42	Pine	Not assessed
Tortricidae	*Ctenopseustis obliquana* Walker	10	Pine, kanuka	nil
	Ctenopseustis herana Felder & Rogenhofer	7	Pine	nil
	Unidentified *Ctenopseustis* sp.	7	Pine	Campopleginae
	Cydia succedana Denis & Schiffermüller	1	Gorse	nil
	Holocola zopherana Meyrick	4	Pine, kanuka	nil
	Planotortrix notophaea Turner	29	Pine, gorse, kanuka	*Sympiesis* sp., Tachinidae sp.
Unknown	Unidentified Lepidoptera	19	Pine, kanuka	nil

A search of the FRNZ collection, FRI files and the literature identified 12 further species, giving a total of 13 primary and two hyperparasitoid species utilizing *P. suavis* (Table 2). According to Zondag (1956), no egg parasitoids were found during the Canterbury outbreaks, although a trichogrammatid reared from noctuid eggs attacked *P. suavis* eggs under laboratory conditions. However reference is made to an egg parasitoid of *P. suavis* in the FRI files (undated report, possibly July 1952), and an unidentified *Trichogramma* (Hymenoptera: Trichogrammatidae) egg parasitoid is mentioned in Rawlings (1953) and Valentine (1967). An additional tachinid fly (*Uclesiella* sp. nov.) is also listed in Valentine (1967). No further information was found on either species so these records were excluded from the parasitoid list given here. Notes on the biology of the parasitoids of *P. suavis*, listed in Table 2, are given below in alphabetical order.

***Aleiodes declanae* van Achterberg (Hymenoptera: Braconidae: Rogadinae).**

This widespread endemic braconid was the most common larval parasitoid of *P. suavis* at Eyrewell Forest in both the current study and in collections made during the outbreaks in the 1950s and 1960s (FRI files, Rawlings 1953). Previous records refer to this species as *Rogas* sp. (Zondag 1956, Valentine 1967, Schnitzler *et al*. 2004) or *Rhogas* sp. (FRI files). It is a solitary larval endoparasitoid, probably attacking the host in the first or second instar and mummifying the mid to late instar larvae (van Achterberg *et al*. 2004). Eleven of 105 *P. suavis* larvae successfully reared in the present study were attacked by *A. declanae*. *Mesochorus* sp. and *G. tenellus* are hyperparasitoids of this species. *Aleiodes declanae* was also recorded from earlier surveys and during the 1960-62 outbreak where it apparently exerted no demonstrable

Table 2: Parasitoids of *Pseudocoremia suavis*.

Order/Family	Subfamily	Species	Biology	Stage attacked
Hymenoptera				
Braconidae	Euphorinae	*Meteorus pulchricornis* (Wesmael)	Solitary larval endoparasitoid	Unknown
	Microgastrinae	*Glyptapanteles* sp.	Solitary larval endoparasitoid	Probably early instar larvae
	Rogadinae	*Aleiodes declanae* van Achterberg	Solitary larval endoparasitoid	1st or 2nd instar
Ichneumonidae	Anomaloninae	*Aphanistes kayi* Gauld	Larval/pupal endoparasitoid	Probably early instar larvae
	Campopleginae	*Diadegma* sp.	Probably solitary larval endoparasitoid	Unknown
		Casinaria sp.	Probably solitary larval endoparasitoid	Unknown
	Ichneumoninae	*Aucklandella conspirata* (Smith)	Solitary pupal endoparasitoid	Pupa or prepupa
		Aucklandella pyrastis (Cameron)	Solitary pupal endoparasitoid	Pupa or prepupa
		Degithina exhilarata (Smith)	Solitary endoparasitoid	Unknown
	Mesochorinae	*Mesochorus* sp.	Hyperparasitoid, solitary, endoparasitoid	Unknown
	Pimplinae	*Lissopimpla excelsa* (Costa)	Solitary pupal endoparasitoid	Pupa
Eulophidae	Eulophinae	*Zealachertus longus* Berry	Gregarious pupal endoparasitoid	Unknown
		Zealachertus conjunctus Berry	Hyperparasitoid of *Casinaria* sp.	Unknown
Diptera				
Tachinidae	Goniinae	*Pales feredayi* (Hutton)	Usually solitary, larval endoparasitoid	Host larva ingests microtype eggs laid on foliage
	Voriinae	*Uclesiella irregularis* Malloch	Usually solitary, larval endoparasitoid	Larva

Stage killed	Cocoon	Source	Notes and references
4th instar	Tan coloured oval cocoon hanging on a thread	Rearing data, this study	Exotic species. Berry & Walker 2004, Berry 1997
Probably late instar larvae	Oval white or green silken cocoon	FRNZ collection (incorrectly identified as *Apanteles demeter* by A.W. Parrott)	Valentine1967, Early 1984, Valentine & Walker 1991
3rd or 4th instar	Mummifies host larva	Rearing data, this study, FRI files, FRNZ collection	Previously *Rogas* sp., van Achterberg *et al*. 2004, Valentine 1967
Pupa	Develops within host pupa	Gauld 1980	Gauld 1980, Valentine & Walker 1991
Late instar larvae	Oval brown silken cocoon	FRNZ collection	
4-5th instar larvae	Mottled black or brown and white cocoon attached to leaf	FRNZ collection	J. Bain pers. comm. 2005, Gauld 1984
Pupa	Develops within host pupa	FRNZ collection, FRI files	Previously *Ichneumon conspiratus*. Zondag 1956, Valentine 1967, Valentine & Walker 1991
Pupa	Develops within host pupa	FRNZ collection, FRI files	Previously *Ichneumon placidula*. Zondag 1956, Valentine 1967, Valentine & Walker 1991
Pupa	Develops within host pupa	FRNZ collection	M. Kay pers. comm. 2005
Unknown	Develops within *Aleiodes* mummy	Rearing data, this study	Valentine 1967, Gauld 1984
Pupa	Develops within host pupa	FRNZ collection	Valentine 1967, Zondag 1956, Gauld 1984, Valentine & Walker 1991
Pupa	Develops within host pupa	FRNZ collection, FRI files	Recorded as ‘chalcid’ ‘eulophid’ or ‘Eurytomidae’. Zondag 1956, Berry 1999
Cocoon	Develops within host cocoon	FRNZ collection, FRI files	Recorded as ‘chalcid’, ‘eulophid’ or ‘Eurytomidae’. Zondag 1956, Berry 1999
Last instar/ prepupa/ teneral pupa	Puparium with host remains	Rawlings 1960 (as *Cerosomyia feredayi* Hutton), FRNZ collection	Rawlings 1960, Valentine 1967, J. Dugdale pers. comm. 2005
Unknown	Puparium in host shelter with remains	Rawlings 1960	Rawlings 1960, Valentine 1967, J. Dugdale pers. comm. 2005

control over *P. suavis* populations (Dugdale 1964). This species is also known to attack *D. flocossa*, *Pseudocoremia fenerata* Felder & Rogenhofer and *Cleora scriptaria* (Walker) (Geometridae: Ennominae) (van Achterberg *et al*. 2004).

***Aphanistes kayi* Gauld (Hymenoptera: Ichneumonidae: Anomaloninae).**

Aphanistes kayi is an endoparasitoid of forest lepidopterans, attacking host larvae and emerging from pupae (Gauld 1980). It is the only species of its genus known from New Zealand. Two specimens of *A. kayi* were reared from *P. suavis* from a plantation forest in the North Island, and adults (without rearing records) have been collected from plantations in the South Island (Gauld 1980).

***Aucklandella conspirata* (Smith) and *A. pyrastis* (Cameron) (Hymenoptera: Ichneumonidae: Ichneumoninae).**

Aucklandella conspirata (previously *Ichneumon falsus* or *I. conspiratus*) and *A. pyrastis* (previously *Ichneumon placidus*) are pupal parasitoids of *P. suavis*, attacking and emerging from the host pupa (Zondag 1956). *Pseudocoremia suavis* is the only known host of these species (Valentine & Walker 1991). These parasitoids were common at Eyrewell Forest during the *P. suavis* outbreaks (FRI files, Rawlings 1953), but their role in non-outbreak populations is unknown. During the 1960-62 outbreak, the first *A. conspirata* emerged in September, with a peak in December, and the next generational peak in late January. *Aucklandella pyrastis* first emerged in October, with a peak in early November, and another in late January. Of the two species, only *A. pyrastis* increased in numbers as host numbers increased (Dugdale 1964, Zondag 1964). Specimens of *A. conspirata* and *A. pyrastis* (or *placidula*, sic) (identified by Henry Townes (American Entomological Institute)) reared from *P. suavis* are deposited in FRNZ.

***Casinaria* sp. (Hymenoptera: Ichneumonidae: Campopleginae).**

This is the first published record of *Casinaria* parasitising *P. suavis*, and is based on four specimens from the 1950s found in the FRNZ collection. One of these specimens was reared from *P. suavis* collected at Eyrewell Forest, and the other specimens were reared from *P. suavis* from Whirinaki, Ohakune and 'Viewhill' (location unknown). Schnitzler *et al*. (2004) recorded the same *Casinaria* species (determined by J. A. Berry) parasitising first or second instar *C. scriptaria* (feeding on *Macropiper excelsum*) and emerging from the fifth instar. The FRNZ *Casinaria* specimens have late instar larval remains attached to the associated cocoons, indicating a similar habit. *Casinaria* is a large, cosmopolitan ichneumonid genus. Australian species are parasitoids of hesperiid, pyralid, geometrid and notodontid lepidopterans (Gauld 1984). Four undescribed native species of *Casinaria* are known from New Zealand (J. Bain, pers. comm. 2005).

***Degithina exhilarata* (Smith) (Hymenoptera: Ichneumonidae: Ichneumoninae)**.

Specimens identified as *Degithina exhilarata,* and labelled as reared from *Pseudocoremia* sp. pupae, were found in the FRNZ collection. The host larvae were collected during the *P. suavis* outbreak at Kaingaroa Forest in the 1970s, and, as no other *Pseudocoremia* species were present in the field at this time, the host association can probably be attributed to *P. suavis* (M. Kay pers. comm. 2005). *Degithina* is an endemic genus with nine described species. Only two of these have known hosts, attacking noctuids and hepialids (Valentine & Walker 1991). No hosts have previously been recorded for *D. exhilarata* (Valentine & Walker 1991).

***Diadegma* sp. (Hymenoptera: Ichneumonidae: Campopleginae).**

This is the first published record of *Diadegma* parasitising *P. suavis*, and is based on FRNZ specimens collected in the 1950s and 1960s. An unidentified congeneric species attacks *C. scriptaria* (Schnitzler *et al*. 2004). Four described species of *Diadegma* are recorded in New Zealand from a total of around 50 known lepidopteran species (Berry 2005).

***Glyptapanteles* sp. (Hymenoptera: Braconidae: Microgastrinae).**

A search of the FRNZ collection produced one specimen of *Glyptapanteles* reared from *P. suavis*. This was identified by A. W. Parrott as *Apanteles demeter* (now *Glyptapanteles demeter* (Wilkinson) (Austin & Dangerfield 1992)). A number of

conspecific but unidentified specimens were also found in the collection, reared from *P. suavis*, *P. fenerata*, and *Pseudocoremia leucelaea* (Meyrick). These specimens were compared with paratypes of *G. demeter* (deposited in NZAC), and were determined to be another, probably undescribed, endemic species of *Glyptapanteles*. They were reared from larvae collected between 1957 and 1959 and were widespread in the North and South Islands, but were not reared from *P. suavis* larvae collected at Eyrewell Forest during the outbreaks in the 1950s and 1960s. No records were kept of plant hosts, but needle fragments mounted with many of the specimens suggest *Pinus* spp. were the host. Valentine & Walker (1991) and Austin & Dangerfield (1992) recorded "?*Pseudocoremia suavis*" as a host of *A. demeter*, but it remains unclear if this record refers to the misidentified FRNZ specimen.

***Lissopimpla excelsa* (Costa) (Hymenoptera: Ichneumonidae: Pimplinae)**.
This species is a solitary pupal endoparasitoid of various lepidopterans (Zondag 1956, Early 1984, Valentine & Walker 1991). It does not appear to be a common parasitoid of *P. suavis* (FRI files). One specimen of *L. excelsa* reared from a *P. suavis* pupa (collected at Woodhill, Auckland, in 1960) was found in the FRNZ collection.

***Mesochorus* sp. (Hymenoptera: Ichneumonidae: Mesochorinae).**
This hyperparasitoid emerged from four of the 12 mummies resulting from *Aleiodes declanae* parasitism on *P. suavis* in this study. *Mesochorus* sp. is a hyperparasitoid via larval parasitoids of a number of geometrids and tortricids (Valentine 1967). Such biology is typical of this large, poorly described cosmopolitan genus (Gauld 1984). All *Mesochorus* species recorded from New Zealand are yet to be described (Berry 2005).

***Meteorus pulchricornis* (Wesmael) (Hymenoptera: Braconidae: Euphorinae)**.
This solitary endoparasitoid is an introduced species with a very wide host range, attacking lepidopteran larvae from at least 11 families worldwide (Berry & Walker 2004). *Meteorus pulchricornis* has not previously been recorded as a parasitoid of *P. suavis*, although it has been reared from six other New Zealand geometrids and 22 species from other lepidopteran families (J. A. Berry, unpublished data). It was not a common parasitoid of *P. suavis* in the 2002-2003 Eyrewell Forest study, attacking only one of 105 reared larvae. This species was accidentally introduced, possibly from Asia (Berry & Walker 2004), and was first recorded in New Zealand in 1996 (Berry 1997). It is distributed widely in New Zealand, from Northland to Central Otago, and has been collected most commonly in modified habitats (Berry & Walker 2004). *Meteorus pulchricornis* was also reared from the geometrids, *Declana floccosa* Walker and *Poecilasthena schistaria* Walker, collected at Eyrewell Forest during this study (Table 1).

***Uclesiella irregularis* Malloch and *Pales feredayi* (Hutton) (Diptera: Tachinidae).**
These tachinid flies were recorded as parasitoids of *P. suavis* in Rawlings (1960) and Valentine (1967). A specimen of *P. feredayi,* reared from *P. suavis* collected in Kaingaroa State Forest in 1956, is lodged in the FRNZ collection. Both species are usually solitary, internal parasitoids that attack and emerge from *P. suavis* larvae. *Pales feredayi* lays microtype eggs on the hosts' food plant which are then ingested by the host and hatch inside the foregut, but it is unknown how the larva of *U. irregularis* enters its host (J. Dugdale pers. comm. 2005).

***Zealachertus longus* Berry and *Z. conjunctus* Berry (Hymenoptera: Chalcidoidea: Eulophidae)**.
One or both of these species were common pupal parasitoids of *P. suavis* during the outbreaks at Eyrewell Forest, but remained unidentified in the FRNZ collection and were referred to as 'eulophid', 'chalcid' or 'Eurytomidae' (FRI files). Pinned specimens of *Zealachertus longus* suggest it is a gregarious endoparasitoid, and this is supported by a comment in the FRI Files (report to Director of Forestry, 12/8/1952) stating that up to 70 wasps emerge from one host pupa. *Zealachertus conjunctus* may be a hyperparasitoid, as one specimen, reared from *P. suavis*, is mounted with a *Casinaria* cocoon. The genus *Zealachertus* is endemic, with 12 described species (Berry 1999). Another species, *Z. binarius,* is a hyperparasitoid of

C. scriptaria via '*Rogas'* sp. (possibly *A. declanae*) (Schnitzler *et al*. 2004). The biology and hosts of *Z. longus* and *Z. conjunctus* were previously unknown, and both species are only recorded from the South Island (Berry 1999).

Predators

Fourteen predators of *P. suavis* were recorded, including insects, spiders, mites, birds and mammals (Table 3). The theridiid spider *Achaearanea veruculata* (Urqu.) was observed feeding on *P. suavis* larvae during an experiment in which laboratory-reared larvae were released on potted pine trees in Eyrewell Forest (Berndt, pers. obs. 2003). Three species of carabid beetle, *Megadromus antarcticus* (Chaudoir), *Metaglymma moniliferum* Bates, and *Oregus crypticus* Pawson, were observed to feed on *P. suavis* pupae in the laboratory (Berndt, pers. obs. 2005). These large, endemic, ground active predators are common in Eyrewell Forest, and are likely to encounter *P. suavis* in the leaf litter. All of the other records of predation listed in Table 3 were observed at Eyrewell Forest during the outbreaks when *P. suavis* was highly abundant and predation events were easily seen. Both nymphal and adult stages of pentatomid bugs preyed on *P. suavis* larvae (Zondag 1956, Larivière 1995); nymphs of *Cermatulus nasalis* (Westwood) were observed feeding at night on adult *P. suavis* (FRI Files, April 1957). Asilid robber flies were

Table 3: Predators of *Pseudocoremia suavis*, based on field observations.

Taxon	Family	Species	Stage attacked	Source
Insecta				
Diptera	Asilidae	Probably *Neoitamus* spp. (= *Itamus* spp.)	Adults on the wing	FRI files, Valentine 1967
Hemiptera	Pentatomidae	*Cermatulus nasalis* (Westwood)	Larvae and adults	FRI files, Zondag 1956
		Oechalia schellenbergii (Guérin)	Larvae	FRI files, Zondag 1956 (listed as *O. consocialis*), Rawlings 1960, Larivière 1995
Orthoptera	Mantidae	*Orthodera novaezealandiae* (Colenso)	Larvae	Zondag 1956 (listed as *O. ministralis*)
Arachnida				
Araneae	Theridiidae	*Achaearanea veruculata* (Urqu.)	Larvae	Personal observation
Acari		Unknown species	Pupae	Zondag 1956
Aves				
		Fantail (*Rhipidura fuliginosa*)	Adults	FRI files
		Tomtit (*Petroica macrocephala*)	Adults	FRI files
		Grey warbler (*Gerygone igata*)	Adults	FR files
Mammalia				
	Erinaceidae	Hedgehog (*Erinaceus europaeus*)	Pupae	Zondag 1956
	Phalangeridae	Possum (*Trichosurus vulpecula*)	Adults and pupae	FRI files

reportedly numerous during the *P. suavis* outbreak, catching adult moths on the wing (FRI Files, April 1957). Birds also fed on adult *P. suavis* during the outbreaks, with grey warblers and tomtits clipping the wings off the moths before eating the thorax, and fantails eating the moths whole (FRI Files, April 1957). Remains of *P. suavis* adults and pupae were found in possum droppings during the outbreaks (FRI files, 1960-61).

Conclusions

Many forest Lepidoptera exhibit population outbreaks which may occur in response to changes in pathogens, host plant chemistry, climate, or natural enemy interactions (Berryman 1996, Royama 1997). For *P. suavis* the key factors are thought to be climate and host plant condition (Kay 1982, 1983, White 1974), however the role of natural enemies in the frequency, severity or duration of outbreaks has not been determined. The updated list of parasitoids and predators presented here provides background information for future research into their ability to regulate moth population dynamics in exotic, as well as native forests, which, in turn, could lead to greater understanding of the causes of *P. suavis* outbreaks.

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