INVERTEBRATE FAUNA OF FOUR TREE SPECIES IN ORONGORONGO VALLEY, NEW ZEALAND, AS REVEALED BY TRUNK TRAPS

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SUMMARY: Tree trunks are important links between the forest floor and canopy, especially for flightless invertebrates that move from the forest floor to feed or breed in the canopy. Traps were used to sample invertebrates moving up and down on mahoe *(Melicytus ramiflorus),* hinau *(Elaeocarpus dentatus),* hard beech *(Nothofagus truncata),* and kamahi *(Weinmannia racemosa)*. In 19 months 22 696 invertebrates were collected. Many unexpected groups e.g. ground wetas, ground beetles, some caterpillars, amphipods, spring-tails, mites, peripatus, and earthworms were caught in up-traps 1.5 m above ground. Overall, up-traps caught more (80%) invertebrates than down-traps (20%) and 16 of 29 groups of invertebrates were caught more often in up-traps. Fewer invertebrates were caught on hard beech than on hinau with comparable catching surface area. The numbers of spiders caught were significantly correlated with tree circumference. The invertebrates caught fell broadly into 3 trophic levels-most were saprophytes, with equal numbers of herbivores and predators. Perched leaf litter in epiphytes and in tree cavities contain invertebrates otherwise associated with the forest floor. Invertebrates in the lowland forests of New Zealand appear to be generalists in their use of habitats (as many of them are saprophytes and predators).

KEYWORDS: Trunk trap; forest; invertebrates; arboreal fauna; Melicytus ramiflorus; Elaeocarpus dentatus; Nothofagus truncata; Weinmannia racemosa; Orongorongo Valley, New Zealand.

INTRODUCTION

In the forest of Orongorongo Valley (41° 21'S, 174° 58'E), near Wellington, tree trunks provide an important pathway, especially at night, for many ground-living invertebrates that move from the forest floor to feed or breed on tree stems and in the canopy. We investigated the movements of invertebrates, both up and down, on tree trunks of four lowland forest species, mahoe *(Melicytus ramiflorus),* hinau *(Elaeocarpus dentatus),* hard beech *(Nothofagus truncata),* and kamahi *(Weinmannia racemosa)* by using specially designed trunk traps.

Although some of the larger invertebrates of the New Zealand lowland forest are reasonably well known taxonomically, information on habitats and associations with plants and with other invertebrates is less well known.

Whereas a number of overseas investigators have looked at the emerging insects on tree trunks (see Glen, 1976), to our knowledge only Funke (1971) and Nielson (1974) have recorded the upward activity of insects on beech trunks *(Fagus silvatica)* in West Germany and Denmark respectively. There has been no previous work in New Zealand on this subject.

STUDY AREA

The vegetation of the study area can be divided into two main types: lowland broadleaf/podocarp forest on the lower slopes and adjacent to the Orongoronga River, and hard beech forest on the slopes above the river bed. Forest structure and species composition of the study area are outlined by Moeed and Fitzgerald (1982) from detailed descriptions of Fitzgerald (1976) and D. J. Campbell (pers. comm.).

The climate is temperate with moderate seasonal changes in temperature and rainfall. Frosts and snow are unusual in the study area. Mean monthly temperature and rainfall for the sampling period recorded at the Orongorongo Valley field station situated in a clearing are shown in Figure 1. The mean temperature ranges between 8° and *18°C*. Most rain falls during the cooler months.

MATERIAL AND METHODS

Two types of trunk traps were used (Fig. 2): up-traps that caught invertebrates on their upward movement and down-traps that caught invertebrates moving downwards. Because there were few suitable kamahi trees in our study area, only one trap of each

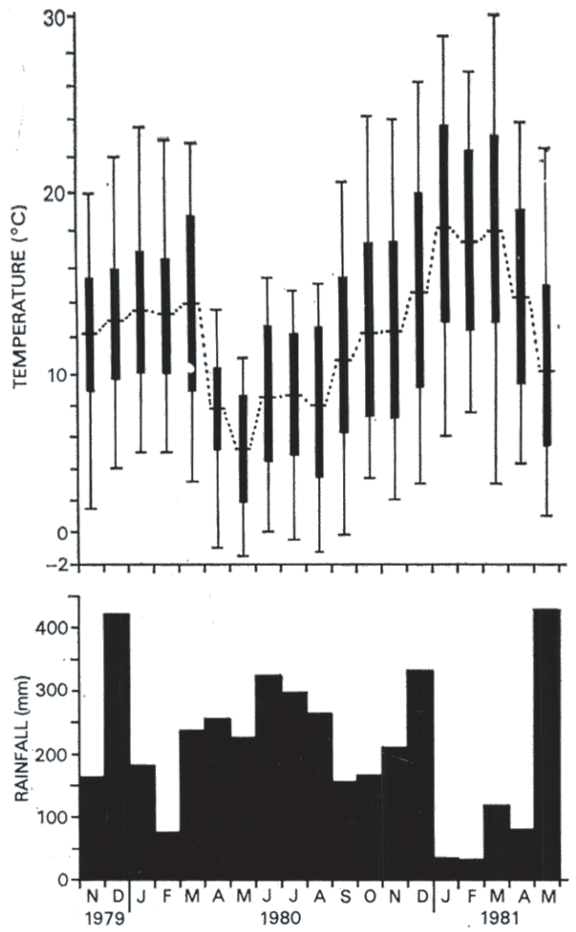

FIGURE 1. *Air temperature and rainfall for the period November 1979 to May 1981 at the Orongorongo Valley field station. Range, mean maximum, and mean minimum temperatures are plotted above and below monthly means.*

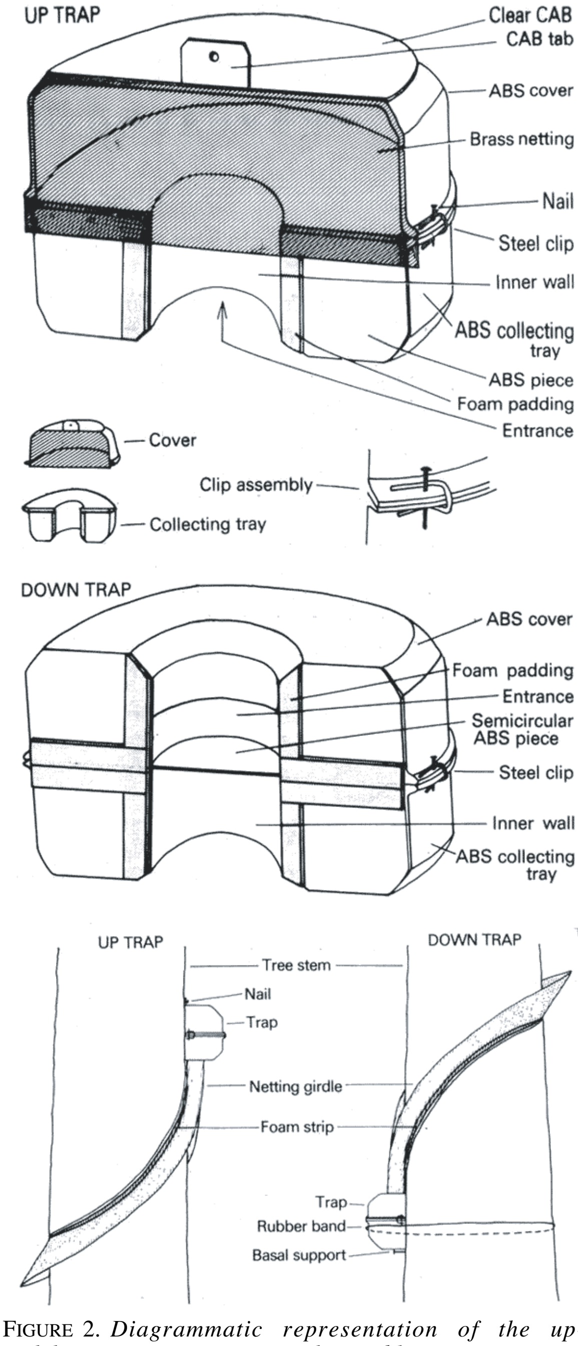

FIGURE 2. *Diagrammatic representation of the up- and down-traps, components and assembly.*

design was used on kamahi, but three traps each of both designs were used on mahoe, hinau, and hard beech. The number of trees with traps and tree circumference at breast height are summarised in Table 1. The traps, 1.5 m above ground, were operated from November 1979 to May 1981 inclusive.

Each trap comprised three main parts: a removable collecting tray, a cover, and a netting girdle to guide invertebrates into the trap. The collecting tray made of white plastic (acrylonitrile-butadiene-styrene, ABS), was a semicircular ring dish 200 mm in diameter and 70 mm deep. The dish had a narrow lip around the upper edge. The two ends of the collecting tray were sealed, by glueing pieces of ABS to each end, to retain Galt's solution (see Barber, 1930) used as preservative. Pieces of ABS were dissolved in ethyl methyl ketone (EMK) to form the glue.

Strips of foam padding on the rear of the collecting tray sealed it against the tree trunk and the cover (Fig. 2). The cover for up-traps was made of the other half of the plastic ring dish whose base and inner wall were removed. The base was replaced by a clear semicircular piece, 160 mm in diameter, of cellulose-acetate-butyrate (CAB) that allowed light to pass through. Fine-mesh brass gauze (less than 0.5 mm) was glued across the open end of the dish. The cover was then inverted and placed directly on the collecting tray so the edges corresponded. The lips were pinned through with three galvanised nails, 20 mm long, embedded in the lip of the cover. A stainless steel wire clip around the top and bottom of each nail held the cover and collecting tray together; when the traps were inspected, the clips were removed and the collecting tray lowered from the nails. A tab of CAB was attached to the top of the cover, in the centre of the straight edge, to nail the trap to the tree. Chloroform was used :lS solvent to glue pieces of CAB together.

The collecting tray for the down-traps was similar to that of up-traps except that a semi-circular piece of ABS, 65 mm in diameter, was glued to the inner wall of the ring to prevent invertebrates passing through to the ground (Fig. 2). The cover of the down-traps was made of the other half of the ring dish with 20 mm of the inner wall of the ring cut away to allow entry to the collecting tray.

The girdle consisted of a 300-mm-wide strip of wire netting, mesh size 1.5 mm, cut lengthwise in two but left joined at the top and bottom to form a tunnel that fitted into the half ring of the collecting trays (Fig. 2). The outside edge of the wire netting strip was folded under on each side, stretched around the tree, and stapled to the trunk through a band of foam padding that served as a seal. The two ends of the netting guide were joined where they met on the other side of the trunk. The free edge of the netting guide stood out from the tree at a sharp angle to prevent invertebrates climbing over.

We did not include a test to determine the efficacy of traps in our sampling design as Nielsen (1974) described for his traps. However, our observations of insect behaviour (both diurnal and nocturnal) over several weeks with a prototype up-trap, placed on a mahoe tree showed that a variety of invertebrates followed the netting girdle and passed into the collecting tray. The exceptions were a small number of cockroaches (Blattodea) and a ground beetle (Coleoptera) that climbed over the netting girdle to avoid capture. These observations were confirmed again when we watched the traps in the study area. Because some cockroaches and ground beetles escaped from the traps and some Collembola and mites (Acari) passed through the fine (1.5 mm) mesh of the netting girdle their catches are regarded as underestimates.

In the last quarter of our sampling period we found spiders (Araneida) residing on three occasions in a different down-trap each time and once in an up. trap. Perhaps the clear ABS piece in the cover of up-traps discouraged spiders. The traps were therefore cleaned at every sampling occasion. We consider these as isolated instances whose consequences on the invertebrate catches may have been serious if spiders were found in more traps. Nielson (1974) also reported spiders residing in his traps.

The only design problem encountered was the rusting of galvanised nails, which made the separation of collecting trays difficult. The nails may have rusted because they came in contact with the salt-based Galt's solution used as preservative. Stainless steel nails would have prevented this trouble. Trap interference by possums *(Trichosurus vulpecula)* was negligible.

The invertebrate species mentioned in the text were determined by comparing them with the reference collection of Orongorongo Valley invertebrates and identified by various taxonomists from time to time. Because of the lack of taxonomic revisions other groups are treated at the familial or ordinal level.

RESULTS

During 19 months 22696 invertebrates from 28 orders were collected on the four tree species (Appendix 1). Kamahi, compared with other three tree species (Table 1), had only one-third of the trapping effort. Overall, up-traps caught more (80%) than down-traps (20%) because many invertebrate (e.g. wetas (Orthoptera), stick insects (Phasmatodea), beetles, larvae, spiders) would drop to the ground from the canopy instead of retracing their steps down the trunk. We deal mainly with catches in up-traps because these represent the invertebrates actively seeking the forest canopy. Results from down-traps reflect the presence of perched litter, especially in epiphyte clumps, which extends the distribution of invertebrates that otherwise would be confined to the forest floor. Members of 11 of the 28 orders recorded are wholly or partly associated with leaf litter, decaying matter, or mostly confined to the forest floor.

The catching circumference of mahoe was about half that of hinau and hard beech. Kamahi was intermediate (Table 1). To some extent this is reflected in the total number of invertebrates caught on mahoe, hinau, and kamahi. The texture of the stem was rougher on hinau and hard beech than on mahoe and kamahi. Fewer invertebrates were caught on

TABLE 1. *Number of trees with trunk traps and their circumference at breast height.*

Tree species	Circumference (cm) Tree number 1	2	3	Mean
Up-traps				
Mahoe	63	53	68	61
Hinau	141	142	79	121
Hard beech	114	118	116	116
Kamahi	68	—	—	—
Down-traps				
Mahoe	57	122	65	81
Hinau	130	167	66	121
Hard beech	113	82	119	105
Kamahi	85	—	—	—

hard beech than on hinau with comparable catching surface area, perhaps because there are fewer forest floor invertebrates under beech than under broadleaf / podocarp forest. Monthly distributions of the commonly occurring invertebrates in both up- and down-traps are presented in Figures 3 to 7.

Numerically, up-traps caught, in dcreasing order of importance, Collembola (27.7%), Coleoptera (19.7%), Araneida (9.7%), Hymenoptera (7.5%), Diptera (7.2%), Acari (6.5%), Orthoptera (6.5%), Hemiptera (3.6%), insect larvae (2.6%), Blattodea (2.5%), and others (6.5%) (Table 2). Percentage occurrence varied considerably within and between tree species.

The order of percentage occurrence was slightly different for invertebrates caught in down-traps. Of 29 groups of invertebrates, including insect larvae, caught in both up- and down-traps, 13-Archaeognatha, Isoptera, Thysanoptera, insect larvae, Terricolae, Amphipoda, Ostracoda, Isopoda, Chilopoda, Diplopoda, Gastropoda, Acari, and Opiliones-were caught more in down-traps than in up-traps (Appendix 1).

The following examines the seasonal distributions and tree-species associations of invertebrates on the four tree species, as recorded in Appendix 1.

ARCHAEOGNATHA. The native bristle-tails were caught infrequently in up-traps on all four tree species and in down-traps on all except hard beech.

COLLEMBOLA. Three families (Poduridae, Entomobryidae, Sminthuridae) of spring-tails were caught in all traps on all tree species. More sminthurids were caught than entomobryids and podurids. In up-traps their numbers were highest on hinau followed by mahoe and hard beech. Although the abundance of Collembola on the forest floor is correlated with moisture (McColl, 1975), seasonal differences in our samples of Collembola caught in trunk traps could not be related to rainfall.

BUTTODEA. Two species of cockroaches *(Parellipsidion conjunctum, Celatoblatta* sp.) were caught in up- and down-traps on all four tree species. The few unidentified specimens were probably juveniles of the two species caught. *P. conjunctum* was more active in summer and autumn than in winter and spring (Fig. 3B). Most were caught on hinau followed by mahoe and hard beech and a similar distribution was noted for *Celatoblatta* sp. in up-traps (Fig. 3A). Numbers caught on the one kamahi suggest a higher total if trapping effort had been the same. More *Celatoblatta* sp. than *P. conjunctum* were caught in down-traps, and the distribution of *Celatoblata* sp. (Fig. 7 A) was similar to that in up-traps.

ISOPTERA. The native termites (probably *Kalotermes* sp.) were caught only in February 1980 in a down-trap on hard beech.

PLECOPTERA. Stoneflies were caught in low numbers on all four tree 5pecies in up-traps only.

ORTHOPTERA. Ground wetas *(Hemiandrus furcifer)* and tree wetas *(Hemideina crassidens)* were caught on all four tree species, and at least four species of cave wetas (Rhapidophoridae) on the four tree species combined. Ground wetas were caught mostly

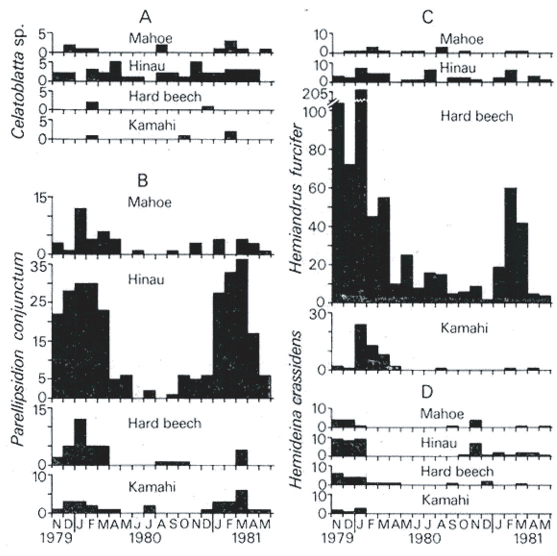

FIGURE 3. *Seasonal distribution in up-traps of* Celatoblatta *sp. (A),* Parellipsidion conjunctum *(B),* Hemiandrus furcifer *(C), and* Hemideina crassidens *(D) on mahoe, hinau, hard beech, and kamahi trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

TABLE 2. *Invertebrate groups and their percentage of occurrences in up- and down-traps on mahoe, hinau, hard beech and kamahi trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

Order	Common Name	Up-traps Mahoe	Up-traps Hinau	Up-traps Beech	Up-traps Kamahi	Up-traps Total	Up-traps %	Down-traps Mahoe	Down-traps Hinau	Down-traps Beech	Down-traps Kamahi	Down-traps Total	Down-traps %
Archaeognatha	Bristle-tails	1	1	1	2	5	<0.1	9	5	0	3	17	0.4
Collembola	Spring-tails	1462	3182	201	231	5076	27.7	201	163	208	90	662	15.0
Blattodea	Cockroaches	57	325	42	35	459	2.5	6	54	9	7	76	1.7
Isoptera	Termites	0	0	0	0	0	0.0	0	0	5	0	5	0.1
Plecoptera	Stoneflies	2	13	6	4	25	0.1	0	0	0	0	0	0.0
Orthoptera	Wetas	61	182	841	106	1190	6.5	19	47	59	6	131	3.0
Phasmatodea	Stick insects	12	52	22	25	111	0.6	1	3	0	1	5	0.1
Psocoptera	Book-lice	64	84	71	18	237	1.3	5	13	4	1	23	0.5
Hemiptera	Plant-bugs	137	287	167	65	656	3.6	15	27	26	7	75	1.7
Thysanoptera	Thrips	20	12	5	1	38	0.2	12	4	2	4	22	0.5
Neuroptera	Ant-lions	0	1	1	0	2	<0.1	0	0	0	0	0	0.0
Coleoptera	Beetles/Weevils	2635	660	227	91	3613	19.7	157	151	143	33	484	11.0
Diptera	Flies	335	523	341	120	1319	7.2	76	60	47	18	201	4.6
Trichoptera	Caddis-flies	0	2	1	1	4	<0.1	0	0	0	0	0	0.0
Lepidoptera	Moths	28	111	107	45	291	1.6	3	4	8	5	20	0.5
Hymenoptera	Wasps/Ants	419	845	66	33	1363	7.5	24	65	23	9	121	2.7
Larvae		138	243	57	41	479	2.6	246	166	94	19	525	11.9
Onychophora	Peripatus	0	1	0	0	1	<0.1	0	0	0	0	0	0.0
Terricolae	Earthworms	20	6	1	5	32	0.2	13	5	26	10	54	1.2
Amphipoda	Hoppers	19	12	25	21	77	0.4	145	29	30	26	230	5.2
Ostracoda		0	0	0	0	0	0.0	0	1	1	0	2	<0.1
Isopoda	Woodlice	3	7	1	3	14	0.1	173	62	15	2	252	5.7
Chilopoda	Centipedes	5	8	2	3	18	0.1	15	8	17	4	44	1.0
Diplopoda	Millipedes	1	2	0	0	3	<0.1	28	18	6	10	62	1.4
Gastropoda	Snails/Slugs	24	45	2	9	80	0.4	85	65	9	5	164	3.7
Acari	Mites	479	569	94	50	1192	6.5	358	222	98	36	714	16.2
Araneida	Spiders	312	777	486	206	1781	9.7	84	109	92	36	321	7.3
Opiliones	Harvestmen	35	141	46	4	226	1.2	54	127	6	3	190	4.3
Pseudoscorpionidea		1	1	0	0	2	<0.1	1	1	0	0	2	<0.1
Total		6270	8091	2813	1119	18294		1730	1409	928	335	4402	

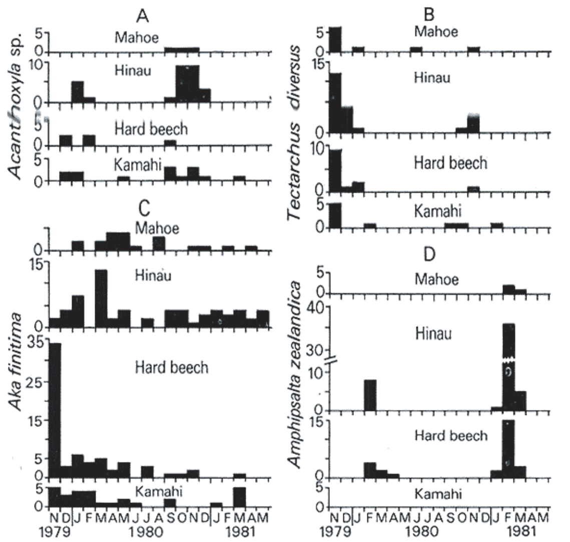

FIGURE 4. *Seasonal distribution in up-traps of* Acanthoxyla *sp. (A),* Tectarchus diversus *(B),* Aka finitima *(C), and* Amphipsalta zealandica *(D) on mahoe, hinau, hard beech, and* kamahi *trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

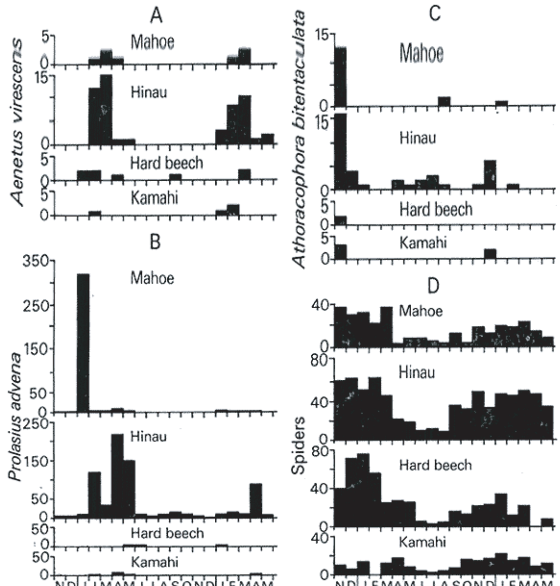

FIGURE 5. *Seasonal distribution in up-traps of* Kikihia scutellaris *(A),* Brachyolus punctatus *(B),* Crisius binotatus *(C),* Mesocyphon marmoratus *(D), and* Platyomida hochstetteri *(E) on mahoe, hinau, hard beech, and kamahi trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

on hard beech in summer (December-February). Fewer were caught on the other three tree species (Fig. 3C). This seems to be the first record of extensive above-ground movement of ground wetas on the four tree species studied. At peak density more juveniles than adults were caught.

The tree wetas were caught mostly in spring and summer (September-February) in up-traps on all four tree species. The numbers were highest on hinau followed by hard beech and mahoe (Fig. 3D).

PHASMATODEA. Two species of juvenile stick insects *(Tectarchus diversus, Acanthoxyla* sp.) were caught in up-traps on all four tree species, but in down-traps on hinau and kamahi only. More were caught on hinau than on the other tree species, mainly in spring and summer. Adult stick insects live in trees and their eggs fall to the forest floor. After hatching, juveniles climb the trees (Miller, 1971) (Fig. 4A, B). In 1979, *T. diversus* emerged earlier than *Acanthoxyla* sp. and the emerging pattern was different for the two species in different years. The numbers of *T. diversus* were highest in 1979 whereas more *Acanthoxyla* sp. were caught in 1980. This may be a result of differ ences either in the number of eggs laid each year or in the hatching rate of eggs from year to year.

PSOCOPTERA. Book-lice were caught in all traps on all four tree species. In up-traps they occurred more on hinau, followed by hard beech and mahoe.

HEMIPTERA. Plant-bugs were caught in all traps but most in up-traps on hinau, followed by hard beech, mahoe, and kamahi. Adults of two species of cicadas *(Amphipsalta zealandica, Kikihia scutellaris)* were caught in late summer and autumn on hinau, hard beech, and mahoe but not on kamahi (Figs 4D, 5A). The greater number of A. *zealandica* in up-traps in 1981 corresponds with the higher summer temperatures in 1980-81 than in 1979-80. *Aka finitima* was caught throughout the sampling period on all four tree species (Fig. 4C). Other unidentified plant-bugs belonging to Coccidae, Pseudococcidae, Cicadellidae, and Psyllidae occurred throughout the sampling pericd on all four tree species.

THYSANOPTERA. Thrips were present in both up- and down-traps on all four tree species. In descending order they were caught more in up-traps on mahoe, hinau, hard beech, and kamahi. Most were caught in late spring and early summer.

NEUROPTERA. One specimen of ant-lion was caught in an up-trap on hinau and hard beech only.

COLEOPTERA. Numerically, beetles and weevils were the second largest group (after Collembola) caught in up-traps, but contained the greatest number of recognisable species of all groups reported here. More beetles and weevils were caught on mahoe than on the other three tree species. Numbers on mahoe

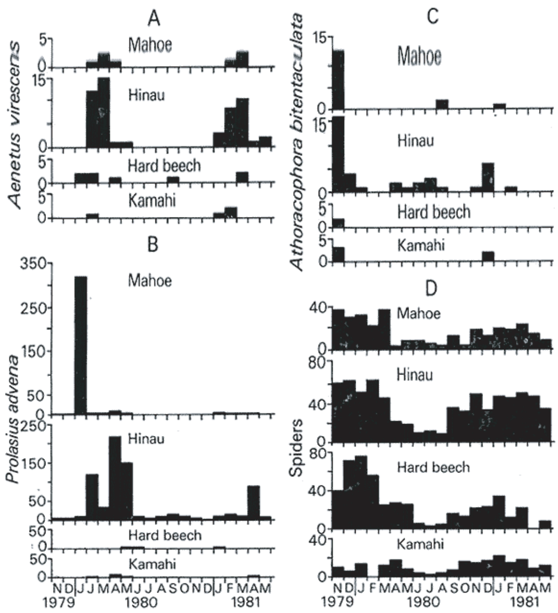

FIGURE 6. *Seasonal distribution in up-traps of* Aenetus virescens *(A),* Prolasius advena *(B),* Athoracophora bitentaculata *(C), and spiders (D) on mahoe, hinau, hard beech. and kamahi trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

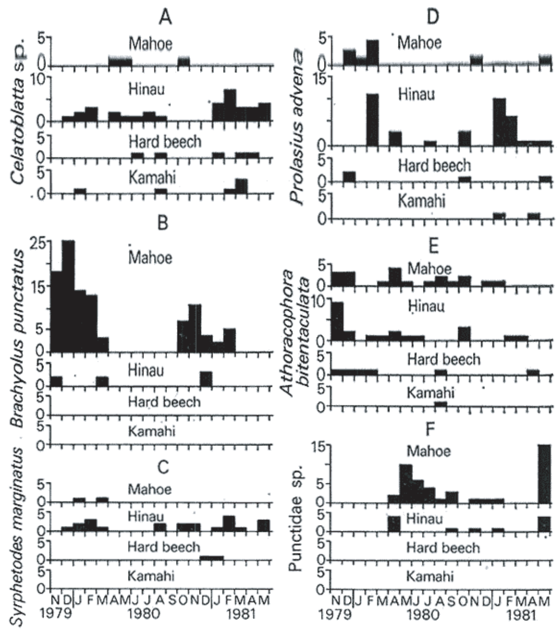

FIGURE 7. *Seasonal distribution in down-traps of* Celatoblatta *sp. (A),* Brachyolus punctatus *(B),* Syrphetodes marginatus (C) Prolasius advena *(D),* Anthoracophora bitentaculata *(E), and Punctidae sp. (F) on mahoe, hinau, hard beech, and kamahi trees in Orongorongo Valley between November 1979 and May 1981 inclusive.*

were boosted by *Brachyolus punctatus,* a weevil which occurred mostly in up-traps from spring to early autumn (Fig. 5B). Even on mahoe one trap caught most of the weevils. Numbers in down-traps (Fig. 7B) on mahoe were less variable between traps and the distribution pattern was similar to that in the up-traps. Only three and seven specimens of *B. punctatus* were caught on hinau in up- and down-traps respectively, and none on hard beech and kamahi.

Several long-horned borer beetles, e.g. *Blosyropus spinosus, Hexatricha pulverulenta, Oemona hirta, Poecilippe flavicollis, Somatida antarctica, Stenellipsis bimaculata,* S. *latipennis, Votum mundum, Xuthodes batisi, Xylotelus humeratus* and the giraffe weevil, *Lasiorrhynchus barbicornis,* were caught in up-traps. Five of the beetles were caught on mahoe, 8 on binau, 6 on hard beech and 4 on kamahi. Only *L. barbicornis* and *O. hirta* were caught in down-traps.

Interestingly, four ground beetles occurred: *Amarotypus edwardsi, Demetrida nasuta, Mecodema simplex,* and *Zolus carinatus* (Carabidae). Different ground beetles were caught in up- and down-traps on all four tree species. Pit traps operated in the same area from May 1975 to June 1976 caught 15 species of ground beetles including the four species mentioned here.

The pinhole borer *(Platypus apicalis)* was caught in down-traps only on hinau and hard beech. It has been reported (Ferro, 1976) to attack southern beeches, some species of *Eucalyptus* and various conifers including Douglas fir *(Pseudotsuga menzieisii)* and rimu *(Dacrydium cupressinum)*. Occurrence on hinau appears to be an extension of its host plants.

Only one beech buprestid *(Nascioides enysi)* was caught in a down-trap on hard beech. According to Ferro (1976) *N. enysi* has been blamed in the past for beech mortality, but it is in fact only a secondary species apparently unable to damage healthy trees. The occurrence of *N. enysi* in December 1980 is perhaps related to the present (1982) poor condition of the beech trees sampled.

DIPTERA. Flies (Acalypterae, Tipulidae, Calliphoridae) were caught more in up- than in down-traps on all four tree species. More acalypterate flies were caught than tipulids and calliphorids. Greatest numbers were caught on hinau, with about equal numbers on mahoe and hard beech and fewest on kamahi.

TABLE 3. *Number of caterpillars trapped on mahoe, hinau, hard beech and kamahi trees in Orongorongo Valley between November* 1979 *and May* 1981 *inclusive.*

Caterpillars	Trees									
	Up-traps					Down-traps				
	Mahoe	Hinau	Hard	Kamahi	Total	Mahoe	Hinau	Hard	Kamahi	Total
Aenetus virescens	7	53	8	4	72		1	2		3
Austromathes purpurea	3				3					
Cleora scripta	11	4		3	18					
Cryptolechia liochroa			1		1			1		1
Ctenopseustis obliquana						1				1
Declana feredayi			1		1					
Declana floccosa	1	10	3	2	16					
Declana leptomera	5	10			15			3		3
Declana sp.			1		1					
Epalxiphora axenana	1				1					
Feredayia graminosa	7				7					
Feredayia sp.	2				2					
Gargaphia muriferata						1				1
Gellonia dejectaria	3	5			8					
Gellonia sp.	1				1					
Gymnobathra sp.								2		2
Heterocrossa eriphylla							1	3		4
Homodotis megapilata						1				1
Ischalis variabilis		8			8		1			1
Larentiine sp.		1			1					
Liothula omnivora				1	1					
Mallobathra sp.			1		1					
Meterana sp.		2	4	1	7					
Pseudocoremia aristarcha	1	7			8					
Pseudocoremia pelurgata		3	1		4					
Pseudocoremia productata			2	3	5					
Pseudocoremia sp		1			1					
Pseudocoremia suavis	2	10	9	3	24					
PSYCHEODINAE									2	2
Psycheodius sp.				1	1			2		2
PSYCHIDAE	6	14	2	2	24	2	1			3
Reductoderces sp.	1				1					
Rhapsa scotosialis		1			1	1				1
Sarisa muriferata							1			1
Tatosoma fasciatta			1		1					
Tingena sp.							1	3		4
Tortix flavescens								3		3
TORTRICIDAE	1	11	8	5	25	2	1		1	4
Xyridacma alectoraria	1				1					
Total	52	141	42	25	260	8	7	19	3	37

TRICHOPTERA. Only four caddis-flies were caught in up-traps on hinau, hard beech, and kamahi.

LEPIDOPTERA. Moths were caught more in up- than in down-traps on all four tree species. Numbers were higher in up-traps, with similar numbers on hinau and hard beech, and more on kamahi than on mahoe.

Caterpillars of 39 different species were caught on the four tree species combined in both up- and down-traps (Table 3). Twenty-two species were caught in up-traps only and nine in down-traps. Numbers of species trapped on mahoe, hinau, hard beech, and kamahi were 19, 21, 19, 10 respectively.

Early-instar puriri moth caterpillars *(Aenetus virescens)* were caught in up-traps on all four tree species in summer and autumn; most were caught on hmau (Fig. 6A). Their occurrence in up-traps helped to clarify stages in its life history (see Grehan, 1981).

Three caterpillars *(Ischalis variabilis, Pseudocoremia aristarcha, P. pelurgata)* that feed on silver fern *(Cyathea dealbata)* and other *Cyathea* spp. (J. S. Dugdale, pers. comm.) were caught in up-traps on mahoe, hinau, and hard beech. Two litter or perched litter feeders, *Gymnobathra* sp. and *Tingena* sp., were caught in down-traps only (Table 3). The occurrence of *Gymnobathra* sp. in a trunk trap is its first arboreal record (J. S. Dugdale, pers. comm.).

HYMENOPTERA. Several species of undetermined wasps were caught in both up- and down-traps on all four tree species, and four species of ants were recorded. Amongst ants *Prolasius advena* was most numerous, being caught in both up- and down-traps on all four tree species (Figs. 6B, 7D). They were most common on hinau. Other ants were caught irregularly on different tree species.

LARVAE. Lepidoptera larvae were identified and their distribution is shown in Table 3. Undetermined Coleoptera, Diptera, and Hymenoptera larvae were caught in both up- and down-traps on all four tree species. Although larvae were caught throughout the sampling period, most occurred in summer and early autumn. Larval numbers were higher on hinau, followed by mahoe, hard beech, and kamahi.

ONYCHOPHORA. One peripatus *(Peripatoides novaezealandiae)* was caught in March 1980 in an up-trap on hinau. Peripatus is usually found in low numbers under moist rotting logs.

TERRICOLAE. Earthworms were caught in both up- and down-traps on all four tree species, with slightly more in down-traps. Fewer were caught in summer than in winter. Higher numbers in down-traps suggests downward movement, perhaps from the epiphytes or from perched litter.

AMPHIPODA. As with earthworms, amphipods (mainly *Orchestia tenuis)* were caught mostly in down-traps on all four tree species.

OSTRACODA. Ostracods *(Mesocypris audax)* were caught in down-traps on hinau and hard beech only. According to Chapman (1961) ostracods are found in forest litter, where they live in the water film around soil particles and feed on fungi, diatoms, or on rotting leaves and twigs. Their occurrence in down-traps suggests that they are also associated with epiphytes or perched litter, and this is believed to be their first arboreal record.

ISOPODA. Woodlice (mainly *Trichoniscus* spp. and *Spherillo* spp.) were caught in both up- and down-traps on all tree species. Most were recorded in down-traps. Numbers caught were higher on mahoe, followed by hinau, hard beech, and kamahi.

CHILOPODA. Centipedes (mostly Geophilidae) were caught on all four tree species, mostly in down-traps.

DIPLOPODA. Millipedes (mostly Sphaerotrichopidae) were caught mostly in down-traps on all four tree speCIes, but in up-traps only on mahoe and hinau. Their numbers were highest on mahoe, followed by hinau, kamahi, and hard beech. Their occurrence in down-traps suggests that they are associated with epiphytes or perched litter in addition to their presence on the forest floor.

GASTROPODA. Snails and slugs were represented by nine and two species respectively. More snails were caught in autumn, winter and spring in down-traps than in up-traps on mahoe, followed by hinau, kamahi, and hard beech. This is perhaps because snails move downwards in cooler months to avoid exposure to windchill in the canopy. Almost all slugs were *Athoracophora bitentaculata,* caught irregularly throughout the sampling period, with a peak in summer (Fig. 6C). The high catches of *A. bitentaculata* in up-traps in the first 1-2 months of trapping suggests that the trees had a localised population which the traps gradually removed. Their distribution in down-traps is shown in Figure 7E.

ACARI. Most of the mites caught in both up- and down-traps on all four tree species were oribatids and prostigmatids. Most mites were caught in up-traps and on hinau and mahoe.

ARANEIDA. Spiders were caught in both traps on all four tree species. Up-traps caught most spiders and the numbers were highest on hinau, followed by hard beech, mahoe, and kamahi. Winter catches were lower than those in other seasons (Fig. 6D). More spiders were caught in the first summer after the traps were put up than in the same period the following year; this suggests that either the summer distribution of spiders between the two years was different or the spiders were distributed locally and their numbers, because of trapping, were reduced in the first year. Spider numbers were significantly correlated ($p < 0.05$, Spearman rank correlation test, $r = 0.694$) with increasing stem circumference when all four tree species were combined.

OPILIONES. Like spiders, harvestmen were caught in both up- and down-traps on all four tree species.

PSEUDOSCORPIONIDEA. One pseudoscorpion was caught in each of the up- and down-traps on mahoe and hinau.

Discussion

Our results show that tree trunks are important links between the forest floor and canopy for many ground-living invertebrates which feed or breed on tree trunks and in the canopy. It is also evident that the movement is seasonal (Figs 3-7), invertebrate activity and reproduction, coinciding with the warmer times of year.

The invertebrates in our study were trapped over much longer periods than reported by Neilsen (1974) on beech *(Fagus silvatica)* trunks in Denmark at latitude 56°N. For example, the weevil *Brachyolus punctatus* was caught in up-traps on mahoe in all months. In contrast, species of weevils reported by Neilsen *(Rhynchaenus fag;* and *Phyllobius argmtatus)* had a much restricted distribution on beech trunks. This extended period of activity of invertebrates in New Zealand is a reflection of the mild oceanic climate.

Constricted activity in invertebrates is associated with increasing latitudes where differences between the colder and warmer months are pronounced. In still higher latitudes invertebrates become dormant for part of the year to cope with the cooler temperatures. This is in contrast with the tropical areas where temperatures change very little seasonally and the invertebrates are usually active throughout the year, sometimes with overlapping populations.

The trunk traps revealed useful information regarding seasonal activity of many species. For example, the two species of stick insect *Acanthoxyla* sp. and *Tectarchus diversus* showed differential emergence and abundance (Fig. 4A, B). Differences in the numbers of two species of cockroach *Celatoblatta* sp. and *Parellipsidion colljllnclum* shows that they vary considerably amongst the two types of traps and tree species (Figs 3A, B; 7A). Johns (1966) reported *P. conjunctum* to occur under the bark of several native trees. However, the list did not include hard beech. The occurrence of *P. conjunctum* on hard beech in our study area of mixed lowland forest throws light on the relationship between vegetation diversity and invertebrate abundance. More diverse habitats such as in Qrongorongo Valley support a greater diversity of invertebrates compared to some offshore islands that we have sampled whose second ary forests were at different developmental stages and supported variably diverse invertebrate faunas.

Although Johns (1966) mentioned that *P. conjunctum* were rarely found on the ground, their occurrence in up-traps (Fig. 3B) 1.5 m above ground suggests that they were moving up from the forest floor. Considerably more *P. conjunctum* were caught in up- than in down-traps, whereas similar numbers of *Celatoblatta* sp. were caught in both trap types.

Differences in the numbers of the cicada *Amphipsalta zealandica* caught in up- traps in the 1980 and 1981 emergence periods (Fig. 4D) show their variable emergence between years. This difference in trunk-trap catches is in agreement with the results of our continuing study of emerging insects in the same area.

The abundance of ground wetas and spiders in up-traps on all four species showed seasonal differences: they were caught more in spring, summer, and autumn than in winter (Figs 3C, 6D). This pattern coincides with their activity on the forest floor as revealed in a study, conducted by us, of ground. dwelling invertebrates by using pit traps in the same study area. Similarly the seasonal distribution of insect larvae on tree trunks coincided with their distribution in the litter samples investigated by us in the same study area.

Lee (1959) reported soil and litter earthworms moving to the surface during heavy rains because of flooding of burrows. Earthworms in our up-traps were perhaps moving upwards to avoid supersaturated forest floor in heavy rains and those caught in down-traps may have been flooded from their perched litter and epiphytic habitats. Their capture was more noticeable in wet periods of the study. Occurrence of earthworms in epiphytes (e.g. *Astelia* spp.) has been reported by Lee (1959).

Catches in the continually-operated trunk traps revealed quantitative information on seasonal abundance and diversity of various invertebrates on the four tree species studied. The traps may also be useful in forest entomology for obtaining quantitative information on the arboreal activity of insects, provided that the traps are used in adequate numbers and on a variety of tree sizes of the same species. In our samples there were large differences in the numbers of some invertebrate species caught in different trunk traps on the same tree species, for example the weevil *Brachyolus punctatus* on mahoe and the ground weta *Hemiandrus furcifer* on hard beech (Appendix 1). This shows either a preference for certain trees or a patchy distribution of invertebrates. Three traps were too few to test the effect of tree circumference on the number of invertebrates caught within and amongst the four tree species.

The 28 orders of invertebrates caught on mahoe, hinau, hard beech, and kamahi combined (Table 4) fell broadly into three trophic levels-herbivores, saprophytes, and predators. Most (21) of them were saprophytes while equal numbers (11) fell into each of the other category (Table 4). These invertebrate orders are wide assemblages with more than one trophic level. However, a large number of invertebrate groups are associated with the dead or decaying organic matter or are predators, which would enable them to live in a wide range of forest habitats.

The foods of six insectivorous birds-riflemen *(Acanthisitta chloris),* hedge sparrows *(Prunella madularis),* whiteheads *(Mohoua albicilla),* grey warblers

TABLE 4. *Invertebrate orders caught on mahoe, hinau, hard beech and kamahi trees in Orongorongo Valley between November 1979 and May 1981 and their trophic level (* =represented in more than one trophic level).*

Herbivore	Saprophyte		Predator
Collembola*	Archaeognatha	Onychophora	Plecoptera*
Plecoptera*	Collembola*	Terricolae	Orthoptera*
Orthoptera*	Blattodea	Amphiphoda	Neuroptera
Phasmatodea	Isopoda	Isopoda	Coleoptera*
Hemiptera	Orthoptera*	Chilopoda*	Diptera*
Thysanoptera*	Psocoptera	Diplopoda	Hymenoptera*
Coleoptera*	Thysanoptera*	Gastropoda*	Chilopoda.
Lepidoptera*	Coleoptera*	Acari*	Acari*
Hymenoptera*	Diptera*	Opiliones*	Araneida
Ostracoda	Trichoptera		Opiliones*
Gastropoda*	Lepidoptera*		Pseudoscorpionidea
	Hymenoptera*		
Summary of invertebrate orders (*n* = 28)			
No. in each trophic level:	11	21	11
No. represented in more than one trophic level:	8	11	8
No. specific to trophic level:	3	10	3

(Gerygone igata), fantails *(Rhipidura fuliginosa),* and pied tits (*Petroica macrocephala)* in the Orongorongo Valley forest included wetas, plant-bugs, beetles, caterpillars, wasps, and spiders (Moeed and Fitzgerald, 1982). Although the species of birds varied considerably as to where they fed in the forest and in the air (also see Gibb, 1961; Gravatt, 1971), there was considerable overlap in the groups of invertebrates eaten. This can now be partially explained by the results of this study, where groups usually associated with the forest floor (e.g. ground wetas, ground beetles, caterpillars, amphipods, ostracods, earthworms, spiders, mites) are shown to be active well above ground level.

Perched leaf litter in epiphytes and in tree cavities provides important habitat for many invertebrates (e.g. some caterpillars, ants, amphipods, ostracods, isopods, earthworms) otherwise associated with the forest floor. This above-ground extension of invertebrates is evident from their presence in down-traps, and the interchange is shown by their catches in up-traps. The seasonal distributions in the traps of *Cetatoblatta* sp., *Brachyolus punctatus,* and *Athoracopphora bitentaculata* indicate broad similarities in activity. Since leaf fall in the Orongorongo Valley forest occurs throughout the year, but mostly in summer and autumn (Daniel, 1975), the arboreal extension of the forest floor as perched litter is continually supplied with fresh material. This explains the pre~ence of other invertebrates, especially ants, in our samples. Native ants live in small colonies in litter on the forest floor where they feed on small arthropods (Don, 1974).

Spiller and Wise (1982) list 11, 5, 1, and 14 insect species in four orders on mahoe, hinau, hard beech, and kamahi respectively. We have considerably extended that list to 72 species, 20 families, and 16 orders of insects (Table 5).

The relationship between invertebrate numbers and tree circumference was examined to see if higher numbers were correlated with increasing circumference or vice versa. Because of small differences in the range of circumference and, in addition, large differences in invertebrate numbers within and between tree species (Table 1), the results were inconclusive. However, when this aspect was examined for a generalised predator groups, e.g. spiders, their numbers were significantly correlated with increase in trunk circumference.

The knowledge we have gained on the biology and behaviour of the early instars of the puriri moth suggests an interesting evolutionary possibility. The larva is a wood borer of several native and introduced trees. (Miller, 1971) but not previously recorded

TABLE 5. *Number of insects recorded on mahoe, hinau, hard beech and kamahi trees in this study and by Spiller and Wise (1982) (*).*

	Mahoe			Hinau			Hard beech			Kamahi		
Insects	Sp. *	Fam.	Sp.	Sp. *	Fam.	Sp.	Sp. *	Fam.	Sp.	Sp. *	Fam.	Sp.
Archaeognatha		1			1							
Collembola		3			3			3			3	
Blattodea			2			2			2			2
Isoptera									1			
Plecoptera		1										
Orthoptera	3		6			5			3			4
Phasmatodea			2			2			2			2
Psocoptera		1			1			1			1	
Hemiptera	3	3	3	5	3	3	1	3	3	12	3	1
Thysanoptera		1			1			1			1	
Neuroptera		1			1			1				
Coleoptera			24			35			34			18
Diptera	1	4			4			4			4	
Trichoptera					1			1			1	
Lepidoptera	4		19			21			19	2		10
Hymenoptera	4		4		4	4		4	3		4	1
Total	11	19	60	5	20	72	1	19	67	14	18	38

on mahoe hinau or kamahi as reported here. Grehan (1981) described a three-phase larval life history, with a litter phase, transfer phase, and a tree phase. With the exception of two first-instar (litter-phase) specimens, the larvae we caught in trunk traps belonged to the transfer phase. The litter-phase larvae are found on dead wood and fungi, while the tree-phase larvae live in certain species of trees. Since none of the trees on which we caught puriri moth larvae are known hosts we suggest that after an initial development as generalist feeders in litter and on fungi the larvae in the transfer phase move widely to explore the habitat for suitable host plants while they are still generalist feeders. Being a generalist feeder would help in maintaining the energy requirement when searching for host trees. Grehan (1981, Fig. 2) described transfer-phase larvae as distinct in colour pattern with a striped appearance of alternating yellow-white and dark bands. This cryptic appearance is likely to conceal the caterpillars and enable them to avoid predation when most vulnerable. Transformation info tree-phase larvae occurs after they find a host.

To summarise, it appears that in the lowland forests of New Zealand the invertebrates (e.g. ground wetas, ground beetles, some caterpillars, amphipods, spring-tails, mites, and earthworms) show a remarkable generality in the use of habitat and its resources. This seems in agreement with Elton (1966, 1971) who, while studying insects in a wide range of forests in Great Britain, expressed the view that although some herbivorous animals are restricted to certain species of plants, a majority of saprophytes and predators have a varied food habit and occupy a range of habitats.

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APPENDIX 1

Number of invertebrates caught in up- and down-traps on mahoe, hinau, hard beech and kamahi trees between November 1979 and May 1981 inclusive

Invertebrates	Mahoe		Hinau		Hard beech		Kamahi	
Trap:	Up	Down	Up	Down	Up	Down	Up	Down
Archaeognatha	1	9	1	5	1		2	3
Collembola								
Poduridae	78	15	162	18	8	6	9	4
Sminthuridae	970	146	2130	106	165	180	174	73
Entomobryidae	414	40	890	39	28	22	48	13
Blattodea indet.	2		1	5	3		3	
Celatoblatta sp.	12	3	39	34	3	5	4	6
Parellipsidion conjunctum	43	3	285	15	36	4	28	1
Isoptera						5		
Plecoptera	2		13		6		4	
Orthoptera indet.	29	18	91	44	111	42	43	4
Hemiandrus furcifer	14	1	45	2	709	14	53	2
Hemideina crassidens	16		43	1	21	3	6	
Pachyrhamma longipes			2				2	
Pallidoplectron sp.							2	
Pleioplectron hudsoni	1							
Zealandosandrus gracilis	1		1					
Phasmatodea indet.			3		2			
Acanthoxyla sp.	3	1	28	3	7		16	1
Tectarchus diversus	9		21		13		9	
Psocoptera	64	5	84	13	71	4	18	1
Hemiptera indet.	94	12	148	27	72	26	36	7
Aka finitima	21	1	65		66		29	
Amphipsalta zealandica	3		50		27			
Kikihia scutellaris	19	2	24		2			
Thysanoptera	20	12	12	4	5	2	1	4
Neuroptera			1		1			
Coleoptera indet.	225	31	445	68	126	79	56	20
Carabidae								
Amarotypus edwardsi	4		5		1	2		
Demetrida nasuta						2		
Mecodema simplex								1
Oopterus laevicollis		6		10	1	6		1
Zolus carinatus		3	1	8	1	1		
Hydrophilidae								
Rygmodus modestus			4					
Lucanidae								
Ceratognathus parryi			1					
Dorcus novaezelandiae	1			1				
Lissotes reticularis	4	7	8	8	2	15	1	7

Invertebrates	Mahoe		Hinau		Hard beech		Kamahi	
Trap:	Up	Down	Up	Down	Up	Down	Up	Down
Scarabaeidae								
Sericospilus costella		1	17	6	1	4		
Dascillidae								
Atopida tricostellus					1	3	1	
Mesocyphon marmoratus	3	7	24	7	2	1	1	1
Buprestidae								
Nasioides enysii						1		
Elateridae								
Geranus lineicollis			2					
Metablax brouni	2				1			
Metablax cinctiger			1		1			
Trogossitidae								
Leperina nigrosparsa			2					
Cleridae								
Balcus signatus			1					
Paupris aptera	2		4		12		7	
Coccinellidae								
Leis antipodarum					2			
Tenebrionidae								
Artystona sp.	3				1			
Minopeus opaculus						6		
Pheloneis sp.						1		
Syrphetodes marginatus	1	2		22	1	2		
Oedemeridae								
Thelyphassa lineata			2		1			
Thelyphassa stringipennis	6		8		4		1	
Cerambycidae								
Blosyropus spinosus	2		1		1		1	
Calliprason sinclairi			1					
Hexatricha pulverulenta			5					
Ochrocydus huttoni					6			
Oemona hirta	1		2		1			
Poecilippe flavipes					3			
Somatida antarctica	5	1	12	6	3	9		2
Stenellipsis bimaculata	4		9		4		3	
Stenellipsis latipennis			2	1				
Votum mundum							2	
Xuthodes batesi			1					

Invertebrates	Trap: Mahoe Up	Mahoe Down	Hinau Up	Hinau Down	Hard beech Up	Hard beech Down	Kamahi Up	Kamahi Down
Xyloteles humeratus	4		4		6		1	
Chrysomelidae								
Luperus vulgaris	8		12	2	1		1	
Brenthidae								
Lasiorrhynchus barbicornis		1	6	2				
Curculionidae								
Anagotis helmsi				1				
Brachyolus punctatus	2344	101	3	7		1		
Crisius binotatus	10		21	2	8		6	
Microcryptorhynchus horridus	3		12					
Platyomida hochstetteri			32	2	18		5	
Platypus apicalles				2		8		
Psepholax sp.	2		12		17		2	
Ryncodes ursus						1	1	
Scolopterus tetracanthus	1				1			
Sympedius costatus					1			
Diptera indet.	35	9	64	11	33	6	28	4
Acalyptrate	277	42	365	31	230	28	68	10
Tipulidae	20	24	86	16	72	11	18	3
Calliphoridae	3	1	8	2	6	2	6	1
Trichoptera			2		1		1	
Lepidoptera indet.	28	3	111	4	107	8	45	5
Aenetus virescens	7		53		8	2	4	
Hymenoptera indet.	70	15	132	28	45	16	20	7
Amblyopone saundersi			3					

Invertebrates	Trap: Mahoe Up	Mahoe Down	Hinau Up	Hinau Down	Hard beech Up	Hard beech Down	Kamahi Up	Kamahi Down
Huberia striata	1		3		1	1		
Mesoponera castanea	1		4		9	2		
Prolasius advena	347	9	703	37	11	4	13	2
Insect larvae*	138	246	243	166	57	94	41	19
Onychophora			1					
Terricolae	20	13	6	5	1	26	5	10
Amphipoda	19	145	12	29	25	30	21	26
Ostracoda				1		1		
Isopoda	3	173	7	62	1	15	3	2
Chilopoda	5	15	8	8	2	17	3	4
Diplopoda	1	28	2	18		6		10
Gastropoda indet.	6	8	4	8		2	3	
Athoracophora bitentaculata	15	20	38	22	2	6	5	1
Charopa coma	2	8	2	9				1
Charopa pilsburyi				1				
Flammulina perdita	1	1		8				2
Laoma mariae		1						
Phenacharopa novoseelandiae		2					1	
Phenocohelix stokesi		1	1	4		1		1
Punctidae sp.		44		11				
Pseudomeitea aspera				1				
Rhytida urnula				1				
Acari	479	358	569	222	94	98	50	36
Araneida	312	84	777	109	486	92	206	36
Opiliones	35	54	141	127	46	6	4	3
Pseudoscorpionidea	1	1	1	1				

*Excluding Lepidoptera