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An appraisal of simple tree-mounted shelters for non-lethal monitoring of weta (Orthoptera: Anostostomatidae and Rhaphidophoridae) in New Zealand nature reserves

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Abstract

When monitoring rare insect species, or when surveying faunas within nature reserves, it is desirable not to use indiscriminate lethal sampling techniques. In this investigation we assessed the usefulness of simple tree-mounted wooden shelters to monitor endemic weta (Orthoptera) in nature reserves in Canterbury, New Zealand. Fifty shelters were placed out at six sites and examined at three-monthly intervals for a year. A wide variety of invertebrates were found utilizing the shelters, with Arachnida, Blattodea and Collembola being the most common occupants. After three months over 80% of the shelters exhibited signs of use by invertebrates, increasing to 96% after 12 months. Only seven tree weta (Anostostomatidae) and one (dead) ground weta (*Hemiandrus* sp.) were observed in the shelters over the full 12 month period. There were 52 observations of cave weta (Rhaphidophoridae) in the shelters, 36 of which occurred at one site, Orton Bradley Park. Occupation of the shelters by cave weta was not affected by soil conditions, light intensity or aspect of the shelter. However, cave weta exhibited a preference for shelters less than 50 cm above the ground and for shelters attached to kanuka and vines. Although weta were found in only a small proportion (9%) of the shelters, this method proved useful in confirming the presence of weta without risk of harming vulnerable populations. These shelters are inexpensive and easy to manufacture and have potential for long-term non-lethal monitoring of weta and as a collection/carriage device for live specimens used in conservation translocations.

Introduction

Arthropods, and the composition and structure of their communities, provide valuable indicators for biodiversity assessment and for monitoring the 'success' of sustainable agricultural practices and conservation management (Keesing and Wratten 1998; McGeoch 1998; Ward and Laviere 2004). Arboreal arthropods form an easily-defined unit for study and have been used to examine fundamental ecological themes such as the trophic structure of assemblages and species-abundance relationships (e.g. Basset and Arthington 1992; Hodge et al. 2001; Southwood et al. 2005). A subset of the arboreal arthropod community involves those species that utilize tree cavities, such as holes made by animals, cracks in the tree's bark and natural hollows (e.g. Bennet et al. 1994; Ranius and Nilsson 1997; Ranius 2002). Weta (Orthoptera: Anostostomatidae and Rhaphidophoridae) are large, flightless insects that utilize such tree cavities. There are over 70 species of weta in New Zealand, all endemic, at least 16 of which are considered to be at risk (Anonymous 2005). As well as the intrinsic value of studying the ecology and behaviour of weta to increase knowledge and provide information helpful towards their conservation, their large size, endemism and general scarcity have promoted their use as indicators for monitoring the 'health' of forest ecosystems in New Zealand (Spurr and Drew 1999; Spurr and Berben 2004).

Although broad spectrum techniques for arthropod monitoring, such as Malaise and pitfall trapping, ensure rapid acquisition of substantial collections, these lethal trapping techniques can prove counter-productive when investigating sites and/or taxa of conservation importance (Southwood 1978; Ausden 1996; Spear 2004). Non-lethal sampling is an important aspect of conservation genetics (e.g. Lushai et al. 2000; Holehouse et al. 2003) and the development of non-lethal, discriminate, population census techniques is of general conservation importance. For insects, timed hand searches and transect sampling can be useful, especially when assessing populations of large, active, readily-identified insects such as butterflies (Lepidoptera) and dragonflies (Odonata) (Pollard 1991; Brooks 1993). Another group of non-lethal methods that provides standardized arthropod samples involves 'shelter traps' or 'artificial retreats' (Southwood 1978). These shelters range from 'cryptozoa boards' used to sample epigeal animals, through to commercially-produced insect 'houses' used to attract and accommodate beneficial predatory insects (e.g. Coccinellidae and Neuroptera) and species of conservation value (Carabidae, weta, bumble and mason bees) (Cole 1946; Trewick and Morgan-Richards 2000; Mann 2002; Abell 2003; Bowie and Frampton 2004; Samways 2005).

Artificial shelters have provided a useful technique for studying populations and behaviour of weta, often involving elaborate free-standing weta 'roosts', with multiple galleries and a range of entrance sizes (Ordish 1992; Trewick and Morgan-Richards 2000; Spurr and Berben 2004). Kelly (2005) reported that Wellington tree weta (*Hemideina crassidens* (Blanchard)) readily inhabited abandoned bird nest-boxes and Trewick and Morgan-Richards (2000) suggested that simple, single-holed refuges, placed directly onto trees may be a fruitful approach for weta population assessment. Our aim was to assess the usefulness of such tree-mounted shelters as a means of non-lethal monitoring weta in conservation and restoration sites in Canterbury, New Zealand, and investigate the effect of tree species, height of shelter from the ground and other environmental factors on shelter occupation.

Methods

Shelters were constructed from blocks of untreated pine wood ($45 \times 45 \times 150$ mm) cut with a 30° 'roof' (Figure 1). A central groove (18×18 mm) was cut two-thirds down the length of the block using a router. Transparent acetate was stapled over the groove as a window to enable the occupants to be viewed rapidly. Black polythene was stapled over the window to prevent light from entering when the shelter was in position, and could be folded back to view any occupants when required. A plastic cover was stapled to the top of the shelter to reduce rain damage to the wood. The shelters were attached to trees using plastic-coated wire, so that the grooved side was firmly against the trunk of the tree, creating an 18×18 mm entrance hole at the bottom. The height of the shelter from the ground was then recorded.

The shelters were placed out at six nature reserves in Canterbury, New Zealand: Hinewai Reserve (43.81687S, 173.02254E), Orton Bradley Park (43.67042S, 172.71387E), Quail Island (43.63103S, 172.69008E), Ahuriri Scenic Reserve (43.66375S, 172.61782E), Travis Swamp (43.48647S, 172.68791E) and View Hill (43.28676S, 172.07572E). These sites ranged greatly in the plant species present and the quality of forest remnant. Quail Island, which is currently being ecologically restored (Bowie et al. 2003), contained the fewest native tree species, whilst Hinewai Reserve (Ward et al. 1999) and Ahuriri Scenic Reserve (Butcher and Emberson 1981) had the most diverse floras. At each site, five tree species were chosen (where possible) and replicated at least 10 times, giving a total of 50 shelters per site.

The shelters were attached to trees in spring 2000 (between 28th August and 17th October) and

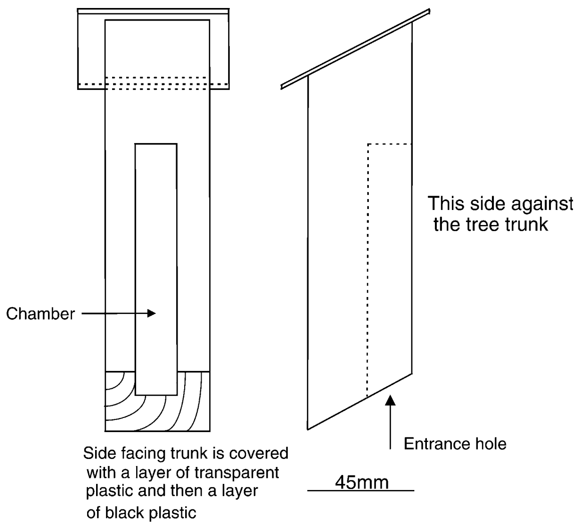

Figure 1. Back and side elevation of the wooden shelter used in this study. Viewing window and black plastic 'blind' have been removed for clarity.

checked at approximately 3 monthly intervals for 12 months. On the first three sampling dates, the occupants of each shelter were identified *in situ* to the best of our ability. On the final 12-month sampling date (spring 2001) voucher specimens were collected into 70% ethanol and returned to the laboratory to confirm our identifications.

For each shelter a number of environmental factors were measured. These were: light intensity at the face of the shelter (Yew 3281; Yokogawa lux meter), moisture of the soil at the base of the tree (Hydrosense, Campbell Scientific, Australia), ground slope (using a clinometer), ground cover (i.e. percent area leaf litter, bare ground, vascular plants) and the depth of loose litter above firm soil. The aspect of the shelter was measured using a compass and each shelter classified as facing north (315–44°), east (45–134°), south (135–224°) or west (225–314°).

Results

Weta

Of the 300 shelters used, only 27 (9%) were found to contain live weta during the course of the investigation (Table 1). The seven tree weta (Anostostomatidae) were found in shelters attached to three different tree species: the four *Hemideina femorata* (Hutton) at View Hill were found in shelters attached to vines (*Parsonsia* sp.) whereas the single *H. femorata* at Orton Bradley Park was found in a shelter attached to kanuka (*Kunzea ericoides*). The two observations of *Hemideina ricta* Hutton at Hinewai occurred in the same shelter attached to a pepperwood tree (*Pseudowintera colorata*).

Fifty two cave weta (Rhaphidophoridae) were observed in the shelters, the majority (69%) of which was found at Orton Bradley Park (Table 1). A number of shelters housed more than one individual or had cave weta present on subsequent visits: for example, the 36 cave weta observations at Orton Bradley Park were made in only 15 of the 50 shelters. There were significant seasonal differences in the number of cave weta observed ($\chi^2 = 11.2$, $df = 3$, $p < 0.025$) with peak occupancy (21) occurring in the autumn samples. The lowest numbers of cave weta (5) were observed after the shelters had been in position for 12 months, in the spring 2001 samples.

Because sample sizes were small at the other five sites, the influence of the various environmental factors on occupancy was assessed using cave weta (*Isoplectron aciculatum* Karny) in the shelters at Orton Bradley Park. Each shelter was classified for the presence or absence of cave weta occurring at any time during the monitoring period and to whether the value of each environmental factor was below (or equal to) the median value of that factor (at Orton Bradley Park). This produced a series of 2×2 contingency tables that could be analyzed using chi square tests. Ground cover, litter depth, soil moisture and light levels all had no effect on the levels of occupancy by cave weta (Table 2). There was also no association between the direction the shelter was facing and occupation by cave weta ($\chi^2 = 0.8$, $df = 3$, $p > 0.75$). Cave weta were, however, significantly more likely to occupy shelters where the ground slope was low and to occupy shelters set below 50 cm in height (Table 2).

Cave weta occurred in shelters on all four of the tree classes used at Orton Bradley Park: mahoe (*Melicytus ramiflorus*), kowhai (*Sophora microphylla*), kanuka (*Kunzea ericoides*) and 'vines' (*Parsonia* sp, *Rubus* sp). In terms of the proportion of shelters occupied, there appeared a slight preference for shelters attached to kanuka and vines (Figure 2: $\chi^2 = 6.7$, $df = 3$, $p = 0.08$). If actual numbers of

Table 1. Total observations of weta in artificial tree-mounted shelters at six sites in Canterbury, New Zealand. Number given is the total weta observed from 200 trap-visits per site.

	Species	Ahuriri	Hinewai	OB Park	Quail Is.	Travis	View Hill	Total
Tree weta	*Hemideina femorata*	–	–	1	–	–	4	5
	Hemideina ricta	–	2	–	–	–	–	2
Cave weta	*Isoplectron aciculatum*	–	–	36	–	5	–	41
	Pleioplectron simplex	–	2	–	–	–	9	11
Ground weta	*Hemiandrus* sp.	–	–	1*	–	–	–	1
	Total	0	4	38	0	5	13	60

*Found dead in shelter.

weta were considered then the bias towards those shelters attached to kanuka was even more pronounced Figure 2: $\chi^2 = 15.9$, $df = 3$, $p < 0.005$).

Other invertebrate taxa

After 3 months, 80% of the shelters showed signs of use by invertebrates (e.g. live specimens, exuvia, spiders webs, egg sacs, etc) and this remained more or less constant through the remaining three seasons ($\chi^2 = 3.4$, $df = 3$, $p > 0.3$). After the final (12 month) assessment, only 12 of the 300 shelters had never shown signs of invertebrate use.

A diverse array of taxa were found in the shelters, with Arachnida, Blattodea, Collembola and Lepidoptera (adults and larvae) being the most commonly encountered (see Appendix). A number of species of endemic slugs (Athoracophoridae) were found, including some that had oviposited in the shelters. Also of note was the carabid beetle *Dromius meridionalis* Dejean found at Travis Swamp which was previously unrecorded in New Zealand (A. Larochelle, pers. comm.). Spiders accounted for around 90% of the live occupants, and an important finding was adult male *Nuisiana arboris* (Marples) which had previously been known only from female specimens in New Zealand (Forster and Wilton 1973).

Weta were found cohabiting in shelters with a number of these other invertebrate taxa. *Hemideina femorata* was found with the tenebrionid beetle *Artystona wakefieldi* Bates and *H. ricta* was found with the agelenid spider *Neoramia janus* (Bryant). Of the cave weta, *I. aciculatum* was found sharing shelters with the spiders *Theridion zantholabio* Urquhart and *Cambridgea ambigua* Blest and Vink. Tree weta and cave weta were also found together in shelters.

Discussion

Using this non-lethal census technique identified differences in the numbers and species of weta occupying the shelters at different nature reserves and at different times of the year. No weta were observed in the shelters placed out at Ahuriri and Quail Island even though species of cave and ground weta have previously been recorded at

Table 2. Association of shelter occupancy by cave weta (*Isoplectron aciculatum*) with levels of environmental parameters at Orton Bradley Park ($N = 50$).

Variable			Shelters occupied (%)			
	Range	Median	≤ Median	> Median	χ^2	*p*
Height (m)*	0.11–1.63	0.49	45	15	4.29	<0.05
Light (lux)	15–3000	500	23	38	1.24	n.s.
Slope (degrees)	0–78.5	26.5	44	16	4.67	<0.05
Soil Moisture (g water/100cc soil)	15–62	30	39	21	1.85	n.s.
Litter depth (cm)	1–4	1	30	31	0.01	n.s
Litter cover (%)	0–100	75	23	38	1.24	n.s.
Vascular plant cover (%)	0–100	0	32	27	0.14	n.s.
Bare ground (%)	0–90	5	31	29	0.02	n.s.

*Based on sample of 40 shelters for which height data were available.

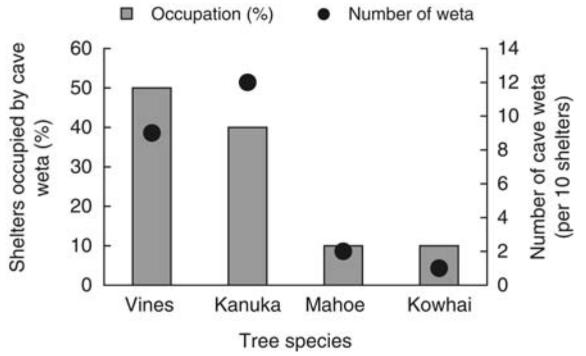

Figure 2. The influence of tree species on numbers of cave weta observations and levels of shelter occupation at Orton Bradley Park.

both of these sites (Bowie et al. 2003). Although Quail Island is considered floristically poor, with weta numbers depressed due to predation by exotic predators, Ahuriri is considered one of the finest remaining stands of native forest on the Port Hills (Kelly 1972). Only a small proportion of the total shelters were utilized by weta and it is important to separate low occupancy caused by small population size from that caused by a reluctance of the animals to enter the refuges. The shelters were inhabited by all of the cave and tree weta species that occur in this region of New Zealand (Peter Johns, pers. comm.) suggesting that individuals of at least these four species can find the shelters acceptable.

The lack of shelter occupation may reflect an excess of available refuges (shelters and natural galleries) relative to weta population densities: a large proportion of natural galleries are also often found unoccupied (Field and Sandlant 2001). Another factor may be that initial colonization of artificial shelters can be slow and they have been perceived as being of more use as a long term monitoring tool than a short term sampling technique (Trewick and Morgan-Richards 2000). However, in our study there was no increase in weta occupation as the study progressed and, although it is conceded that 12 months may not be sufficient time for weta numbers to stabilize, the number of shelters unoccupied by weta was still of concern.

Weta can locate galleries by reacting to volatiles emitted from damaged wood or from the animal making the hole (e.g. the kanuka long-horn beetle, *Ochrocydus huttoni* Pascoe (Field and Sandlant 2001)). Shelters made from exotic pine wood may lack the specific volatiles to which weta respond and using native woods to manufacture the shelters may make them more attractive. Chemicals emitted by weta faecal pellets are used by conspecific weta for gallery location and may explain why Trewick and Morgan-Richards (2000) found larger numbers of weta in their condominium style shelters compared to those used in our study (Field and Sandlant 2001). Thus, attaching our shelters, or several shelters, on trees already inhabited by weta may lead to an increase in shelter use.

Field and Sandlant (2001) suggested that, for tree weta at least, there appeared little preference for any particular tree species and galleries were exploited opportunistically wherever they occurred. However, in our study there was some tentative indication that cave weta at Orton Bradley Park exhibited a preference for shelters on kanuka and vines. Previous investigations demonstrated a positive association between the tree weta *Hemideina femorata* and kanuka (Townsend et al. 1997) and may be due to weta actively searching for natural holes made by the kanuka long-horn beetle.

Although factors such as ground structure, light and shelter aspect appeared not to influence occupation (c.f. Townsend et al. 1997), there was some indication that cave weta preferred shelters low down on the tree and on a gentle slope. When cave weta search for a gallery they often do so from the forest floor, walking up the trunk starting from the base, and it is possible they happen upon these low shelters more readily than shelters higher up the tree. Rufaut and Gibbs (2003) also found patterns in the vertical distribution of weta in natural galleries, with *Hemideina crassidens* appearing to colonize galleries lower down on trees once predation pressures had decreased due to pest control measures. Investigation of the vertical distributions of weta is an area where the use of these small shelters could prove valuable, especially if it was demonstrated that the distribution of weta in natural galleries exhibited similar patterns.

Another method of increasing the number of weta occupants may be to use vegetable baits (see Hodge and Standen 2006). Spurr and Berben (2004) reported 12 species of weta found on carrot/cereal baits and Bowie and Ross (unpublished) found cave and ground weta strongly attracted to cereal baits in field surveys and laboratory bioassays. Baiting may attract other types of invertebrate detritivores, as well as rodents and other predators. However, if the increases in weta occupation are substantial then these potential problems may be acceptable.

A wide variety of other invertebrate taxa were found in the shelters, many of which were also noted in previous studies of artificial weta roosts (Trewick and Morgan-Richards 2000; Spurr and Berben 2004). Weta were found cohabiting with a number of other taxa, a phenomenon also observed in natural galleries by Field and Sandlant (2001), and considerable potential exists for the use of these shelters to investigate the interactions between these taxa in more detail.

Potential application of shelters as a conservation tool

Weta have become icons for invertebrate conservation in New Zealand (Sherley 1998; Anonymous 2005), in part because of their charismatic nature and place in New Zealand folklore (e.g. Gibbs 1994), and Sherley (2001) suggested that further research was required on translocation methods for weta. By reducing the entrance hole size to 14 mm diameter to exclude mice and removing the acetate 'window' so that the gallery was surrounded by wood on all sides, weta occupation rates of 64% have been achieved at some sites (Bowie, McCaw and Evans, unpublished). The success of the modified shelters has enabled the 'capture' and translocation of 28 Banks Peninsula tree weta (*H. ricta*) to Quail Island. The shelters form a safe means of carriage for the weta between sites and reduce the incidence of transit mortality. By marking the weta, further information on the ecology and site fidelity of weta can be obtained. Indeed, without marking individuals it was impossible to tell in the current investigation whether weta observed in the same shelter on different occasions represented repeat observations of the same individual. The use of mark and recapture techniques, along with more regular shelter visits, would be a valuable addition to the information obtained from future artificial shelter studies and help to estimate population densities, site faithfulness and migration distances (see Jamieson et al. 2000; Joyce et al. 2004; Spurr and Berben 2004).

Conclusions

Although the numbers of weta in the refuges were low, we feel this form of artificial shelter still warrants further inquiry. The lack of weta utilizing the shelters at sites where they are known to occur emphasizes the point that refuges should be used in conjunction with other census techniques and, where possible, behavioural observations to establish whether vacant shelters are due to low population numbers, an excess of natural galleries or a reluctance of the animals to occupy the refuges. Utilizing information acquired in the current investigation might enhance levels of weta occupation in future studies. By attaching shelters, or several shelters, on trees already inhabited by weta, low down, on trees of preferred species and possibly utilizing some initial baiting, the levels of shelter occupation may be increased. The relationship between occupancy rates and height of the shelter from the ground needs clarification and further study to see whether this pattern is general to other sites and other species of weta and also whether the patterns seen in the shelters reflect the height distribution of weta in natural galleries. The shelters are cheap and relatively simple to manufacture and by incorporating mark-recapture techniques with more regular inspections information on site fidelity and home ranges can be obtained. The shelters have proven to be a valuable collection method for live weta and as a carriage device for use in translocations in support of conservation restoration.

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Appendix

Taxa observed using tree-mounted artificial shelters in Canterbury, New Zealand, plus sites where each taxon was observed (AH - Ahuriri; H - Hinewai; OB - Orton Bradley Park; QI - Quail Island; TS - Travis Swamp; VH - View Hill). † =often found dead in the shelters in spider webs; * = first New Zealand record

BLATTODEA. BLATTELLIDAE: *Parellipsidion pachycercum* Johns (OB,VH). BLATTIDAE: *Celatoblatta 'peninsularis'* (QI). *Celatoblatta vulgaris* Johns (VH). **COLEOPTERA.** ANTHRIBIDAE: *Cacephatus incertus* (White) (VH). CARABIDAE: *Agonochila antipodum* Bates (QI). *Dromius meridionalis* Dejean* (TS). CLERIDAE: *Paupris aptera* Sharp (VH). COCCINELLIDAE: *Rhyzobius ?forestieri* (Mulsant) (OB,QI). CORTICARIIDAE: *Aridius nodifer* (Westwood) (AH). CORYLOPHIDAE: *Anisomeristes* sp. (OB). CURCULIONIDAE: (H). DERMESTIDAE: (TS). ELATERIDAE: "*Ctenicera*" sp. (H†). LUCANIDAE: *Paralissotes reticulatus* (Westwood) (VH). NITIDULIDAE: *Platipidia ?asperella* Broun (VH). TENEBRIONIDAE: *Artystona rugiceps* Bates (QI). *Artystona wakefieldi* Bates (OB,VH), *Mimopeus granulosis* (Breme) (OB†). SCARABAEIDAE: *Costelytra* sp. (OB†). **DIPTERA.** PSYCHODIDAE: (TS). SCIARIDAE: (TS). TIPULIDAE: (TS†,OB†). **HEMIPTERA.** PSYLLIDAE: (QI). LYGAEIDAE: (VH†). MARGARODIDAE: *Coelostomidia zealandica* (Maskell) (QI). **HYMENOPTERA.** SCELIONIDAE: *Baeus*? sp (QI,OB). **LEPIDOPTERA.** GEOMETRIDAE: *Cleora scriptaria* Walker (TS). NOCTUIDAE: *Bityla defigurata* Walker (VH). TORTRICIDAE: (H). **NEUROPTERA.** HEMEROBIIDAE: *Micromus tasmaniae* (Walker) (VH). **ORTHOPTERA.** ANOSTOSTOMATIDAE: *Hemiandrus* sp. (OB). *Hemideina femorata* (Hutton) (OB,VH). *Hemideina ricta* Hutton (H). RAPHIDOPHORIDAE: *Isoplectron aciculatum* Karny (TS,OB). *Pleioplectron simplex* Hutton (H,VH). **ARANEAE.** AGELENIDAE: *Neoramia janus* (Bryant) (AH,OB,H,VH,TS). *Neoramia setosa* (Bryant) (OB). AMAUROBIIDAE: (OB). AMPHINECTIDAE: *Maniho ngaitahu* Forster & Wilton (H). ARANEIDAE: *Eriophora pustulosa* (Walckanaer) (QI,TS). CLUBIONIDAE: *Clubiona convoluta* Forster (TS). *Clubiona huttoni* Forster (QI). *Clubiona peculiaris* L. Koch (QI). CYCLOCTENIDAE: (AH). DESIDAE: *Badumna insignis* (L. Koch) (TS). *Matachia* sp. (VH), *Nuisiana arboris* (Marples) (AH,OB,H,VH). GNAPHOSIDAE: *Hemicloea rogenhoferi* L. Koch (QI). *Taieria erebus* (L. Koch) (VH), *Taieria kaituna* Forster (AH,H). HEXATHELIDAE: *Porrhothele antipodiana* (Walckenaer) (AH,H). ORSOLOBIDAE: (H). SALTICIDAE: *Trite auricoma* (Urquhart) (TS). STIPHIDIIDAE: *Cambridgea ambigua* Blest & Vink (QI,TS,VH). *Cambridgea peelensis* Blest & Vink(VH), *Cambridgea quadromaculata* Blest & Taylor (AH,VH,H). THERIDIIDAE: *Achaearanea veruculata* (Urguhart) (QI,TS,OB, VH). *Rhomphaea* sp. (OB), *Steatoda capensis* Hann (QI), *Theridion zantholabio* Urquhart (AH,H,OB, VH,QI). ZOROPSIDAE: *Uliodon* sp. (VH). **AMPHIPODA.** TALTRICIDAE: (AH). **DIPLOPODA.** DALODESMIDAE: *Icosidesmus* sp. (QI,OB,AH). **ISOPODA.** PORCELLIONIDAE: *Porcellio scaber* Latreille (TS,VH). **MOLLUSCA.** ATHORACOPHORIDAE: *Athoracophorus bitentaculatus* (Qu. & Gaim.) (AH). *Pseudaneitea aspera* Burton (VH). *Pseudaneitea maculata* Burton (OB) Unidentified species (H). CHAROPIDAE: (AH). **TUBELLARIA.** GEOPLANIDAE: (AH,H).

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