Invertebrates seen on cereal baits

A study of video and manual observation methods

SCIENCE FOR CONSERVATION 137

M.D. Wakelin

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DOC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed.
Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

ISSN 1173-2946
ISBN 0-478-21869-9

Cataloguing-in-Publication data
Wakelin, M. D.
Invertebrates seen on cereal baits : a study of video and manual observation methods / M.D. Wakelin. Wellington, N.Z. : Dept. of Conservation, 2000.
1 v. ; 30 cm. (Science for conservation, 1173-2946 ; 137).
Includes bibliographical references.
ISBN 0478218699
1. Invertebrates-New Zealand. 2. Pests-Control-New Zealand. 3. Sodium fluoroacetate. I. Title. Series: Science for conservation ; 137.

CONTENTS

Invertebrates seen on cereal baits: A study of video and manual observation methods

M.D. Wakelin

Science & Research Unit, Department of Conservation,
PO Box 10-420, Wellington, New Zealand.

ABSTRACT

A video observation method and a manual observation method of determining which invertebrates are at risk from pest mammal control programmes were trialled at Otari Native Botanic Garden, Wellington, New Zealand, during 10 days in July 1998. The effort required and the invertebrates recorded by each method were compared, and analysed with regard to weather conditions, date and time. The number and diversity of invertebrates observed were lower using the video method, partly because more invertebrates hide underneath the bait. No disturbance effect was found with the manual observation method. The number of invertebrates found on baits varied and was correlated with litter depth and temperature. A broad range of invertebrates are reported to visit baits and are thus potentially at risk when 1080 is used for poisoning operations. The implications and considerations for future monitoring work are discussed.

Keywords: video monitoring, invertebrates, baits, 1080, Otari Native Botanic Garden, Wellington, New Zealand

Wakelin, M.D. 2000. Invertebrates seen on cereal baits: A study of video and manual observation methods. *Science for Conservation 137*. 35 p.

1. Introduction

1.1 BACKGROUND TO 1080 USE AND RESEARCH

Sodium monofluoroacetate (compound 1080) has been extensively used in New Zealand for the control of vertebrate pests (Eason 1997). In general, the Department of Conservation pest mammal control operations use cereal baits at 0.15 % w/w 1080, aerially sown at 3–10 kg of bait per hectare, once during winter months (Eason 1997).

There is concern in the community as to the effects of such operations (Fraser et al. 1995, Annabell 1995, McLauchlan 1995). 1080 is less frequently used in countries other than New Zealand, and non-target poisoning is rarely studied. In New Zealand, the effect of 1080 poisoning operations on invertebrate populations has been investigated with cereal (Spurr 1994b, 1996) and carrot baits (P. Aspin pers. comm.). None of the above studies involved determining whether invertebrates used baits.

Sherley et al. (1999) and S. McQueen (pers. comm.) have conducted studies to determine which invertebrates used baits and the effect of 1080 on their numbers. The intensive effort and time required for such studies, variation in observer accuracy and the possibility of disturbing invertebrates on the baits are identified as possible limitations. Use of video recorders was proposed as an easier and less disruptive means of determining invertebrates at risk from poisoning (B. Lloyd pers. comm.). Video could also determine how invertebrates were using the baits and for how long.

The aim of the project at Otari was to compare the video monitoring and manual observation methods, in terms of the accuracy of the data from each and the amount of effort required in obtaining it. Additional information was collected, such as the duration of individual invertebrate visits, factors that affect invertebrate activity, and variation with weather conditions, time of night, and depth of leaf litter. Research involving 1080 and invertebrates is reviewed, and the taxa at risk from 1080 operations are summarised and discussed.

2. Study site

2.1 LOCATION

The Otari Native Botanic Garden in the Kaiwharawhara Valley, Wellington, New Zealand, was chosen as an area of relatively intact native forest with ease of access (Figure 1) in which to undertake the study.

Otari consists of 75 ha of mature and regenerating forest, on a shallow colluvium—Korokoro soil type over greywacke (W.C.C. 1996). Most of the valley was deeded to families of local pa in 1847 as a native reserve, but Maori

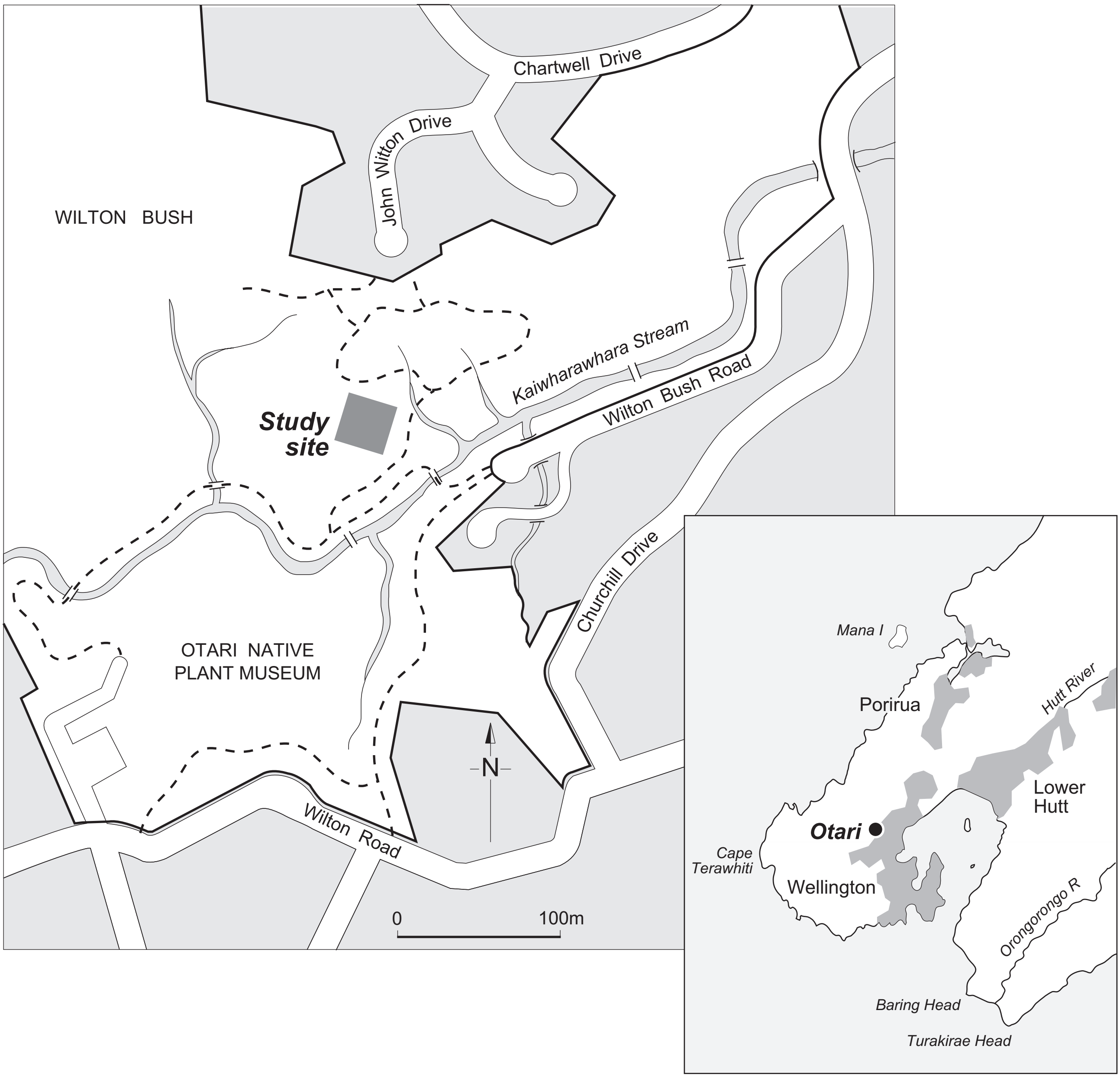


Figure 1. Site locality: Otari Native Botanic Garden, Wellington.

numbers in the region declined and within ten years the land was auctioned. Job Wilton obtained a section in 1860 and cleared all but seven hectares which became the popular 'Wilton's Bush' where the main Wilton Road entrance is today. The study site was in the Chartwell section purchased in 1876 by John Witton. He cleared most of the forest but some intact remnants were incorporated into the Otari Scenic Reserve, gazetted in 1906. The Native Plant Museum was instigated by Cockayne in 1926 (with possum control two years later). The last major addition to the reserve came in 1967 when the Witton owned Chartwell sections were sub-divided (W.C.C. 1996).

To minimise public disturbance to this study, an area near an infrequently used track was selected. The site consisted of a 27 m^2 quadrat on a steep (c. 30°) east facing slope of shingle substrate with little top soil. This area was described as a 'portion of Otari in second growth' (W.C.C. 1996) and is within 100 m of the original forest.

2.2 VEGETATION

The vegetation was surveyed in the study quadrat using five 3 m^2 plots (one plot in each corner and one in the centre). The abundance of the large vascular plants and ferns represented was assessed using the Domin scale. This scale estimates by eye each species cover and rates it between 1 (present but no measurable cover) and 10 (91–100% cover) (see Kent & Coker 1992).

The study quadrat is a mahoe (*Melicytus ramiflorus*)/hinau (*Elaeocarpus dentatus*) forest with regenerating rimu (*Dacrydium cupressinum*), rewarewa (*Knightia excelsa*) and tawa (*Beilschemiedia tawa*). Mahoe and hinau were abundant (>25%) in at least three of the plots. Rewarewa and kawakawa (*Macropiper excelsum*) were abundant in two plots while tawa, karaka (*Corynocarpus laevigatus*) and supplejack (*Ripogonum scandens*) were abundant in one plot only. Kohekohe (*Dysoxylum spectabile*) and ponga (*Cyathea dealbata*) were less abundant (5–20%) and rangiora (*Brachyglottis repanda*), hen and chicken fern (*Asplenium bulbiferum*) and hangehange (*Geniostoma rupestre*) occurred only in some plots at low abundance (>1%).

2.3 LEAF LITTER

The depth of leaf litter was measured at each of the 100 bait points on the study quadrat and categorised based on the predominant tree leaf. Depth of leaf litter ranged from 0 to 100 mm but most (72%) were less than 50 mm deep. Hinau (32%), rewarewa (19%), mahoe (17%) and tawa (15%) were the most common litter types while the rest were fern litter or bare soil.

3. Methods

The study was conducted between 15 and 24 July 1998. Although invertebrate density is usually lowest in winter (Moeed & Meads 1986), most 1080 programs are conducted at this time (Eason 1997) and invertebrate activity on baits in July was similar to that for the months of April to September (Sherley et al. 1999).

3.1 OBSERVATIONS

For the purposes of this study, non-toxic 'Wanganui No. 7' baits were used. They are cylindrical baits of about 4 g made from cereal grain with cinnamon lure and green dye added. A 27 m^2 quadrat was marked out with twine and baits were placed at 3 m intervals within this quadrat, in 10 rows of 10 baits. This equates to a bait density of about 6 kg/ha. Between 2000 and 2115 hours, for 10 consecutive nights every bait was inspected using a low wattage head lamp. All invertebrates in contact with the bait were recorded. Those visible on the top and sides of the bait were recorded separately from those underneath revealed by lifting and inspecting the underside of the bait and the leaf litter it was on. Baits removed during the study period (for example, by rodents and possums), were replaced before the following night's observations.

In addition, each night one of the 100 baits used for manual observations was monitored with a time lapse video recorder. A different bait was randomly selected to reduce any bias, and recorded from 1700 until 0500 hours NZST each night (or until the recorder batteries went flat). Sunset and dawn during the 10 days were approximately 1715 hours and 0740 hours respectively. The video was a Panasonic model AG-1070DCE recorder with VPC-505 micro camera and infra red illumination, set to record at 0.18 second intervals with continuous tape travel at 2.6 mm/sec. The camera was placed at approximately 20 cm from the bait to give a 10 × 10 cm field of view. This allowed invertebrates greater than 2 mm to be identified to order, family or sometimes genus.

Temperature, relative humidity and rainfall were recorded throughout the study period using OTLM 'Tiny-tag' data loggers. The data logger station was in the centre of the quadrat and positioned 50 cm above the leaf litter to avoid incurring a site micro-climate bias.

3.2 ANALYSIS

The number and type of taxa observed on baits using the manual and video monitoring methods were compared. A direct comparison of the methods is difficult because they gather different types of data. Video only monitors one bait per night, which often had no invertebrates on it, therefore analysis of the number of invertebrates per bait is limited. Sampling the video data 100 times over the hour gives a more comparable data set but introduces pseudo-replication. An alternative comparison of 'expected' invertebrate occurrence and 'actual' invertebrate occurrence was made. The expected occurrence was calculated from the video data as the amount of time insects were on the bait as a proportion of the total observation time. Hence this gave an expected rate of encounter to compare with the actual occurrence, calculated from the manual observations as the proportion of baits with invertebrates on them. The length of time each taxa remained on the baits was determined by the video monitoring method. Variation in the number of invertebrates on baits with weather conditions, time, day and between the top and bottom of the baits was analysed.

4. Results

4.1 SAMPLING SUMMARY

Sampling for the video observation method is summarised in Table 1. The duration of video recording was variable because every second night the battery charge reduced to the point where recording was no longer possible. After 4.8 hours on 23 July, a possum knocked the camera so that the bait was not visible.

Sampling by the manual observation method is summarised in Table 2. Observations were conducted between 2000 and 2115 hours and took between 50 and 60 minutes to complete. As many as nine baits had been removed by mammals between early afternoon and before observations began. The remaining baits had between 96 and 252 invertebrates observed on them (0.97–2.60 invertebrates per bait per night).

TABLE 1. SAMPLING INFORMATION FOR THE OTARI VIDEO MONITORING METHOD.

DATE	LITTER DEPTH (cm)	LITTER TYPE	VIDEO PERIOD (NZST)	DURATION (hours)	NO. OF INVERTEBRATES
15 July	1	tawa	1700–0500	12	5
16 July	2	tawa	1700–0145	8.75	46
17 July	6	rewarewa	1700–0500	12	49
18 July	4	rewarewa	1700–2220	5.3	6
19 July	1	soil	1700–0500	12	12
20 July	7	hinau	1700–0205	9.1	5
21 July	3	hinau	1700–0500	12	37
22 July	3	tawa	1700–2315	6.25	12
23 July	6	rewarewa	1700–2150	4.8	9
24 July	5	hinau	1700–0220	9.3	28

TABLE 2. SAMPLING INFORMATION FOR THE OTARI MANUAL OBSERVATION METHOD.

DATE	OBSERVATION PERIOD (NZST)	NO. OF BAITS	BAITS WITH INVERTS	NO. OF INVERTS	NO. OF INVERTS/ BAIT
15 July	2000–2100	100	72	159	1.59
16 July	2000–2100	100	59	104	1.04
17 July	2015–2115	97	84	189	1.95
18 July	2005–2105	95	74	144	1.52
19 July	2010–2100	91	74	145	1.59
20 July	2010–2105	100	80	168	1.68
21 July	2015–2105	99	51	96	0.97
22 July	2010–2105	96	80	204	2.13
23 July	2010–2105	97	87	252	2.60
24 July	2010–2105	98	83	210	2.14

4.2 AMOUNT OF TIME INVOLVED

The preparation of the manual observation grid and the placement of the 100 baits took approximately eight hours, including some time for replacing baits that had been removed. Observations required 1.5 hours during each of 10 nights, and a further two hours were required to remove the grid afterwards. Thus the manual observation method required 25 hours for 1000 bait observations over 10 days. The video method involved an hour each day, shifting the camera and replacing the battery and tape. The time taken in reviewing the tapes is dependent on the abundance and activity of invertebrates on the bait, but was a minimum of 1.5 hours for 12 hours footage. This equals 25 hours minimum effort for 120 hours recording over 10 nights.

4.3 TAXA RECORDED

The taxa recorded by video and manual observation methods are listed in Table 3. The more common taxa recorded were Entomobryinae, Poduridae, and Paronellinae (collembolans), snails, *Puhuruhuru* (amphipod), Chrysomellidae

TABLE 3. TAXA FOUND USING DIFFERENT OBSERVATION METHODS ON CEREAL BAITS USED IN 1080 OPERATIONS.

TAXA		VIDEO	MANUAL OBSERV-ATIONS	MANUAL OBSERVATIONS AT OHAKUNE*
Snail		+	+	+
Amphipoda		+	+	+
Isopoda		+	+	+
Thysanura		+	–	–
Peripatus		+	–	–
Diplopoda		–	+	+
Chilopoda		–	–	+
Symphyla		–	+	+
Araeneae		–	+	+
Acarinae		–	+	+
Opilionidae	Phalangiidae	+	+	+
	Triaenonychidae	+	+	+
Collembola	Entomobryinae	+	+	+
	Paronellinae	+	+	+
	Poduridae	–	+	+
	Sminthuridae	+	+	+
Blattodea		–	–	+
Dermaptera		–	–	+
Phasmatidae		–	–	+
Orthoptera	Rhaphidophoridae	+	+	+
	Stenopelmatidae	–	–	+
Coleoptera	Carabidae	–	+	+
	Scarabidae	–	+	+
	Cerambycidae	–	+	+
	Curculionidae	–	+	+
	Staphylinidae	–	+	+
	Chrysomelidae	+	+	+
Lepidoptera		+	+	+
Diptera		+	+	+
Hymenoptera	Formicidae	–	+	+
	Vespidae	–	–	+
Heteroptera		–	+	+

* Sherley et al. (1999).

(beetle), *Philoscia* (slater) and *Nuncia* (harvestman). Almost half as many taxa were recorded by video as by manual observation, with perhaps notable absences in the video records of beetles, ants and Poduridae. Observations at Otari recorded most of the main taxa observed by Sherley et al. (1999) at Ohakune. Thysanura and *Peripatus* had not previously been observed on types of baits used for 1080 poisoning.

4.4 PROBABILITY OF ENCOUNTER

The number of invertebrates per bait was consistently lower for video data than for manual observations (Table 4). The probability of encounter for each taxon was calculated from the video monitoring, and compared with the actual encounter rate observed in the manual observations. Actual and expected values are shown in Table 4. The actual rate of invertebrate usage of baits was higher than what was predicted from the video data on all dates. Analysis for invertebrates seen on the tops of baits only gave a better comparison of expected and actual values.

TABLE 4. EXPECTED PROBABILITY OF INVERTEBRATE ENCOUNTER ON CEREAL BAITS FROM VIDEO MONITORING DATA, AND THE ACTUAL ENCOUNTER RATE FROM MANUAL OBSERVATION MONITORING.

	EXPECTED ENCOUNTER RATE	ACTUAL ENCOUNTER RATE		NO. OF INVERTS PER BAIT
DATE	RATE[1]	RATE[2]	RATE[3]	VIDEO[4]
15	0.00	1.59	0.76	0.00
16	0.54	1.04	0.52	0.46
17	1.02	1.95	0.86	0.76
18	0.23	1.52	0.61	0.30
19	0.00	1.59	0.46	0.00
20	0.00	1.68	0.52	0.00
21	0.39	0.97	0.26	0.42
22	0.29	2.13	0.87	0.34
23	0.00	2.60	1.03	0.00
24	0.34	2.14	0.79	0.39

[1] Duration of time invertebrates spend on bait/ total video time (for hour of observations only).
[2] Number of invertebrates observed manually/number of baits available.
[3] Number of invertebrates observed manually on TOP of bait/number of baits available.
[4] 100 spot checks on one video bait during the hour.

4.5 DISTURBANCE

On 10 occasions a video monitored bait had a manual observation made of it. The comparison of taxa recorded on those occasions is shown in Table 5. Half of the comparisons yielded the same result. Although some differences were due to invertebrates underneath the bait and therefore obscured, on two occasions small invertebrates on the top of the bait were not visible on video.

TABLE 5. INVERTEBRATES OBSERVED ON THE SAME BAIT SIMULTANEOUSLY BY VIDEO AND MANUAL METHODS.

DATE	VIDEO*	MANUAL OBSERVATIONS	
		TOP	BOTTOM
15	–	–	–
16	1 Collembola sp. A	2 Collembola sp. A	2 Collembola sp. A
17	–	–	1 Collembola sp. A
18	1 Collembola sp. B, *Sphaerillo* sp. A	1 Collembola sp. B, *Sphaerillo* sp. A	–
19	–	–	–
20	–	1 Collembola sp. D	1 Collembola sp. A
21	1 Collembola sp. A	1 Collembola sp. A	–
22	1 *Megalopsalis*	–	*Megalopsalis*
23	–	–	Fly
24	–	–	4 Collembola sp. X, 2 Collembola sp. A

* Before manual observation made.

4.6 TOP AND BOTTOM OF BAIT

The number of invertebrates observed by manual monitoring on top of the baits was compared with those seen beneath the bait. Differences in the mean number of invertebrates per bait and mean number of individuals of each taxa are shown in Figure 2A and B. Significantly greater numbers of invertebrates were found beneath baits than on top of baits (Ttest, $t=4.93$, $p<0.001$, 9 d.f.). Poduridae and Chrysomelidae in particular preferred the bottom of baits, while snails, *Nuncia* sp. and Paronelidae preferred the top.

4.7 DURATION OF VISIT

The average duration of each visit to a bait by an invertebrate taxon on each of the 10 days are shown in Figure 3A and B. Most visits were between two and 10 minutes long, although some individuals stayed for up to 90 minutes on a bait. The outliers of the ‘other’ group were one geometrid caterpillar and an amphipod.

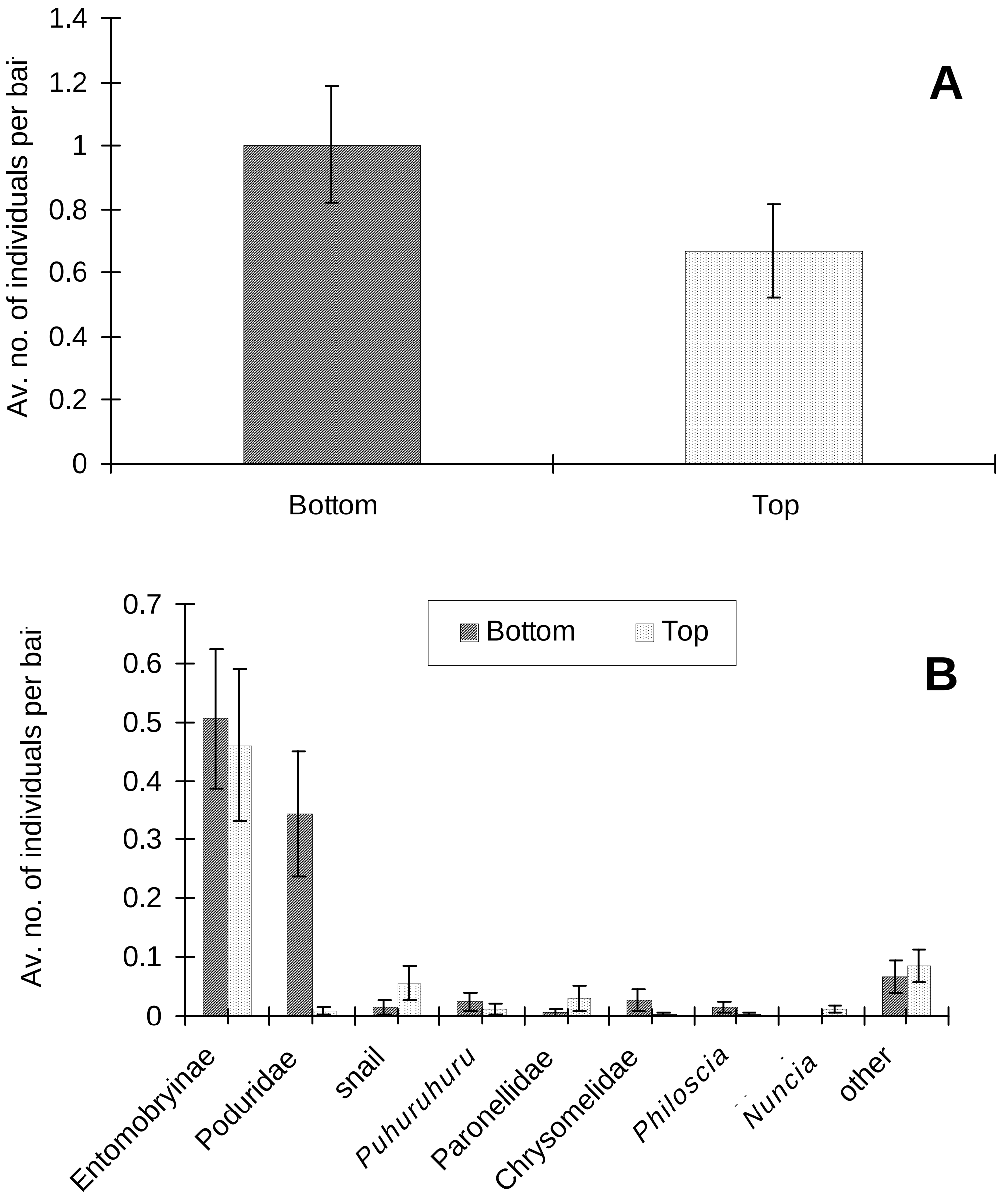


Figure 2. The average number of all taxa combined (A) and of each taxa (B), observed on the top and bottom of baits by observation of 100 baits. (error bars=95% confidence limits.)

4.8 VARIATION

Date

The video monitoring data were standardised for the number of individuals per hour on the bait per night. Variations between dates in the number of invertebrates and the number of individuals of each taxa are shown in Figure 4. Invertebrates on the bait monitored ranged from 0.4 to 5.3 per hour for the 10 nights. The Entomobryinae were the greatest component on all dates, except on 17 and 23 July when the harvestman *Nuncia* sp. occurred more often.

The manual observation data were standardised as the number of individuals per bait. Variations between nights in the number of invertebrates and the

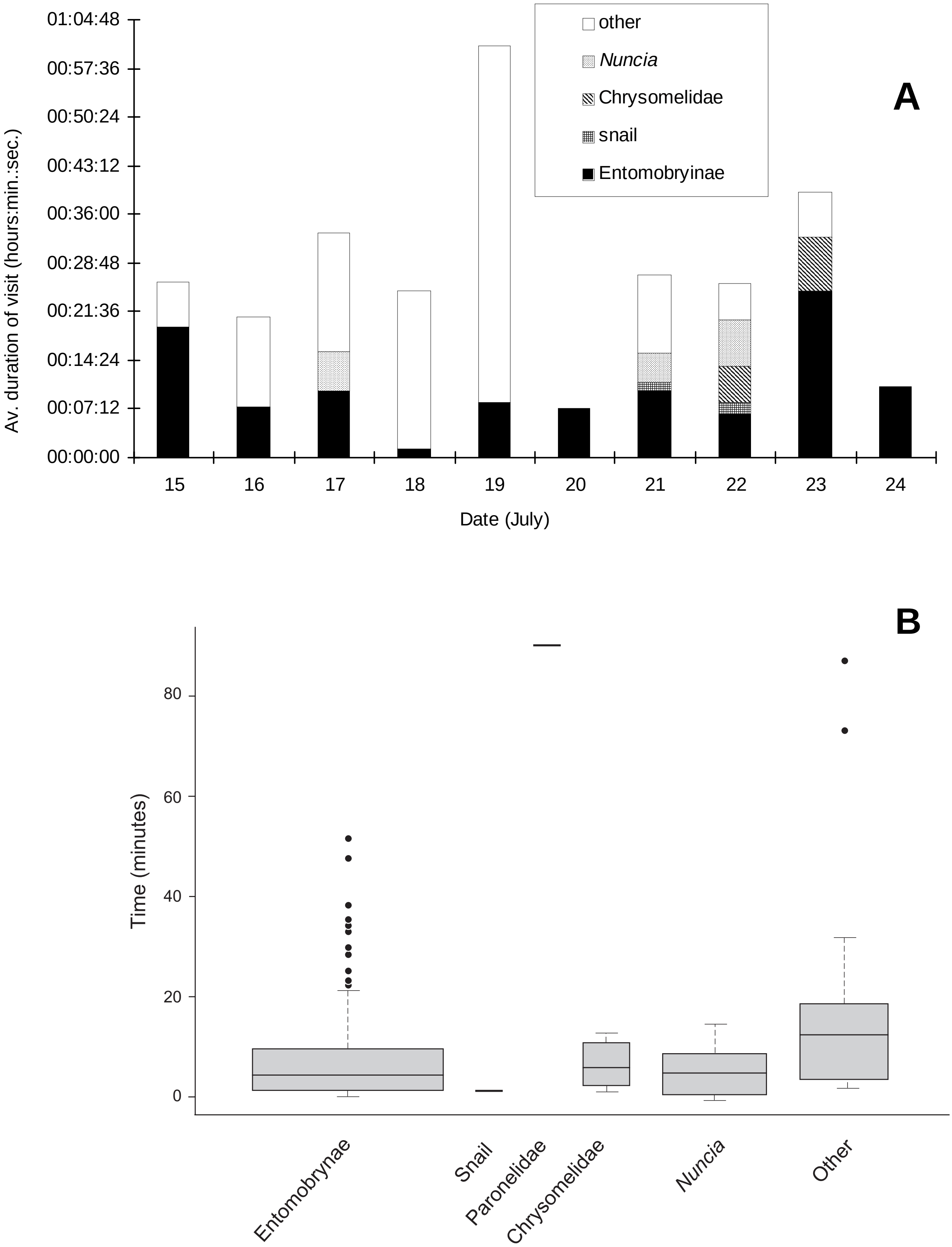


Figure 3. (A) The average duration of visits on baits monitored by video for different taxa on each of 10 nights. (B) Box plots of time spent on baits by each taxa: median, upper, and lower quartiles, fence to value nearest to 1.5× interquartile range, and outliers beyond this value. (Width of box proportional to the square root of sample size.)

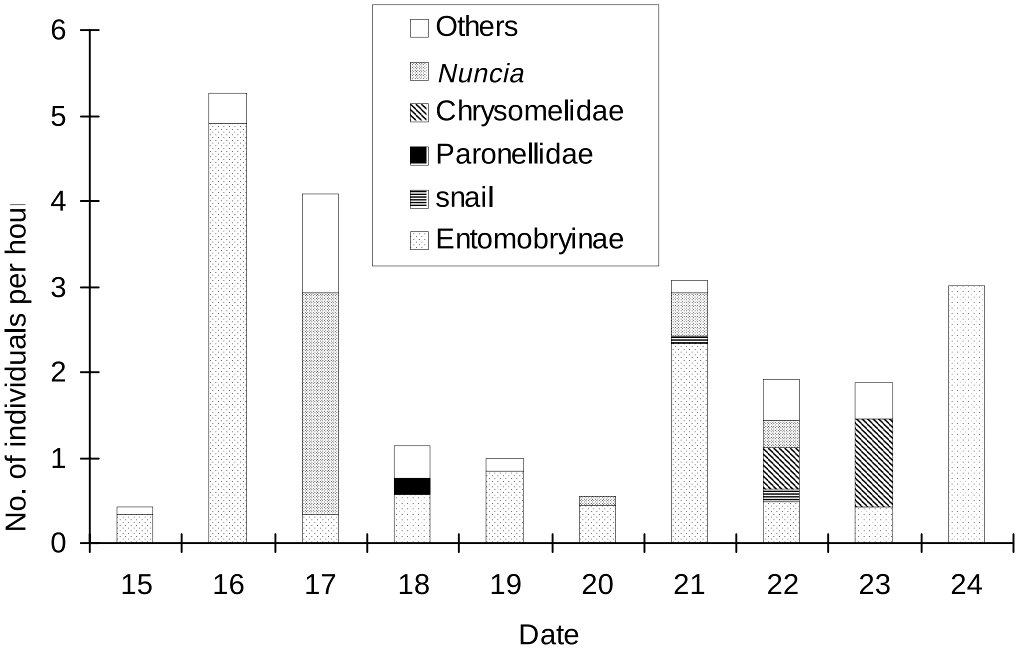


Figure 4. The number of individuals of each taxa observed hourly by video for each of 10 nights.

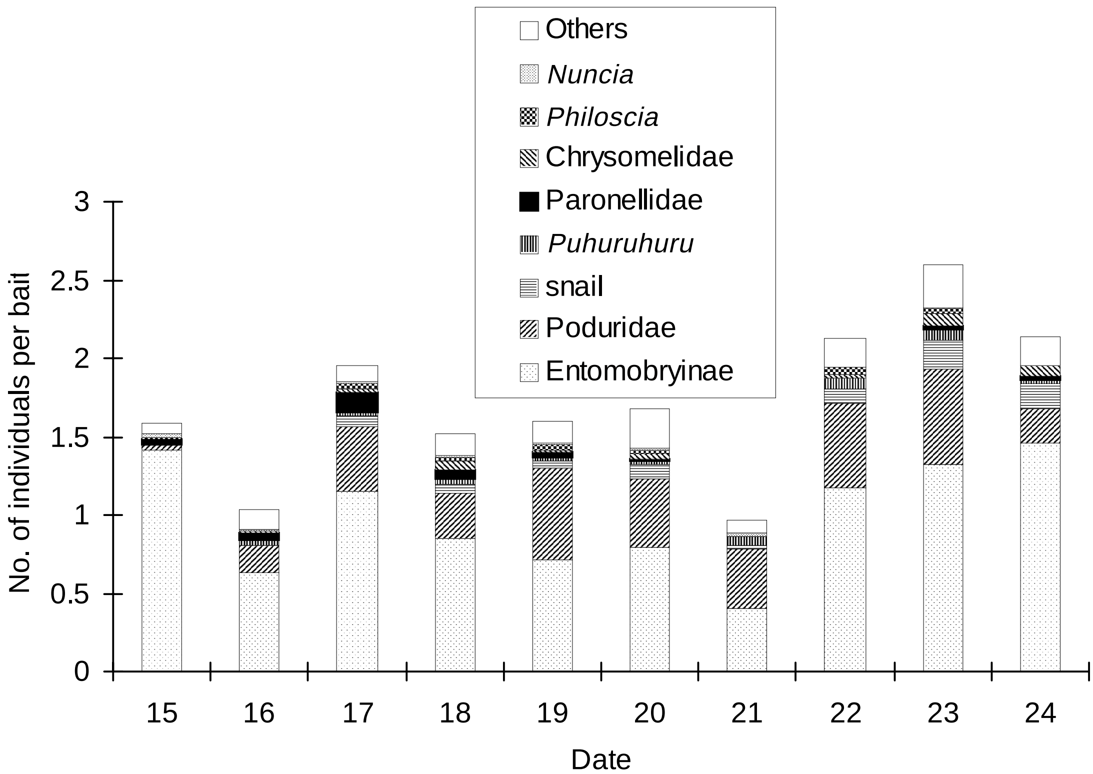


Figure 5. The number of individuals of each taxa per bait recorded manually on each of 10 nights.

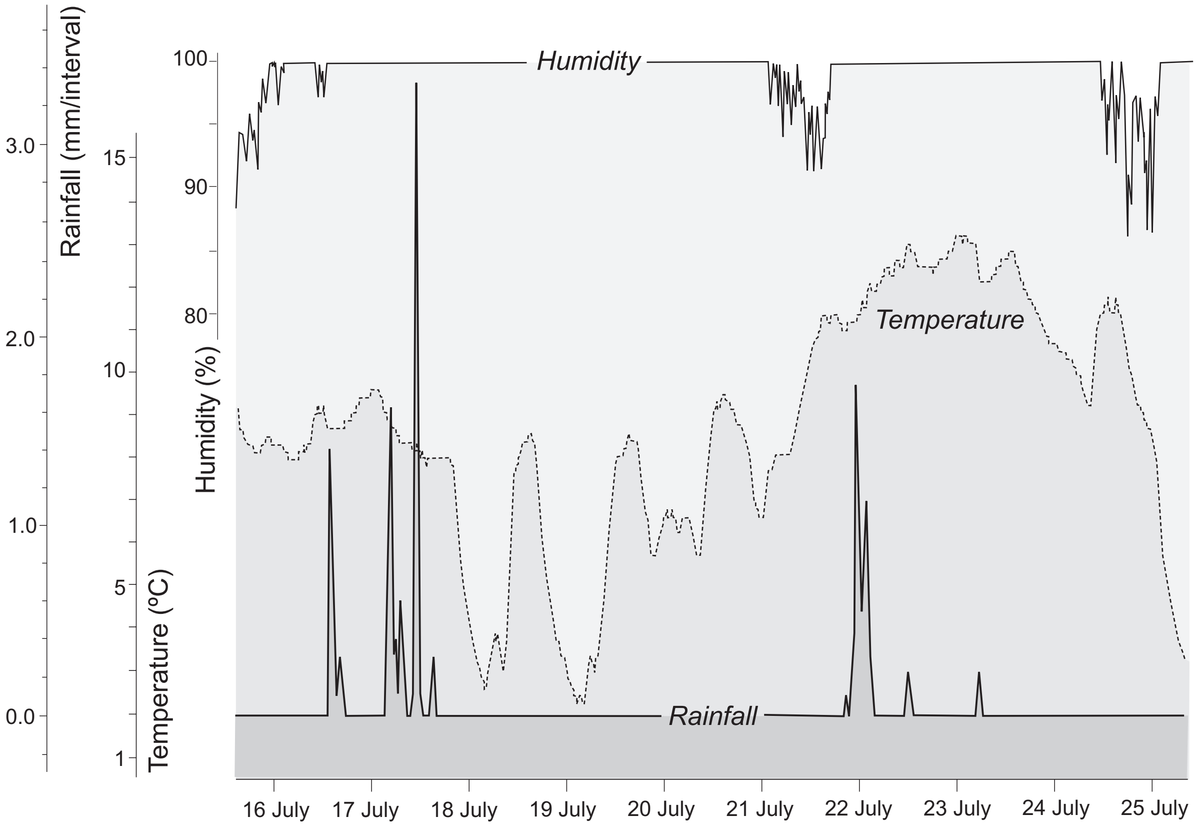


Figure 6. Temperature, rainfall and relative humidity measurements for the 10-day period of the video and manual observation study.

number of individuals for each taxa observed are shown in Figure 5. The numbers of invertebrates per bait for the 10 sampling days ranged from 0.97 to 2.6. Entomobryinae were the greatest component on all dates, Poduridae the next most abundant.

Weather conditions

Rainfall, relative humidity and temperature, were measured throughout the 10 day period (Figure 6). Rain, recorded under the forest canopy, fell on four of the ten days, with up to 3.3 mm in half an hour and lasting as long as five hours. Relative humidity remained high at 100% for most of the ten day period, reducing to 92 and 86% on 21 and 24 July respectively. Variation in rainfall and relative humidity during the observation period were not sufficient to analyse. Temperature ranged from 2.4 to 13.2ºC over the ten days, with cooler nights on 17–19 July and warmer nights on 22–23 July.

The temperature and number of invertebrates on the bait were noted for every minute of video recording (Figure 7A, B). The number of individuals on a bait was usually less than three, but up to five occurred simultaneously. The number of observations at each temperature when standardised showed that the mean number of invertebrates per bait was fairly consistent below 8.5 ºC but decreased at higher temperatures.

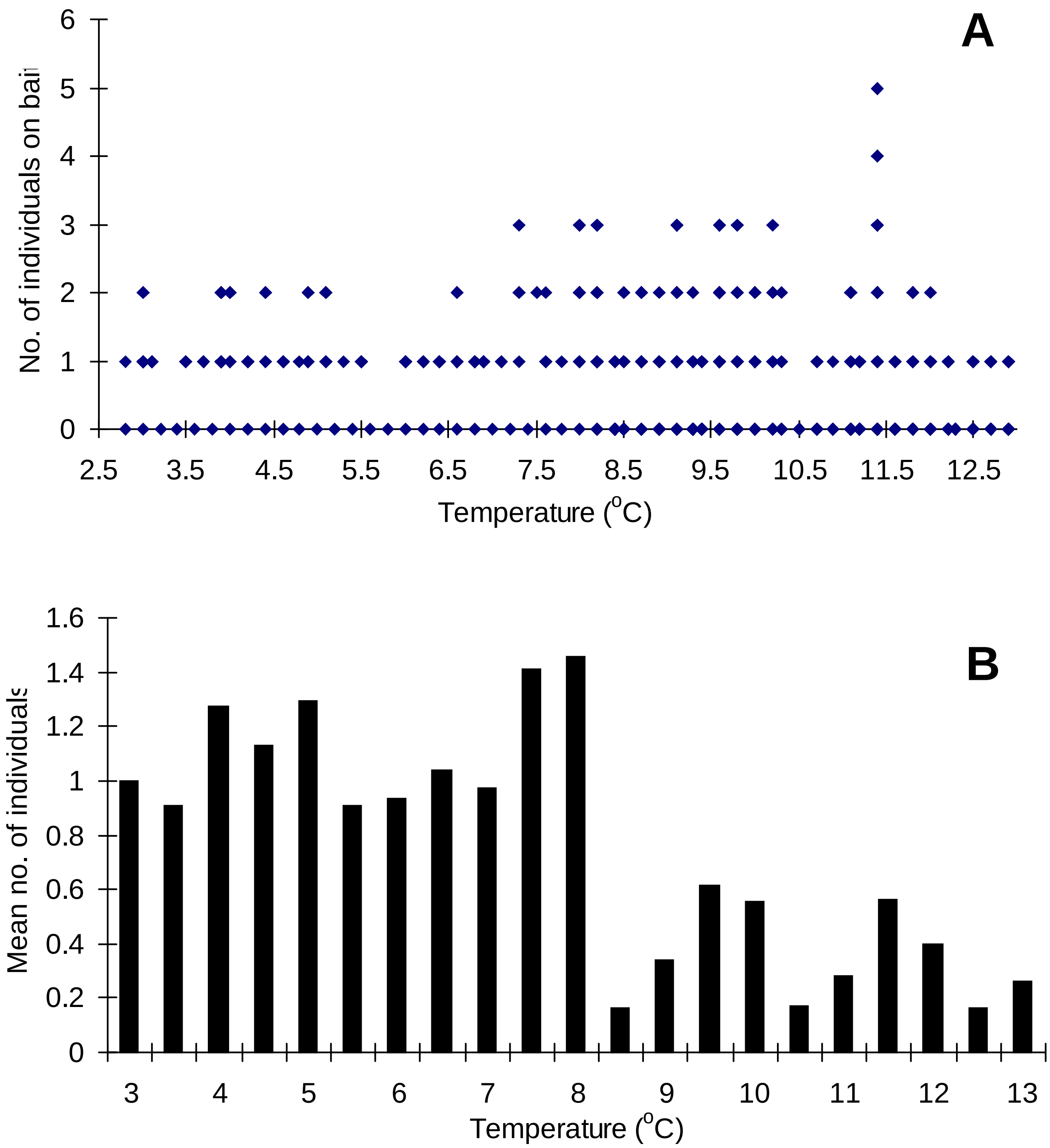


Figure 7. (A) The number of individuals on a bait at different temperatures, and (B) mean number of individuals per bait at different temperatures, at minute intervals observed by video.

There was no change in temperature during the period each night that manual observations were made, but the ten nights were different. The number of invertebrates per bait and the number of individuals of each taxon per bait are plotted against the temperature at the time of observation (Figure 8A and B). There is an association between number of individuals per bait and temperature. The two nights that do not conform to the limited data were 16 and 21 July, which had the lowest number of invertebrates observed and were the only nights preceding a period of rain. The correlation reflects the trend of Entomobryinae; there is no apparent pattern in numbers of other taxa from the ten points.

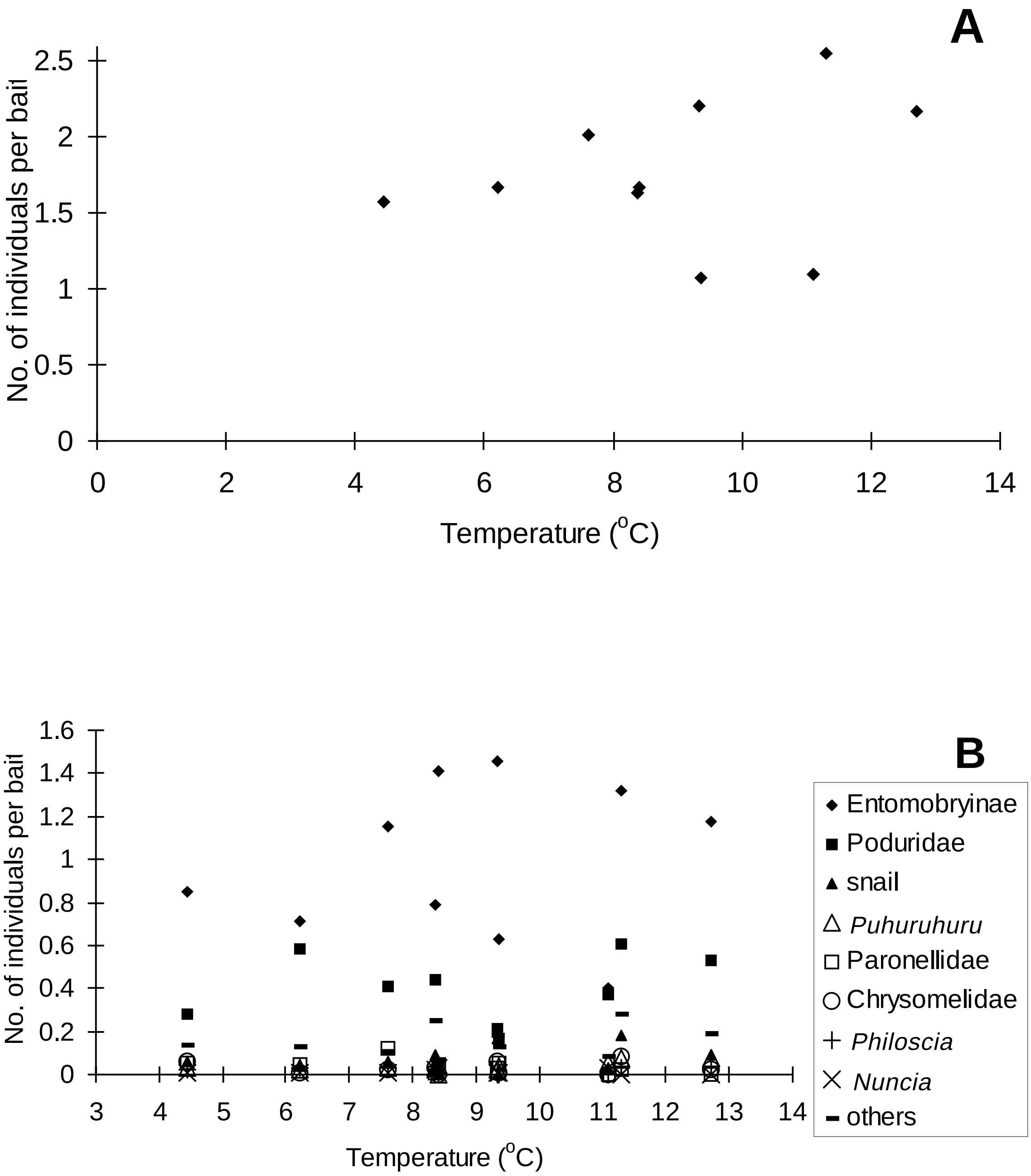


Figure 8. The number of all individuals (A) and number of individuals of each taxa (B) per bait by manual observation over 10 nights at different temperatures.

Time of night

The number of invertebrates observed by video during each hour period was averaged over the number of nights recording was conducted during that hour. Variations in the number of invertebrates observed by video are shown in Figure 9. Although the number of invertebrates seems to reduce around 0100–0200 hours, there is much variation in the data and the large 95% confidence limit error bars indicate testing for significant differences is not warranted.

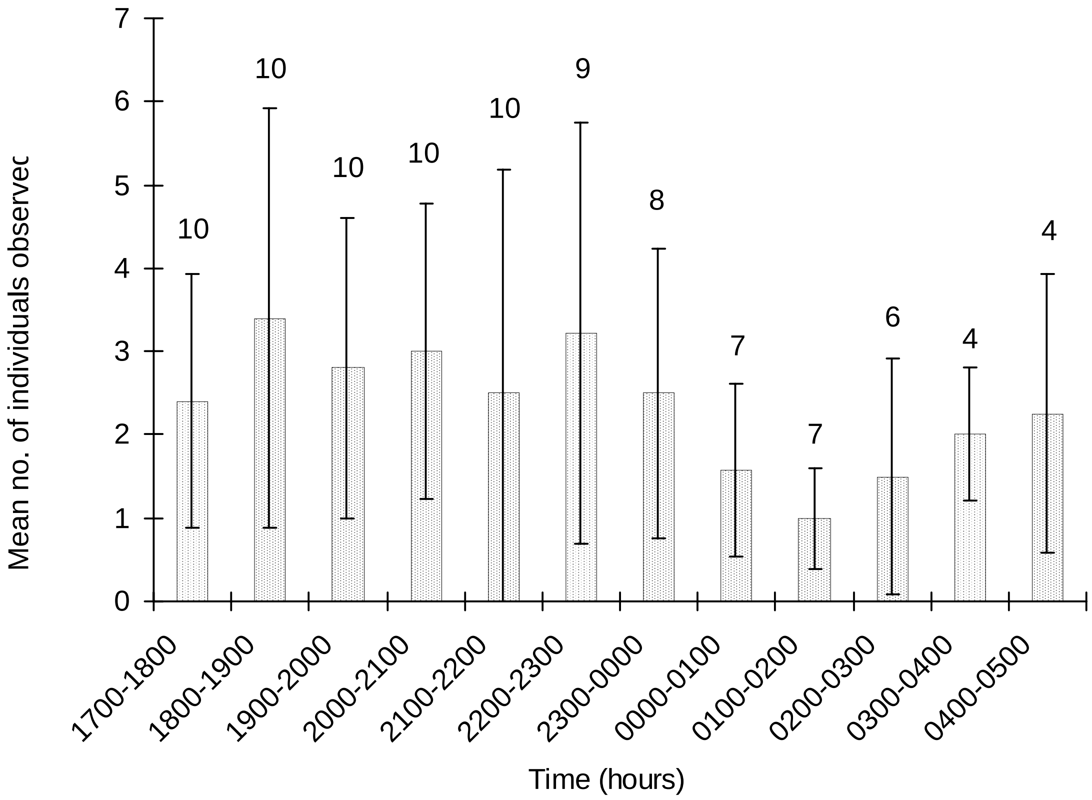


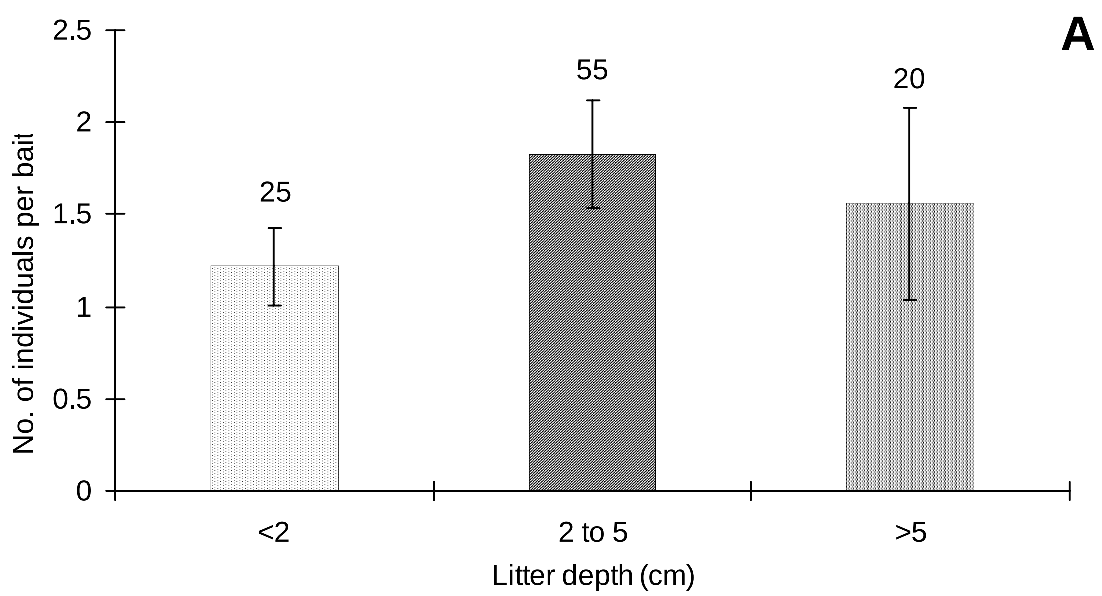
Figure 9. Mean number of individuals observed by video over hour periods between 5 pm and 5 am. (N= number of hour samples (nights), error bars =95% confidence limit).

Litter depth

Variations with litter depth in the number of invertebrates and number of individuals of each taxa observed by the manual method are shown in Figure 10A and B. There were fewer invertebrates on baits with litter <20 mm deep than baits with 20–50 mm deep litter. Although there was large variation in the number of invertebrates it appears that most taxa (except for Entomobryinae and Poduridae) increased in occurrence on baits with increasing litter depth.

Litter type

Variations in the number of invertebrates and the number of individuals of each taxa with type of leaf litter observed by the manual method are shown in Figure 11A and B. Although variable, some of the differences in number of invertebrates on baits appear significant. Baits placed on bare soil had fewer invertebrates than baits on hinau, tawa or rewarewa leaf litter. Baits placed on rewarewa leaf litter had more invertebrates than baits placed on fern and mahoe leaf litter. Variation between litter type for each taxon is very large, of interest were high numbers of Entomobryinae on soil, and Poduridae on rewarewa.



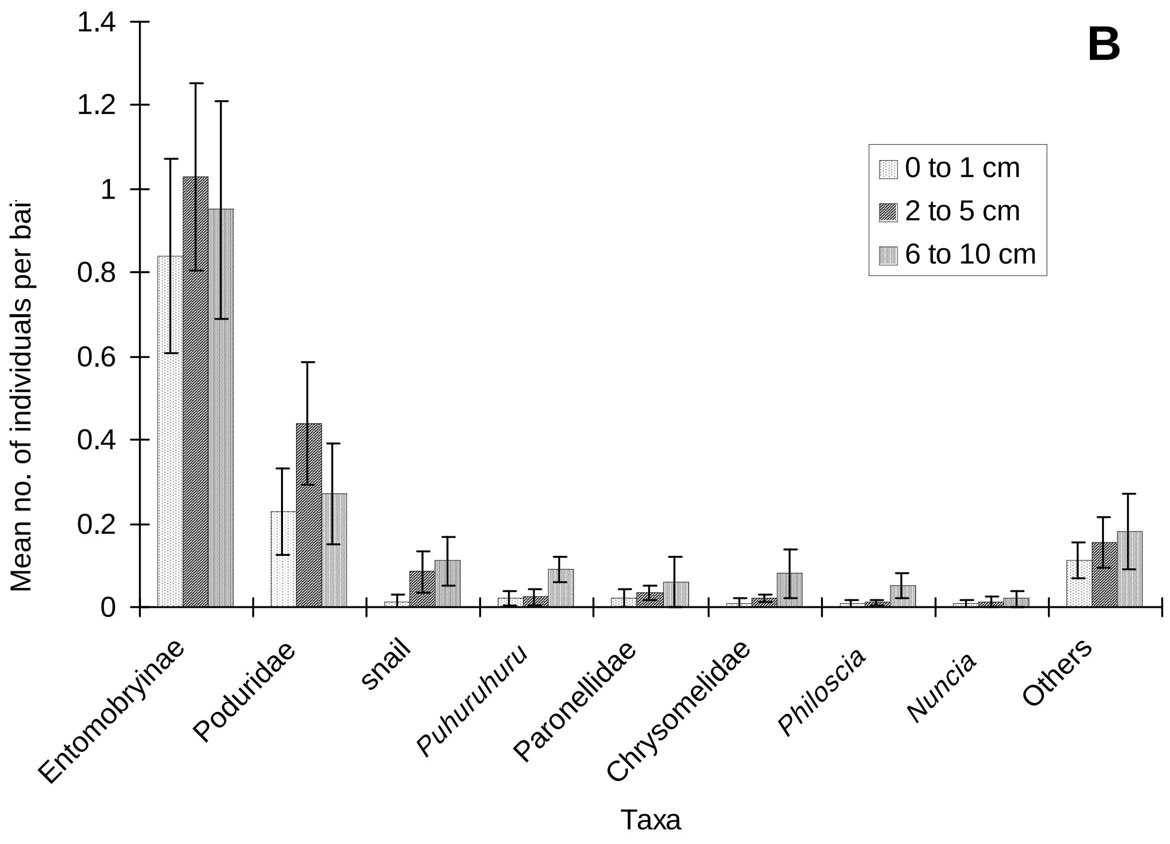


Figure 10. The average number (A) and number of individuals of each taxa (B) recorded over different depth of litter, by manual observation of 100 baits. (N=number of baits, error bars =95% confidence limit.)

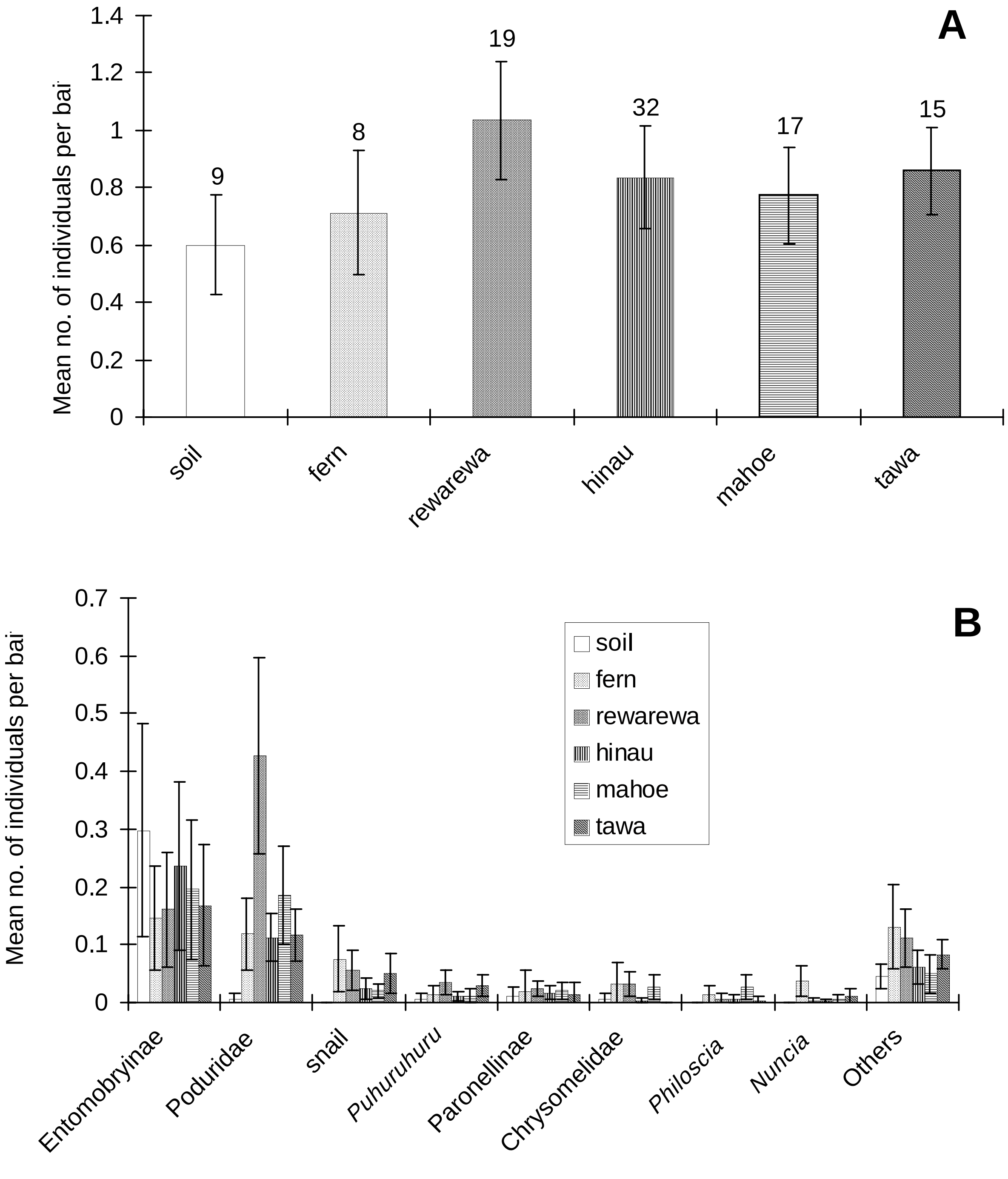


Figure 11. The average number (A) and number of individuals of each taxa (B) recorded over different types of litter, by manual observation of 100 baits. (N=number of baits, error bars =95% confidence limit.)

5. Discussion

Comparing video and manual observation methods, in terms of the accuracy of the data from each and the amount of effort required showed a similar amount of effort was required but the results were different. The video method had a limited ability to sample variation because it sampled only one bait per night. Site of the bait is important and one bait site for each of 10 nights by video was not as thorough as 100 bait sites for each of 10 nights by manual observation. However, using video monitoring could be less time-consuming if a study site was too difficult to access for nightly observations (e.g. in epiphytes), or when observations are made on fewer baits for less days.

5.1 DISTURBANCE OR OBSCURANCE

One of the main concerns with the manual observation method was the potential for disturbance. Ground vegetation was relatively sparse in Otari but the steep slope made travel difficult for the observer and probably increased levels of disturbance. Although the data are few, the video method did not record any invertebrates disturbed by manual observations. Even if invertebrates are disturbed by the manual observation method, more invertebrates are observed than for the video method. A disadvantage of the video method is its inability to observe both the top and bottom of the baits. More invertebrates, particularly Poduridae were observed beneath the baits, while snails, *Nuncia* sp. and Paronellidae were more abundant on top of baits. Size and mobility of the invertebrates are likely to contribute to this variation. Large and mobile taxa might be more likely to move across the litter surface and encounter tops of baits, while small, sedentary taxa might move only up through the litter to the bottom of baits. On five of 10 occasions the video method did not record invertebrates because they were obscured beneath the bait, or not visible on top of the bait due to size, cryptic patterning or observer error. Not observing individuals on half the occasions combined with the reduced number of taxa observed is some cause for concern.

It is not clear what effect infra red light might have on invertebrates. At the close range used in this study heating could be a possibility, and some Coleoptera are reported to orient to infra red light (Prokopy & Owens 1983). Further work on this is necessary before results from using infra red light can be interpreted.

5.2 TAXA OBSERVED

Video monitoring recorded fewer individuals and species on baits than the manual method. Using data from the video method to predict occurrence on manual observation baits was not accurate even when considering tops of baits only. Overall, both methods had a less detailed but similar range of taxa to that reported from nearly 50,000 observations of baits by Sherley et al. (1999). That study had a higher occurrence of *Saphobious squamulosus* and *Huberia brouni* than in this study, and lower occurrence of Poduridae. The difference in relative proportions of taxa is not unexpected given differences in season, climate, forest type and location.

Halliday (1995) studied aquatic invertebrates in the Otari area, but there have been no studies on the terrestrial invertebrates found in Otari. Berndt (1998) found that the rate of spider capture was low in the Karori Wildlife Sanctuary, approximately five kilometres further upstream in the Kaiwharawhara Stream headwaters. Few spiders were observed in this study but this is most likely due to their behaviour rather than abundance. The beetle fauna might be expected to be comparable to Moeed & Meads (1985) report from the Orongorongo Valley, east of Wellington, given that study's comparability with another study on Wellington's south coast (Crisp et al. 1998).

5.3 DURATION

Duration of visit of invertebrates to baits varied among individuals and taxa, with occasional taxa remaining on the bait for 20–90 minutes. This has implications for the manual method because invertebrates that visit for short periods will be less likely to be observed. Further work on this could be valuable. The effect of the duration an invertebrate spends on a bait will depend upon that invertebrates 1080 toxicity levels and feeding habits, knowledge of which is limited. Most LD50's for invertebrates seem to be between 1 and 100 mg/kg (see Appendix 1). For a bait containing 0.15% 1080, as little as 0.0007 mg is lethal to a 1 mg invertebrate with a LD50 of 1 mg/kg. At the other extreme, 667 mg of the same bait would be required to kill a 10 g invertebrate with a LD50 of 100 mg/kg. This suggests a 4 g bait could be lethal to seven million small or seven large invertebrates that consume between 0.07 and 7% of their body weight. It seems possible that visits of the common duration, from two to ten minutes, would be long enough for feeding invertebrates to acquire lethal doses of 1080.

5.4 FACTORS AFFECTING ACTIVITY

A major complication in the assessment of these two methods has been factors that affect invertebrate activity, since changes in activity will affect the results. Statistical modelling using a Poisson distribution of counts failed to account for all the variation in the data. Taxon caused most variation, while leaf litter type and date also contributed. It is apparent that either another factor was not accounted for in the sampling or the invertebrates were not acting truly independently.

The total number of invertebrates per hour and number of individuals of each taxon varied between nights using both video and manual observation methods. Because the video observed a bait at a different point on the grid each night, and for different durations, variation could be due to site or time. Lower occurrence of invertebrates between midnight and 3 am, was not statistically significant. The nightly variations could be due to differences in factors such as temperature.

Although the number of individuals on a bait at one time did perhaps increase with temperature, the points recorded for four and five invertebrates on a bait were all from the same half-hour period and could be attributed to another factor. The video monitoring results suggest invertebrate occurrence declined slightly on baits at higher temperatures. This is in contrast to other studies. The activity of many invertebrates in a Wellington forest was found to be positively correlated with temperature (Moeed & Meads 1985, 1986), including Collembola, Carabidae, Staphylinidae, Curculionidae, Diptera, Lepidoptera, Hymenoptera, Formicidae, Amphipoda, Isopoda, Chilopoda, Diplopoda, Acarinae, Araneae and Opilionidae. Other climate factors, such as rainfall and humidity, have also been found to influence various invertebrates' activity in a Wellington beech forest (McColl 1975). But these were seasonal variations over a year, not a finer correlation of activity with daily temperature changes. Perhaps in winter invertebrates are acclimatised to cooler temperatures and daily increases above a certain temperature will reduce activity. Activity in terms of bait use was not affected by gross changes in weather between April and October but varied with site and with season, peaking in October (Sherley et al. 1999).

The low rate of spider capture in Karori sanctuary showed no seasonality, but taxa varied with leaf litter depth, slope, dead wood, bare soil and canopy cover (Berndt 1998). Litter depth and type seemed to affect the number of invertebrates on a bait in this study. Fewer invertebrates were observed on shallow litter, particularly that of bare soil, mahoe litter and fern litter. However, litter depth is a highly subjective measure, and differences could be related to litter type, for example, bare soil is shallow, rewarewa litter is deep. While this should not cause variation in the manual results, and did not seem to be the cause of variation in the video results, it highlights the need to select representative sampling areas.

The manual monitoring data for number of individuals per bait with temperature was limited, but suggested a weak increase with temperature. Two nights that do not conform to the trend were 16 and 21 July. These two nights had the lowest number of invertebrates observed and were the only nights preceding a period of rain. Perhaps a factor associated with approaching rain, such as decreasing atmospheric pressure, has the effect of reducing invertebrate activity. However, this is unlikely to be true for all invertebrates, for example approaching rain was found to stimulate porina emergence (Helson 1972). Another interesting factor is that collembola numbers are known to increase in response to carbon dioxide given off by disturbed organic soil (Hutcheson 1996). The instability of the site and degree of disturbance on the manual observation grid may have meant higher than normal Collembola numbers were observed.

5.5 EPIPHYTES AND DAYLIGHT HOUR VARIATION

Two factors relating to invertebrate use of baits remain unaddressed: arboreal use and daytime use. As much as 15% (Lloyd & Hackwell 1993) or 34% (Batcheler 1982) of bait may lodge in the canopy after an aerial drop. Such baits pose a risk to arboreal invertebrates, which have been estimated as 28% of forest arthropod numbers, twice as abundant as litter invertebrates (Stork 1988). This was in a Borneo rain-forest, however, which does not have New Zealand's abundance of litter invertebrates. Beetle abundance and richness in malaise traps was lower in a Bay of Plenty canopy than at ground level (Hutcheson 1996).

While some epiphytes were sampled using video during this study, data were not sufficient to draw conclusions. Further research on the invertebrate use of baits in epiphytes is being conducted at Otago University (C. Shrubshall pers. comm.). Invertebrate use of baits during daylight hours was also monitored in the present study, but the data was confounded by low invertebrate occurrence and rodent interference. Only speculation is possible from these data.

5.6 INVERTEBRATES AT RISK

The Ohakune studies reported in Sherley et al. (1999) identified many taxa on the type of baits used in 1080 operations. Reviews of non-target poisoning, such as those by Notman (1989), Spurr (1994b), and Spurr & Powlesland (1997), provide additional information on the invertebrate taxa observed to consume or contact 1080 baits during control operations, or in the laboratory. These taxa potentially at risk of poisoning from pest control operations are listed in Appendix 1.

The wide range of invertebrate taxa seen on baits reflects that present in the forest litter (McColl 1975, Moeed & Meads 1985, 1986, 1987). For example, 21 Coleoptera families were recorded on baits compared with 29 families reported from leaf litter by Moeed & Meads (1985). Invertebrate taxa observed on baits might show seasonal variation due to changes in litter invertebrate activity and abundance. However most invertebrates are active throughout the year, with abundance generally correlated with temperature, peaking between spring and autumn (McColl 1975, Moeed & Meads 1985, 1986, 1987). Although the range of taxa on baits may correspond to that in the litter, there is evidence that they occur in disproportionate numbers. Some taxa are relatively more common on baits than in the leaf litter (Sherley et al. 1999). This is related to each invertebrate's ecological guild for which there is scarce information.

The dominant proportion of invertebrate taxa observed on baits are considered to be leaf litter inhabitants (84%) that feed on live or decaying plant and fungal material (73%). Most of the invertebrates observed on baits were small, 23% of taxa being less than 2 mm long and another 49% less than 10 mm long. However, small, litter-dwelling herbivore/decomposer describes the majority of forest invertebrates. Phytophages and scavengers comprise over a third of temperate forest arthropod species (Stork 1988). Each guild has a different reason for being on the bait. Most of the taxa are likely to be using the bait as a food source (e.g. Collembola). Some predatory taxa are possibly using baits as a source of prey (e.g. Staphylinidae). Occasional taxa may only be on the bait by chance (e.g. stick insect), or attracted to lay eggs (e.g. non-feeding adult Diptera). It appears that most forest invertebrates face degrees of risk of poisoning from toxin in baits through contact, or through primary or secondary consumption.

6. Summary

The video method records lower numbers and diversity of invertebrates, partly because more invertebrates are hiding beneath the bait. Video is still likely to give gross indications of large taxa associated with the baits and is useful to determine how invertebrates use the bait and the duration of invertebrate visits (generally less than 10 minutes). No disturbance by the manual observation method was observed.

Invertebrate numbers found on baits varied, associated with litter depth and type and temperature. While this study gleaned some information on the effect of several factors on activity of litter invertebrates, no conclusions can be made. The sampling period in this study is too limited and the factors too interrelated, to indicate variation in invertebrate activity, especially in comparison with studies of seasonality.

Invertebrates are known to contact baits (Sherley et al. 1999) and to consume 1080 baits (Eason et al. 1991). By consuming 1080, invertebrates sustain primary poisoning, sub lethally (Mcintyre 1987; Hutcheson 1989), or lethally (Booth & Wickstrom 1998), and cause secondary poisoning of insectivores (Hegdal et al. 1986; McIlroy 1984). A broad range of invertebrates are likely to be at risk from 1080 poisoning operations (Appendix 1). While some researchers report 1080 has had no detectable effect on forest invertebrate numbers (Spurr 1994a, 1996; Hutcheson 1996), other researchers have recorded reduced invertebrate numbers (Sherley et al. 1999). Any reduction caused by 1080 is probably localised (less than 20 cm from a bait) and short term (about 6 days) (Sherley et al. 1999).

6.1 CONSIDERATIONS FOR FUTURE MONITORING

The manual observation method of monitoring does not appear to affect results due to disturbance. Video monitoring will not account for those individuals beneath the bait (a large proportion of the invertebrates).

Invertebrate activity varies with site, season, climate, litter depth and type and bait type. Monitoring of invertebrate use of baits by video or manual observation should include as broad a range of factors as possible.

Areas that require further work include invertebrate use of baits in the canopy and during daylight hours, the effect of infra red light and taxa variation in duration of visits.

7. Acknowledgements

I would like to thank the following people for help with study design, field assistance, statistical advice, editing, and proof reading, Greg Sherley, George Gibbs, Ralph Powlesland, Karen Reader, Maree Hunt, Brian Dawkins, Edith Hodgkin, Brian Lloyd, Shirley McQueen, Don Newman, Ian Mackenzie.

8. References

Annabell, R. 1995. Researcher's tale sets alarm bells ringing. *Rural News* October: 21–22.

Batcheler, C.L. 1978. Compound 1080, its properties, effectiveness, dangers, and use. Report to minister of Forests and Minister of Agriculture and Fisheries. New Zealand Forest Service, Wellington.

Batcheler, C.L. 1982. Quantifying "bait quality" from number of random encounters required to kill a pest. *New Zealand Journal of Ecology* 5: 129–139.

Berndt, L.A. 1998. Aspects of the ecology of ground-active spiders (Araneae) of the Karori Wildlife Sanctuary, Wellington. Unpublished MSc thesis. Victoria University, Wellington.

Booth, L.H.; Wickstrom, M.L. 1998. Improving the safe use of Vertebrate pesticides: the toxicity and persistence of 1080 in a native ant species. *Landcare research contract report, LC9798/108.*

Chenoweth, M.B. 1949. Monofluoroacetic acid and related compounds. *Pharmacological reviews* 1: 383–424.

Crisp, P.N.; Dickinson, K.J.M.; Gibbs, G.W. 1998. Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation 83*: 209–220.

CSIRO 1991. The Insects of Australia, a textbook for students and research workers. 1137 p., 2 volumes. Melbourne University Press, Carlton.

David, W.A.L. 1950. Sodium fluoroacetate as a systemic and contact insecticide. *Nature 165*: 493–494.

David, W.A.L.; Gardner, B.O.C. 1951. Investigations on the systemic insecticidal action of sodium fluoroacetate and of three phosphorus compounds on *Aphis fabae* Scop. *Annals of applied biology 38*: 91–110.

David, W.A.L.; Gardner, B.O.C. 1958. Fluoroacetatamide as a systemic insecticide. *Nature 181*: 1810.

Dugdale, J.S. 1996. Natural History and identification of litter-feeding Lepidoptera larvae (Insecta) in beech forests, Orongorongo Valley, New Zealand, with especial reference to the diet of mice (*Mus musculus*). *Journal of the Royal Society of New Zealand 26*: 251–274.

Duncan, K.W. 1994. Terrestrial Talitridae. *Fauna of New Zealand 31*.

Eason, C.T. 1997. Vertebrate pest control Manual—toxins and poisons. Department of Conservation, Wellington.

Eason, C.T.; Batchelor, D.; Wright, G. 1991. Environmental impact assessments on 1080 associated with possum control in the Waipoua Forest Sanctuary, Northland. *Forest Research Institute Contract report, FWE 91/8*.

Eason, C.T.; Gooneratne, R.; Wright, G.R.; Pierce, R.; Frampton, C.M. 1993. The fate of sodium monofluoroacetate (1080) in water, mammals, and invertebrates. Pp. 297–301 in Proceedings 46th New Zealand Plant Protection Conference 1993.

Forster, R.R.; Forster, L.M. 1970. The Small Land Animals of New Zealand. John McIndoe, Dunedin.

Fraser, K.W.; Spurr, E.B.; Eason, C.T. 1995. Non target kills of deer and other animals from aerial 1080 operations. *Rod and Rifle 16(5)*: 20–22.

Goodwin, R.M.; Ten Houten, A. 1991. Poisoning of honey bees (*Apis melifera*) by sodium fluoroacetate (1080) in baits. *New Zealand Journal of Zoology 18*: 45–51.

Halliday, J. 1995. Instream invertebrates of Otari Native Botanic Garden. Unpublished MSc thesis, Victoria University, Wellington.

Hegdal, P.L.; Fagerstone, K.A.; Gatz, T.A.; Glahn, J.F.; Matschke, G.H. 1986. Hazards to wildlife associated with 1080 baiting for California ground squirrels. *Wildlife Society Bulletin 14*: 11–21.

Helson, G.A. 1972. An hypothesis on the effect of atmospheric small ions and weather fronts on the emergence of *Weiseana cervinata. Abstracts of International Congress Entomology 14*: 341.

Hutcheson, J. 1989. Impact of 1080 on weta populations. *Forest Research Institute report, Inv. no: S5020/560*. Prepared for the Department of Conservation, Wellington.

Hutcheson J.A. 1996. Characterisation of insect communities of tawa forest in the Onaia Ecological Area using malaise trapped beetles, and indications of influences, including 1080 operations, on these communities. Unpublished Master of Philosophy thesis, University of Waikato, Hamilton.

Johannsen, F.R.; Knowles, C.O. 1974. Toxicity and action of fluenethyl acaricide and related compounds in the mouse, housefly and two spotted spider mite. *Comparative General Pharmacology 5*: 101–110.

Johns, P.M. 1997. The Gondwanaland Weta: Family Anostostomatidae (formerly in Stenopelmatidae, Henicidae or Mimnermidae): Nomenclatural Problems, World Checklist, New Genera and Species. *Journal of Orthoptera Research 6*: 125–138.

Kent, M.; Coker, P. 1992. Vegetation description and analysis: a practical approach. Belhaven Press, London.

Klimaszewski, J.; Watt, J.C. 1997. Coleoptera: family-group review and keys to identification. *Fauna of New Zealand* 37.

Lloyd, B.; Hackwell, K. 1993. A trial to determine whether kaka consume carrot baits, Kapiti Island, May 1993. *Science and Research Series 62*. Department of Conservation, Wellington.

Lowe, A.D. 1960. Control of the cabbage aphid (*Brevicoryne brassicae* L.) with some systemic materials. *New Zealand Journal of Agricultural Research 3*: 842–844.

Macchiavello, A. 1946. Plague control with DDT and “1080”: Results achieved in plague epidemic at Tumbes, Peru, 1945. *American Journal of Public Health 36*: 842–854.

McColl, H.P. 1975. The invertebrate fauna of the litter surface of a *Nothofagus truncata* forest floor, and the effect of microclimate on activity. *New Zealand Journal of Zoology* 1: 15-34.

McIlroy, J.C. 1984. The sensitivity of Australian animals to 1080 poison. VII. Native and introduced birds. *Australian Wildlife Research 11*: 373–385.

McIntyre, M.E. 1987. Ecological and behavioural relationships of some native cockroaches (Dictyoptera and Blattidae). Unpublished Ph.D. thesis, Victoria University of Wellington.

McLauchlan, M. 1995. Rising to the bait. *North and South*. March: 96–101.

McQueen, S.; Lloyd, B. 1997. Investigation into secondary poisoning: Short tailed bats and their invertebrate prey. *Conservation Science Newsletter 26*: 6–8. Department of Conservation, Wellington.

Marsh, R.E. 1968. An aerial method of dispersing ground squirrel baits. *Journal of Range Management 21*: 380–384.

Menzie, M.C. 1978. Metabolism of pesticides. Update II. *Wildlife 212*. United States Fish and Wildlife Service. Special Scientific Report. 381 p.

Moeed, A.; Meads, M. J. 1985. Seasonality of pitfall trapped invertebrates in three types of native forest, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology 12*: 17–53.

Moeed, A.; Meads, M.J. 1986. Seasonality of litter-inhabiting invertebrates in two native-forest communities of Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology 13*: 45–63.

Moeed, A.; Meads, M.J. 1987. Seasonality and density of emerging insects of a mixed lowland broadleaf-podocarp forest floor, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology 14*: 477–492.

Notman, P. 1989. A review of invertebrate poisoning by compound 1080. *New Zealand Entomologist 12*: 159–195.

Palmer-Jones, T. 1957. Laboratory methods for measuring the toxicity of pesticides to honey bees. *New Zealand Journal of Agricultural Research 1*: 290–300.

Pierce, R.J.; Montgomery, P.J. 1992. The fate of birds and selected invertebrates during a 1080 poison operation. Department of Conservation. *Science & Research Internal Report 121*.

Prokopy, R.J.; Owens, E.D. 1983. Visual detection of plants by herbivorous insects. *Annual Review of Entomology 28*: 337–364.

Rammell, C.G.; Fleming, P.A. 1978. Compound 1080. Properties and use of sodium monofluoroacetate in New Zealand. Animal Health Division, Ministry of Agriculture and Fisheries, Wellington. 137 p.

Sherley, G.; Wakelin, M.D.; McCartney, J. 1999. Forest invertebrates found on baits used in pest mammal control and the impact of sodium monofluoroacetate (1080) on their occurrence at Ohakune, North Island, New Zealand. *New Zealand Journal of Zoology 26*: 279–302.

Spurr, E.C. 1991. Reduction of wasp (Hymenoptera: Vespidae) populations by poison-baiting: experimental use of sodium monofluoroacetate (1080) in canned sardine. *New Zealand Journal of Zoology 18*: 215–222.

Spurr, E.B. 1994a. Impacts on non-target invertebrate population of aerial application of sodium monofluoroacetate (1080) for brushtail possum control in New Zealand. Pp. 116–123 in Seawright, A.A.; Eason, C.T. (Eds) Proceedings of the science workshop on 1080. *Royal Society of New Zealand Miscellaneous series 28*.

Spurr, E.B. 1994b. Review of the impacts on non-target species of sodium monofluoroacetate (1080) in baits used for brushtail possum control in New Zealand. Pp. 124–133 in Seawright, A.A.; Eason, C.T. (Eds) Proceedings of the science workshop on 1080. *Royal Society of New Zealand Miscellaneous series 28*.

Spurr, E.B. 1996. Impacts of 1080-poisoning for possum control on non-target invertebrates. *Science for Conservation 21*.

Spurr, E.B.; Powlesland, R.G. 1997. Impacts of aerial application of 1080 on non-target native fauna—review and priorities for research. *Science for Conservation 62*.

Spurr, E.B.; Drew, K.W.; Sutton, S.T. 1990. Safety of wasp poison-baiting operations for non-target species. *Forestry Research Institute Contract Report FWE 90/56*.

Stork, N.E. 1988. Insect diversity: facts, fiction and speciation. *Biological Journal of the Linnean Society 35*: 321–337.

Twigg, L.E. 1990. The sensitivity of some Australian caterpillars to fluoroacetate. *Mulga Research Centre Journal 10*: 14–18.

W.C.C. 1996. Otari Native Botanic Garden, management plan 1996. Policy unit, Social and Cultural Commissionary, Wellington City Council.

Appendix 1

INVERTEBRATE TAXA POTENTIALLY AT RISK FROM POISONING OPERATIONS

			SOURCE	GUILD*
MOLLUSCA	**GASTROPODA**			
STYLOMMATOPHORA	ENDODONTINAE	*Fectola infecta*	4	hm / 1 / 2
		Geminoropa moussoni	4	hm / 1 / 2
		Suteria ide	4	hm / 1 / 2
	FLAMMULININAE	*Flammulina zebra*	4	hm / 1 / 2
		Therasia traversi	4	hm / 1 / 3
		Allodiscus dimorphus	1,2,4	hm / 1 / 2
		Allodiscus granum	2,4,5	hm / 1 / 1
		Phenacohelix rusticus	4	hm / 1 / 2
	PUNCTINAE	*Laoma (allochroidea) accelerata*	1,4	hm / 1 / 2
		Laoma mariae	2	hm / 1 / 2
		Laoma marina	5	hm / 1 / 1
		Laoma serratocostata	5	hm / 1 / 1
		Laoma sp.	4	hm / 1 / 2
		Phrixgnathus milleneri	1	hm / 1 / 2
		Taguahelix viridula	5	hm / 1 / 2
		Iotula sericata	4	hm / 1 / 1
		Punctum n.sp. aff. *ordinarium*	4	hm / 1 / 1
		Punctum n. sp. aff. *monospateulata*	5	hm / 1 / 1
		Snail sp.	4,5	– / – / –
	OTOCONCHINAE	*Otoconcha dimidiata*	1,4,5	dm / 1 / 3
	PARAPHANTIDAE	*Schizoglossa* sp.	5	dm / 1 / 3
		slug sp.	4,5,6	– / – / –
PLATYHELMINTHES				
	TRICLADIDA	flat worm sp.	2,4,5	– / – / –
ONYCOPHORA				
		peripatus sp.	32	p / 1 / 2
ARTHROPODA	**CRUSTACEA**			
AMPHIPODA	TALITRIDAE	*Puhuruhuru aotearoa*?	1,2,4,5	d / 1 / 2
		Parorchestia tenuis?	1,2,4,5	d / 1 / 2
		Amphipoda sp.	1,2,3,4,5,12	d / 1 / 2
ISOPODA	ONISCIDAE	*Sphaerillo* sp. A	1,2,4,5	d / 1 / 3
		Sphaerillo sp. B	1,2,4,5	d / 1 / 2
		Philoscia sp.	2,4,5	d / 1 / 2
	ARMADILLIDAE	*Armadillo tuberculosus*?	1,2,4,5	d / 1 / 2
		slater sp.	4,5	– / – / –
DIPLOPODA				
SPIROSTREPTIDA	CAMBALIDAE	*Dimerogonus* sp.	2,3,4,5	d / 1 / 3
JULIDA		Julida indet. sp.	2,4,5	d / 1 / 2
CHORDEUMATIDA	METOPIDIOTRICHIDAE	*Schedotrigona* sp.	1,2,4,5	d / 1 / 3
POLYDESMIDA	POLYDESMIDAE	*Pseudoprionopeltis elaphrus*	1,2,4	d / 1 / 3
	DALODESMIDAE	*Icosidesmus* sp. A	1	d / 1 / 2
		Icosidesmus sp. B	2	d / 1 / 2
		Icosidesmus sp. C	1,2,5	d / 1 / 3
		Icosidesmus sp.	1,2,3,4	d / 1 / 3

* **Guild** = feeding / habitat / size

			SOURCE	GUILD*
		millipede sp.	4,5, 7a,12, 15	d / 1 / –
CHILOPODA				
GEOPHILOMORPHA		*Geophilomorpha* sp.	1,2,4,5	p / 1 / 2
LITHOBIOMORPHA		*Lithobiomorpha* sp.	4	p / 1 / 2
		centipedes	7a.15	p / 1 / 2
SYMPHYLA				
SCOLOPENDRELLIDA	SCUTIGERELLIDAE	*Hanseniella brachycera*	1,2,4,5	dh / 1 / 2
ARACHNIDA				
ARANEAE	THOMISIDAE	*Sidymella angularis*	2,4,5	p / 1 / 3
	ORSOLOBIDAE	*Waipoua* sp.	2	p / 1 / 2
	ERYCINIOLIIDAE	*Eryciniolia purpura punctata*	1,2	p / 1 / 2
		Eryciniolia purpura punctata?	2	p / 1 / 2
	ANAPIDAE	*Novanapis spinipes*	2	p / 1 / 2
	AGELENIDAE	*Cambridgea foliata*	2	p / 1 / 2
		spider sp.	2,4,5,12	p / 1 / 2
ACARINAE	CRYPTOSTIGMATIDAE	Cryptostigmata sp.	1,2,4,5	hm / 1 /1
	PROSTIGMATIDAE	Prostigmata sp.	1,2,4	p / 1 / 1
		mite sp.	4,5,22	p / 1 / 1
OPILIONES	PHALANGIIDAE	*Monoscutum titirangiensis*	1,2,3,4,5	hp / 1 / 3
	MEGALOPSALIDAE	*Megalopsalis* sp.	1,2,4,5	hp / 1 / 3
	TRIAENONYCHIDAE	*Nuncia grimmetti*	1,4,5	hp / 1 / 3
		Nuncia alpha	1,4,5	hp 1 / 3
		Nuncia sp.	4	hp / 1 / 3
		Pristobunus hamiltoni	1,2,4,5	hp / 1 / 3
		Soerensenella rotara	1,4,5	hp / 1 / 3
		Algidia sp.?	3,4	hp / 1 / 3
	CYPHOPHTHALMIDAE	*Rakaia pauli*	1,4	hp / 1 / 2
PSEUDOSCORPIONIDA	PSEUDOSCORPIONIDAE	pseudoscorpion sp.	4,5	p / 1 / 1
COLLEMBOLA				
ARTHROPLEONA	PODURIDAE	Poduridae sp.	2,4	dm / 1 / 1
	ENTOMOBRYIDAE	Entomobryinae sp.	1,2,4,5	dm / 1 / 1
	PARANELLIDAE	Paronellinae sp.	1,2,4,5	dm / 1 / 1
SYMPHYPLEONA	SMINTHURIDAE	Dicyrtominae sp.	2,4,5	dm / 1 / 1
		Collembola sp.	4,5,11,14a	dm / 1 / 1
INSECTA				
ISOPTERA		termite sp.	7b,15	dh / 1 / 1
THYSANURA		Thysanura sp.	32	hp / 1 / 2
BLATTODEA	BLATTIDAE	*Cellatoblatta vulgarus*	4,5	dh / la / 3
		cockroach sp.	7b, 8a, 15, 17, 25	– / – / –
DERMAPTERA	LABIDURIDAE	*Parisolabis novaezeelandiae*	1,2,4,5	dhp / 1 / 3
PHASMATODEA	PHASMATIDAE	stick insect sp.	4	h / a / 3
ORTHOPTERA	STENOPELMATIDAE	†*Zealandosandrus gracilis*	1,2,4,5	h / 1 / 3
		†*Zealandosandrus* n.sp.	1	h / 1 / 3
		†*Zealandosandrus* sp.	1,4,5	h / 1 / 3
		Hemideina thoracica	4,5,21	h / a / 3
		Hemideina crassidens	16a	h / a / 3
		tree weta	8c, 8d	h / a / 3
	GRYLLIDAE	*Nemobius bivitattus*	2,4	h / 1 / 3
	RHAPHIDOPHORIDAE	*Gymnoplectron tuarti*	2,4,5	h / 1 / 3
		Isoplectron sp.	1,4,5	h / 1 / 3
		Neonetus sp.	1,4,5	h / 1 / 3
		Rhaphidophorid indet sp.	2,3,4,5,8b	h / 1 / 3
		weta sp.	3,4,5,11,12,21	– / – / 3

* **Guild** = feeding / habitat / size   † Now a synonym of *Hemiandrus* (see Johns 1997).

			SOURCE	GUILD*
COLEOPTERA	CARABIDAE	*Mecyclothorax placens*	1,2,4,5	p / 1 / 2
		Zolus sp. aff. *femoralis*	1,2,4,5	p / 1 / 2
		Selenochilus ruficornis	1	p / 1 / 2
		Carabidae sp.	3	p / 1 / 2
	HYDROPHILIDAE	*Psephorboragus signatus*	1,2	hd / 1 / 2
		Hydrophilidae sp.	4,5	hd / – / –
	LEIOLDIDAE	Cholevinae sp.	4,5	d / 1 / 2
	STAPHYLINIDAE	*Quedius tinctellus*	2,4,5	p / 1 / 2
		Sepedophilus sp.	1,2,4,5	p / 1 / 2
		Pselaphine sp.	4,5	p / 1 / 1
		Silphotelus sp.	4	p / 1 / 1
		Brachynopus latus	4,5	p / 1 / 1
		Staphylinidae indet sp.5	2,4,5	p / 1 / 2
	LUCANIDAE	*Paralissotes reticulatus*	4	h / 1 / 3
	SCARABAEIDAE	*Saphobius squamulosus*	1,2,4,5	hd / 1 / 2
		Odontria sp.?	4	hd / 1 / 3
		Scarabaeidae sp.	3	hd / – / –
	BYRRHIDAE	*Synorthus* sp.	2,4	h / 1 / 1
	DRYOPIDAE	*Parnida agrestis*	1,5	d / 1 / 2
	NITIDULIDAE	*Epuraea* sp.	5	hd / 1 / 2
	PHLOELSTICHIDAE	*Priasilpha obscura*	5	hd / 1 / 2
		Agopytho foveicollis	2	dm / 1 / 2
	SILVANIDAE	*Brontopriscus plueralis*	1,4,5	dm / 1 / 3
	CRYPTOPHAGIDAE	*Atomaria* sp.	5	dm / 1 / 2
		Micrambina sp.	4	dm / 1 / 2
	COCCINELLIDAE	Coccinellidae sp.	5	p / 1 / 3
	CORTICARIIDAE	*Aridius* sp.	4	dm / 1 / 2
	LATHRIDIDAE	*Melanophthalma* sp.	1	dm / 1 / 2
	COLYDIIDAE	Colydiidae sp.	4	dm / 1 / 2
		Colydiidae sp. 2	4	dm / 1 / 2
	TENEBRIONIDAE	*Mesopatrum granulosum*?	5	d / 1 / 2
		Periatrum sp.	4,5	d / 1 / 2
		Tenebrionidae sp.	13	d / 1 / 2
	CERAMBYCIDAE	*Somatidia* sp. A	1,2,4,5	h / 1 / 2
		Somatidia sp. B	1,4,5	h / 1 / 2
		Somatidia sp.?	1,2,4,5	h / 1 / 2
		Cerambycidae sp.	3	h / – / –
	LAMIINAE	Lamiinae sp.	4,5	h / 1 / 3
		Lamiinae sp. 2	4,5	h / 1 / 2
	CHRYSOMELIDAE	Eumolpinae sp.	4,5	h / 1 / 2
	CURCULIONIDAE	*Nestrius sculpturatus*	1,2,4	h / 1 / 2
		Bryocatus sp.	1,4,5	h / 1 / 2
		Bryocatus? (TBID 1,2,3)	4	h / 1 / 2
		Phrynixus terreus	2,4,5	h / 1 / 2
		P. terreus? (TBID 13,14,15)	4,5	h / 1 / 2
		Acalles scitus (*Hiiricalles scitus*?)	1,4	d / 1 / 2
		Hiiricalles scitus	4,5	d / 1 / 2
		Crisius sp.? (TBID 5)	4	d / 1 / 2
		Dermothrius farinosus	1,4,5	d / 1 / 1
		Agacalles formosus	4	d / 1 / 1
		Agacalles sp.? (TBID 9)	4	d / 1 / 1
		Agacalles sp.? (TBID 10)	4	d / 1 / 1
		Scelodolichus celsus? (TBID 8)	4	d / 1 / 2
		Zeacalles binodosus	1,4	d / 1 / 1

* **Guild** = feeding / habitat / size

			SOURCE	GUILD*
		Zeacalles incultus	1,4	d / 1 / 1
		Zeacalles sp.? (TBID 6)	4,5	d / 1 / 1
		Zeacalles sp.? (TBID 7)	4	d / 1 / 2
		Andracalles vividus	1,2,4,5	h / 1 / 2
		Rystheus ocularius	2,4,5	h / 1 / 2
		Geochis similis	1,4,5	h / 1 / 1
		Curculionidae (TBID 11)	4	– / 1 / 2
		Curculionidae (TBID 12)	5	– / 1 / 1
		Curculionidae sp.	4,5	– / – / –
		Coleopteran adult	4, 5, 7c, 12, 14a, 15	– / – / –
		Coleopteran larvae?	4,5	– / – / –
LEPIDOPTERA	OECOPHORIDAE	*Tingena* sp. (larvae)	2,5	d / 1 / 2
	PSYCHIDAE	*Grypotheca* sp. (larvae)	1,2,4,5	h / 1 / 2
	NOCTUIDAE	*Rhapsa scotosialis* (larvae)	1	d / 1 / 3
		Mnesamplea privata (larvae)	31b	– / – / –
	PIERIDAE	Pieris brassicae larvae	18	h / a / 3
		Lepidopteran larvae	1,2,4,5	– / – / –
		Lepidopteran adult	4	– / – / –
		moths	14b,17	– / – / –
DIPTERA	TIPULIDAE	*Leptotarsus (macromastix) binotatus*	2	h / f / 3
		Molophilus sp. (adult)	2	h / f / 3
		Tipulidae indet sp. (adult)	2,5	h / f / 2
	TRICHOCERIDAE	*Paracladura* sp. (adult)	1,2,4	h / f / 2
		Paracladura sp. b (adult)	1,2	h / f / 2
		Trichocera (Trichocera) annulata (adult)	2	h / f / 3
	CHIRONOMIDAE	*Orthocladiinae* sp. (adult)	1,2,4,5	x / f / 2
	PSYCHODIDAE	*Psychoda* sp. (adult)	1,2,5	x / f / 1
	ANISOPODIDAE	*Sylvicola* sp. (adult and larvae)	2	d / f / 2
	CECIDOMYIIDAE	Cecidomyiidae sp. (adult)	2	hp / f /1
	SCIARIDAE	*Sciara* cf. *constrictans* (adult)	1	d / f / 1
	MYCETOPHILIDAE	Mycetophilidae indet sp. (adult)	2,4	d / f / 2
	?BRACHYCERA	?Tabanidae sp. (larvae)	1	d / 1 / 2
	EMPIDIDAE	Ceratomerinae sp. (adult)	2	d / f / 2
	CALLIPHORIDAE	blowflies	29	d / f / 3
		Diptera sp. (adult)	2,4,5,22,26	– / – / –
HYMENOPTERA	BRACONIDAE	Braconidae sp.	2,4	p / f / 1
	DIAPRIIDAE	Diapriidae indet sp.	2	p / f / 2
	APIDAE	*Apis melifera*	9,27,29	h / f / 3
	BOMBIDAE	bumble bee sp.	29	h / f / 3
	VESPIDAE	*Vespula vulgaris*	2, 29,30	p / f / 3
		Vespula germanica	29	p / f / 3
	FORMICIDAE	*Huberia brouni*	1,2,4,5	dhp / 1 /1
		Huberia striata	16b	dhp / 1 /1
		Prolasius advena	1,2,4,5	dhp / 1 /1
		Veranessoi andrei	10	– / – / –
		Liometopum occidentale	10	– / – / –
		Pogonyrme sp.	13	– / – / –
		ant sp.	4,5,7c,15,17,28,29	– / – / –
	hymenoptera larvae	(*Perga dorsalis*)	31a	– / – / –
	hymenoptera		12,29	– / – / –
HETEROPTERA	LYGAEIDAE	*Rhypodes* sp.	1,4,5	h / 1 / 2
		indet sp.	2,4	h / – / –
	REDUVIIDAE	*Ploiaria antipoda*	2	p / 1 / 2
	APHIDIDAE	aphids	17,19,20,23	h / a / 1
SIPHONAPTERA		flea (rat)	24	p / s / 1

* **Guild** = feeding / habitat / size

Notes

Letter codes: d=decomposer, h=herbivorous (incl. nectar), m=mycetophagous, p=predator, x=dont feed, l=litter, a=arboreal, s=host, f= flier, 1=<2 mm, 2=2–10 mm, 3=>10 mm

Information is from: Klimaszewski & Watt (1997)—Coleoptera; R. Forster (pers. comm.)—spiders, harvestman; J.M. Clarke (pers. comm.)—mites; Dugdale (1996)—Lepidoptera; Duncan (1994)—amphipods; CSIRO (1991)—others; Forster & Forster (1970)—others.

Sources—Bait use studies

1. Sherley et al. (1999) non toxic cereal baits (i)
2. Sherley et al. (1999) non toxic carrot baits(ii)
3. McQueen & Lloyd (1997) non toxic cereal baits
4. Sherley et al. (1999) toxic cereal baits
5. Sherley et al. (1999) non toxic cereal baits(iii)

Observed to consume baits in the wild

6. Batcheler (1978) seen on cereal baits
7. Eason et al. (1991) a. residues of 0.28 mg/g; b. residues of 0.48 mg/g; c. residues of 0.05 mg/g
8. Eason et al. (1993) a. residues of 9.11 mg/g from cereal; b. residues of 4.1 mg/g from cereal; c. residues of 46 mg/g from cereal; d. sublethal 15 mg/g oral dose
9. Goodwin & Ten Houten (1991) 3.1–10 mg/kg from jam baits
10. Hegdal et al. (1986) 1.4 ppm killed (0.075 % 1080 crimped oat groats)
11. Lloyd & Hackwell (1993) seen on baits
12. S. McQueen, B. Lloyd and R. Williams. (pers. comm.) seen on toxic cereal baits
13. Marsh (1968) poisoned by bait
14. Notman (1989) a. seen on unknown type baits; b. seen dead beside carrot and cereal baits
15. Pierce & Montgomery (1992) 0.05–0.75 mg/kg from cereal baits

Susceptibility and toxicity data lab experiments

16. Booth & Wickstrom (1998) a. LD50 91 mg/kg lab trial; b. LD50 42 mg/kg lab trial
17. Chenoweth (1949)
18. David & Gardner (1958) systemic lab trial
19. David & Gardner (1951) systemic lab trial
20. David (1950) systemic lab trial
21. Hutcheson (1989) sublethal dosing, cereal
22. Johannsen & Knowles(1974) toxic in lab trial
23. Lowe (1960) systemic toxicity
24. Macchivello (1946) Toxic systemic in rats
25. McIntyre (1987) lab trial
26. Menzie (1978) toxic in lab trial
27. Palmer-Jones (1957) 0.8 mg LD50 lab trial
28. Rammell & Fleming (1978)
29. Spurr et al. (1990) 0.5% 1080 in sardine bait
30. Spurr (1991) 0.001 % canned sardine bait
31. Twigg (1990) a. LD50 1.05 mg/kg; b. LD50 3.88 mg/kg
32. This study. non toxic cereal