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3.4 USE OF ARTIFICIAL REFUGES IN THE FIELD

The average number of weta found in artificial refuges at different sites ranged from a maximum of < 0.1 weta per refuge in the Kaweka Range to c. 1.5 weta per refuge in the Turitea catchment (Figs 8 & 9). The period before the first weta were found in these refuges varied from 1–9 months after they were set out, depending on both the site and the time of year (Figs 8 & 9). Most weta were found singly in galleries. The only exceptions were in the Turitea catchment, where three galleries contained pairs of adult males and females. These pairs comprised 3.9% of all weta found in the Turitea catchment.

A wide size-range of weta was found in all types and sizes of galleries, although small refuges with small galleries and entrance holes contained only juvenile weta, whereas medium and large refuges contained both juveniles and adults.

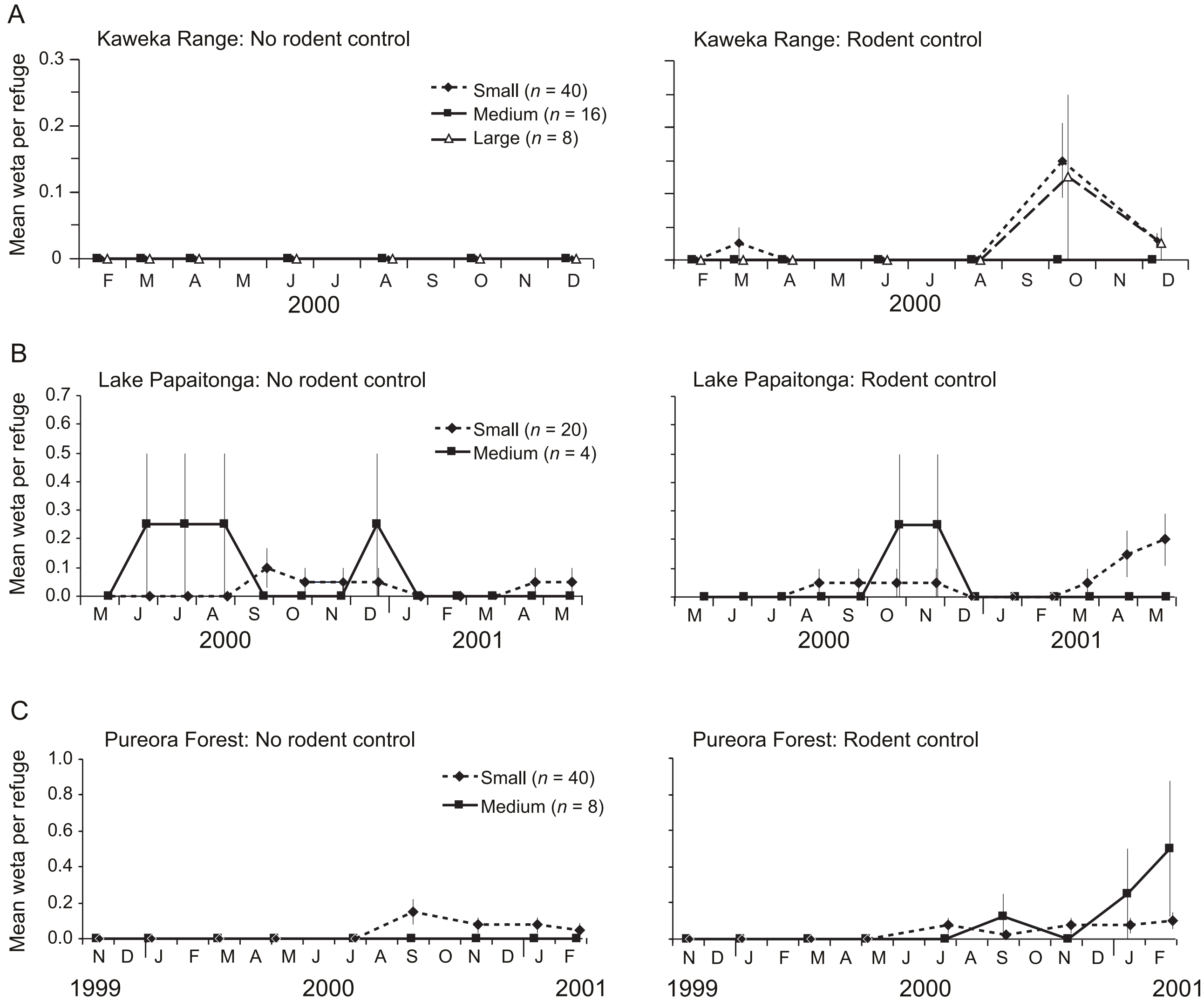

Figure 8. Mean (± SEM) number of *Hemideina crassidens* and *H. thoracica* found in different-sized artificial refuges in relation to rodent control in A. Kaweka Range, B. Lake Papaitonga Reserve, and C. Pureora Forest. *n* = number of refuges used. Data are offset ± 1 day for clarity.

The proportion of each type of gallery occupied by weta varied considerably, but weta were most commonly found in deep galleries with abrupt downward and upward terminations (gallery types 3 & 4) and galleries that opened downward in refuges made from willow wood (gallery type 1), followed by galleries that curved upward gently (gallery type 2). Relatively few weta were found in galleries with entrances that opened downwards in refuges made from pine (gallery type 1) (Table 4).

Figure 9. Mean (± SEM) number of *Hemideina crassidens* and *H. thoracica* found in different-sized artificial refuges in A. Tongariro National Park, B. Ruahine Range, and C. Turitea Catchment. *n* = number of refuges used. Data are offset ± 1 day for clarity.

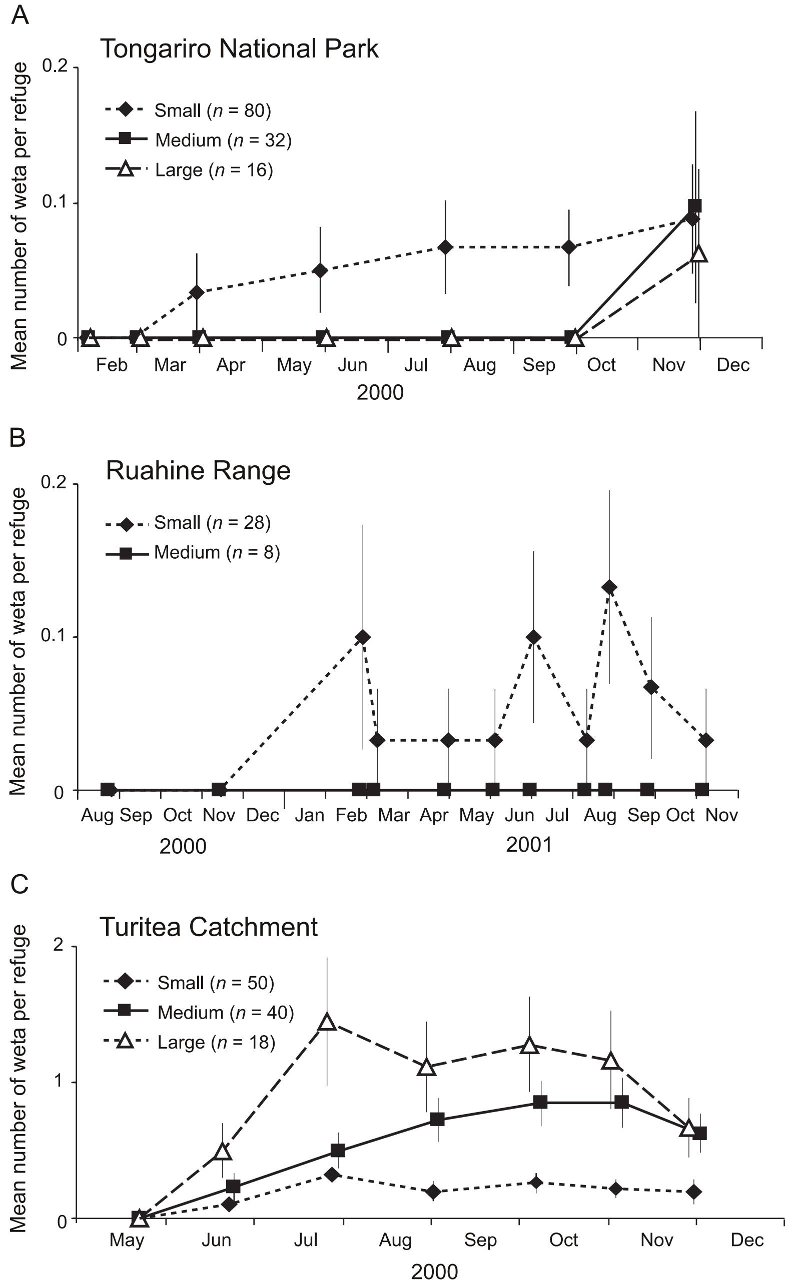

TABLE 4. NUMBER OF *Hemideina crassidens* AND *H. thoracica* FOUND IN DIFFERENT TYPES OF GALLERIES WITHIN ARTIFICIAL REFUGES IN THE TURITEA CATCHMENT.

Refuge designs and gallery types are shown in Figs 3B, 5 & 7.

REFUGE SIZE AND MATERIAL	GALLERY TYPE	NO. WETA	TOTAL NO. GALLERIES	% GALLERIES OCCUPIED (95% CI)
Small pine	–	13	100	13.0 (6.3–9.7)
Medium pine	1	48	160	30.0 (22.8–37.3)
	2	2	40	5.0 (0–11.9)
Medium willow	1	17	160	10.6 (5.8–15.5)
	2	26	40	65.0 (59.9–80.1)
Large pine	3	19	36	52.8 (36.1–69.4)
	4	11	18	61.1 (38.1–84.1)
	5	4	18	22.2 (2.6–41.8)
	6	12	72	16.7 (7.9–25.5)
	7	2	18	11.1 (0–25.9)

3.4.1 Occupancy in relation to the edge and interior of a forest

The probability of finding weta in artificial refuges was not affected by whether the refuges were near the forest edge or in the interior of the forest (Table 5). There was, however, a significant interaction between the type of refuge and the height above ground at which the refuge was placed: medium-sized refuges made of pine and situated at the forest edge or made of willow wood and situated inside the forest were equally likely to be occupied when attached to tree trunks within 2 m of the ground or in the canopy; in contrast, medium-sized refuges elsewhere and large refuges both in the forest and at the forest edge were more likely to be occupied when they were in the canopy than when placed within 2.2 m of the ground (Table 6).

TABLE 5. RELATIONSHIP BETWEEN THE PROBABILITY OF FINDING *Hemideina crassidens* AND *H. thoracica* IN ARTIFICIAL REFUGES AND THE POSITION, HEIGHT AND TYPE OF THE REFUGE.

Refuges were set at the edge or interior of the forest (Position), near the ground or in the canopy of a tree (Height), and varied in construction (Type: medium-sized pine refuge, medium-sized willow refuge or small pine refuge). (Generalised linear model with binomial errors, corrected for overdispersion.)

SOURCE	RESIDUAL		Δ	df	*P*
	DEVIANCE	df	DEVIANCE		
Position	336.87	134	0.03	1	0.87
Type*Height			38.43	6	0.00
Position*Type*Height			5.06	6	0.54

TABLE 6. RELATIONSHIP BETWEEN THE PROPORTIONS OF *Hemideina crassidens* AND *H. thoracica* FOUND IN ARTIFICIAL REFUGES AND THE POSITION, TYPE AND HEIGHT OF THE REFUGE.

Refuges were set at the edge or interior of the forest (Position), varied in construction (large, medium-sized made of pine or willow wood, or small) and were attached to trees at two heights (on trunks within 2 m of the ground or on trunks in the canopy). Percentages of refuges occupied by tree weta are given (with 95% CI). (Generalised linear model with binomial errors, corrected for overdispersion.)

POSITION	TYPE OF REFUGE	HEIGHT ON TREE	
		< 2 m	CANOPY
Edge	Large	37 (15–66)	60 (32–83)
	Medium, Pine	38 (21–59)	37 (20–58)
	Medium, Willow	37 (20–58)	58 (38–76)
	Small	22 (12–35)	–
Interior	Large	38 (14–70)	75 (41–93)
	Medium, Pine	22 (9–43)	47 (28–67)
	Medium, Willow	53 (33–72)	57 (36–75)
	Small	15 (8–26)	–

3.4.2 Occupancy in relation to height above ground

Occupancy in relation to site, height above ground and size of refuges

The probability that refuges of all sizes were occupied varied considerably from site to site, but did not appear to be related to the height above ground, when these refuges were placed within c. 2.2 m of the ground (Table 7).

TABLE 7. RELATIONSHIP BETWEEN THE PRESENCE OF *Hemideina crassidens* AND *H. thoracica* AND THE SIZE, HEIGHT AND LOCALITY OF REFUGES.

Refuges differed in size (small, medium and large), and were set at various heights (within c. 2.2 m of the ground) at three locations (Site: Kaweka Range, Tongariro National Park or Turitea catchment). (Logistic distributions.)

REFUGE SIZE	SOURCE	RESIDUAL DEVIANCE	RESIDUAL df	Δ DEVIANCE	df	*P*
Small	Site	346.4	338	91.7	5	< 0.01
	Height			0.1	1	0.75
	Height*Site			8.5	5	0.13
Medium	Site	74.5	114	88.1	5	< 0.01
	Height			3.5	1	0.06
	Height*Site			0.3	5	0.99
Large	Site	29.2	35	41.0	2	< 0.01
	Height			0.6	1	0.46
	Height*Site			0.3	2	0.86

Occupancy in refuges made from pine v. willow and the relationship with height above ground

Initially, weta moved into refuges made from willow at a faster rate than those made from pine (Fig. 10), and there were significantly more weta in medium-sized refuges made from willow than from pine during the first two sample occasions ($P < 0.05$, proportion test; Agresti & Caffo 2000). However, the mean number of weta found in refuges made from willow decreased 2–3 months after the refuges were set out, so that there was no significant difference between refuges constructed from willow or pine in the subsequent samples. There was also no significant difference in the number of weta found in refuges at different heights above ground when refuges were set up to 8.1 m above the ground (Table 8).

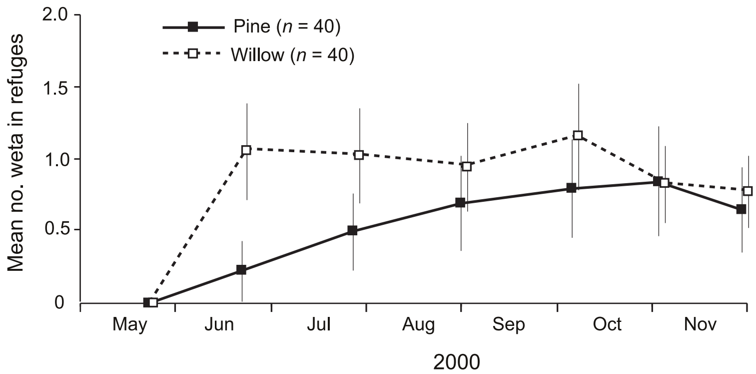

Figure 10. Mean (± 95% CI) number of *Hemideina crassidens* and *H. thoracica* found in medium-sized artificial refuges made of pine and willow wood in the Turitea catchment. Means for pine refuges are also shown in Fig. 9C. *n* = number of refuges used. Data are offset ± 1 day for clarity.

TABLE 8. RELATIONSHIP BETWEEN THE NUMBER OF *Hemideina crassidens* AND *H. thoracica* FOUND IN MEDIUM-SIZED REFUGES AND THE TYPE AND HEIGHT OF REFUGES.

Refuges were constructed from two types of wood (Type: pine or willow wood), and were placed in trees at two heights (Height: near the ground or in the canopy). Refuges were monitored on four occasions from August to November 2001 in the Turitea catchment. (Generalised linear model with binomial errors, corrected for overdispersion.)

SOURCE	RESIDUAL		Δ	df	P
	DEVIANCE	df	DEVIANCE		
Type	224.3	76	0.00	1	0.97
Height			1.18	1	0.28
Height*Type			0.12	1	0.73

3.4.3 Occupancy in relation to density of weta in a forest

The mean number of weta in medium-sized refuges showed a positive relationship with the mean number of weta found elsewhere in 10 × 10 m plots ($r^2 = 0.672$, $F = 8.19$, df = 1, 4, $P = 0.05$); however, this relationship is tentative, as there are only six data points in the regression (data from four areas in Lake Papaitonga Reserve and two areas in the Turitea catchment). There was no relationship between the mean number of weta found in small refuges and the number of weta found elsewhere in the same plots ($r^2 = 0.029$, $F = 0.12$, df = 1, 4, $P = 0.75$).

3.4.4 Effect of rodent control on occupancy of weta in refuges

The number of weta found in refuges was influenced by whether rodents were being controlled in an area, but the effect differed between locations (Fig. 9 & Table 9). Thus, in the Kaweka Range, more weta were found in refuges where rodents were controlled than where they were not, whereas at Lake Papaitonga Reserve and in Pureora Forest there was no significant difference between the numbers of weta found in refuges where rodents were or were not controlled (Table 10). Overall there was no relationship between the probability of finding a weta in a refuge and height above ground up to c. 2.2 m or refuge size (Table 9).

TABLE 9. RELATIONSHIP BETWEEN THE NUMBER OF *Hemideina crassidens* AND *H. thoracica* FOUND IN REFUGES AND THE SIZE OF REFUGES, SITE, HEIGHT AND LEVEL OF RODENT CONTROL.

Refuges differed in size (small, medium and large) and were set out at three sites (Kaweka Range, Papaitonga Reserve or Pureora Forest) at various heights above the ground. The level of rodent control differed between sites (Rodent: with or without control). (Logistic regression: residual deviance = 210.8; residual df = 246.)

SOURCE	Δ DEVIANCE	df	χ^2	P
Site	14.00	2	7.00	< 0.001
Size	0.19	1	0.09	0.91
Height	1.29	2	1.29	0.26
Site*Size	4.92	2	2.49	0.09
Height*Site	1.28	1	0.64	0.53
Height*Size	3.97	2	1.98	0.14
Height*Site*Size	0.32	2	0.16	0.85
Rodent	3.47	1	3.47	0.06
Site*Rodent	11.98	2	5.99	0.003
Size*Rodent	0.20	2	0.10	0.91
Height*Rodent	0.73	1	0.73	0.39
Site*Size*Rodent	4.73	2	2.37	0.09
Height*Site*Rodent	5.48	2	2.74	0.07
Height*Size*Rodent	1.92	2	0.96	0.38

TABLE 10. MEAN (± 95% CI) PERCENTAGE OCCUPANCY OF ARTIFICIAL REFUGES BY *Hemideina crassidens* AND *H. thoracica* AT DIFFERENT SITES IN RELATION TO RODENT CONTROL USING POISON.

SITE	NO CONTROL		CONTROL	
	MEAN ± 95% CI	n	MEAN ± 95% CI	n
Kaweka Range	0.01 ± 0.02%	64	2.50 ± 1.75%	64
Lake Papaitonga Reserve	3.82 ± 2.34%	24	4.92 ± 2.63%	24
Pureora Forest	3.39 ± 1.87%	48	4.69 ± 2.77%	48

3.4.5 Relationship between occupancy of weta in refuges and species of tree

Occupancy of refuges in relation to the species of tree to which they were attached was investigated separately for each site, because the tree species present varied between sites (Appendix 1). Overall, there was substantial variation in the average number of weta found in refuges attached to different species of tree (Appendix 3); however, no significant relationship was detected between the likelihood of weta being found in an artificial refuge located within 2.2 m of the ground and the species of tree to which the refuge was attached (Table 11). This lack of significance was probably due to small sample sizes.

TABLE 11. RELATIONSHIP BETWEEN THE PRESENCE OF *Hemideina crassidens* AND *H. thoracica* IN REFUGES AND THE SPECIES OF TREE THAT REFUGES WERE ATTACHED TO.

Variation due to different sample lines at each site (Location), different types of refuge (Type), different heights above ground (Height: near the ground or in the canopy), and whether rodents were being controlled or not (Rodent), were controlled for in the analysis. (Results corrected for over-dispersion.)

SITE	RESIDUAL		SOURCE	df	Δ	*P*
	DEVIANCE	df			DEVIANCE	
Kaweka Range	17.60	100	Location	3	13.76	< 0.01
			Type	1	2.21	0.14
			Type*Height	3	4.37	0.22
			Tree species	21	8.03	0.99
Tongariro National Park	66.72	101	Location	3	27.18	< 0.01
			Type	2	3.71	0.16
			Type*Height	3	6.44	0.09
			Tree species	18	27.02	0.08
Lake Papaitonga Reserve	72.40	36	Location	1	1.69	0.19
			Type	1	0.49	0.49
			Type*Rodent	2	0.70	0.71
			Height*Size	2	1.17	0.56
			Tree species	5	2.59	0.76
Pureora Forest	184.94	118	Location	5	27.21	< 0.01
			Type	1	0.00	0.93
			Type*Height	2	1.39	0.50
			Tree species	18	16.28	0.57
Ruahine Range	17.82	24	Location	1	8.38	< 0.01
			Type	1	13.97	< 0.01
			Type*Height	2	3.08	0.21
			Tree species	13	15.67	0.27
Turitea catchment	288.63	124	Location	1	0.03	0.87
			Type	3	34.07	< 0.01
			Type*Height	4	10.30	0.04
			Tree species	15	22.51	0.10

4. Discussion

4.1 LABORATORY AND GLASSHOUSE TESTS

Our results from the laboratory tests may not be conclusive because they involved comparing familiar refuge design features with novel features. A further complication was that we had to use field-collected weta in our experiments, as their long developmental period (Stringer & Cary 2001) made rearing them to adults in captivity impracticable. Consequently, we could not know what weta had experienced in the field prior to collection, or how this might have affected their behaviour in the experiments. Adult tree weta do return repeatedly to the same gallery both in captivity and in the wild (Sandlant 1981; Moller 1985; Barrett & Ramsay 1991; Ordish 1992; Jamieson et al. 2000; Trewick & Morgan-Richards 2000; Field & Sandlant 2001) but nothing is known about the cues they use. It is certainly possible that some physical attributes of their galleries might be involved, but it is thought to be most likely that chemical cues—particularly those associated with the faeces—are used (Guignion 2005).

Our data suggest that tree weta will occupy a wide range of different refuge designs. This is supported by the range of artificial refuge designs that have been used successfully in the field (e.g. Ordish 1992; Sherley 1998; Trewick & Morgan-Richards 2000; Spurr & Berben 2004; Powlesland et al. 2005), and the fact that tree weta in the field are clearly opportunistic in relation to the cavities they occupy: we have found them in a wide range of deep holes, cracks and hollows, and *Hemideina ricta* Hutton has even been found in long vertical crevices in fence posts that were open both at the top and sides and appeared to be too exposed to be suitable as galleries (Townsend 1995). Our results with *H. crassidens* and *H. thoracica* indicate that tree weta may prefer certain features of artificial refuges, and that these preferences may vary between species. However, our laboratory and glasshouse tests indicate that almost any design of artificial refuge is likely to be occupied by some weta: some individuals of both species were always found in the less preferred options in our trials. The size of the opening clearly places an upper limit on the size of weta that can enter a gallery, but it does not seem to affect the minimum size of weta within a gallery (Field & Sandlant 2001).

Some refuge designs used by other researchers incorporate a glass or Perspex observation window under the access cover (Ordish 1992; Sherley 1998). Such observation windows are useful for artificial refuges that are used for public display. In this study, the presence of an observation window did not affect *H. thoracica*, but it did adversely affect occupancy by *H. crassidens*. Refuges can be designed to allow inspection through the access cover whilst minimising disturbance to any resident weta by making the grooves c. 20 mm or more deep; we noticed that when this was done most weta remained where they were within the grooves and few tried to escape when the access cover was opened gently. We also recommend that these windows be constructed so that the Perspex can be easily removed for cleaning, as it eventually becomes obscured by dirt and, if the refuges are damp, by mould.

Previous reports show that weta take some months to become established in artificial refuges (Trewick & Morgan-Richards 2000; Spurr & Berben 2004; Powlesland et al. 2005); this finding was supported by the present study. The actual cause of this delay is not known, but it is possible that weta were partly deterred from using the refuges because of chemicals in the fresh pine timber, and thus the refuges became more attractive once these chemicals evaporated. This was supported by the preference shown by both *H. thoracica* and *H. crassidens* for refuges that had previously been aged in the field over those that were freshly made, and by the finding that the material from which refuges are constructed also affects the rate at which weta move into them. In this respect, the field result that weta move at a faster rate into refuges made from willow than those made from pine wood supports the laboratory finding that willow is preferred to pine in the short term (Table 1).

Refuges made from macrocarpa (*Cupressus macrocarpa* Gordon) were used with success by Townsend (1995), but we did not test this wood because its resistance to decay and wood-boring insects indicates that it may contain noxious chemicals. Similarly, we did not test tanalised® pine (treated with copper chrome arsenate) because weta often enlarge the galleries by chewing (Field & Sandlant 2001), so they could potentially be poisoned. Ordish (1992), however, noted that the use of treated timber in refuge construction did not deter tree weta and apparently did them no harm.

Observations made while testing access to galleries by mice indicated that mice could get food close to the entrance, even if the entrance hole was less than 18 mm in diameter. We therefore suggest that galleries should be 18 mm in diameter and of extended length if mice are likely to be a problem.

4.2 USE OF REFUGES IN THE FIELD

Our results indicate that the number of tree weta found in artificial refuges is likely to reflect the number of tree weta in the immediate surrounding area; however, this is only a tentative result based on six samples. We agree with Trewick & Morgan-Richards (2000) that refuges should be placed in the field as early as possible to allow a substantial time before the number of weta observed within them is used to obtain an index of the size of the weta population. In our case, the first weta were found in refuges 1–9 months after they were set out, and the number generally increased subsequently with time. However, our field study was restricted to 1.5 years, which may well have been too short a duration to adequately sample those sites where few weta occupied the refuges. Ordish (1992), who used refuges with one or two galleries in Wellington, reported that the first weta appeared in them c. 3 months after they were set in early January, and that they reached an average of c. four weta per refuge after 1 year. Following this, the average number fluctuated from 3.2 to 5.4 over the next 3 years, with two peaks per year, the first in March–April and the second in June–September. Similarly, in two further studies it was reported that tree weta began occupying artificial refuges 2–9 months after they were put out, both at Mohi Bush, Hawkes Bay (refuges put out in August 1994; Trewick & Morgan-Richards 2000), and in Tararua Forest Park (refuges put out in August 1999;

Spurr & Berben 2004). In both studies, the number of weta generally increased with time, although there were also marked seasonal fluctuations in number. Our results suggest that weta are most likely to move into new artificial refuges from November to December, but subsidiary invasions may occur at any time between February and September depending on the location (Figs 8 & 9). In contrast, Ordish (1992) reported that weta numbers increased in refuges in Wellington during February and March and from May to November, and that the timing of these increases differed over the 3 years of his study. Finally, our results suggest that using refuges made from willow wood instead of pine may increase the rate at which weta initially occupy them, although the overall final occupancy rates did not differ after a year (Table 8 & Fig. 10).

Various authors have suggested that the number of weta present in a habitat may be limited by the availability of galleries (Field & Sandlant 1983; Moller 1985; Field 1993); thus, it follows that setting out artificial refuges may increase the overall weta population in an area. This limitation, however, does not always apply. For example, Field & Sandlant (2001) showed that in some cases a substantial proportion of suitable natural cavities may not be used. They suggested that this could be due to predation pressure or because of the resource-defence polygynous mating system of weta, whereby adult males compete for a resource (i.e. holes containing females). Thus, although we have shown a tentative relationship between the number of tree weta found in refuges and their density in the surrounding forest, further research is still required. Until this is done, we recommend that the number of tree weta in artificial refuges only be used as a relative index of population size for comparative purposes at the same sites over time rather than as an absolute index. This is in accordance with the suggestion of Trewick & Morgan-Richards (2000) that such refuges cannot be easily compared between sites. Putting out artificial refuges for weta may be particularly likely to increase the overall population size where natural cavities are scarce. However, we know of no publication that tests whether artificial refuges can be used to obtain a measure or index for a population of an insect that roosts or hides in natural cavities, or whether providing such artificial refuges affects the insect population. Nest and roost boxes have, however, been used to monitor both bird and mammal populations, and nest boxes have been reported to artificially increase the populations of some birds (Hayward et al. 1992; Franzred 1997; Althoff & Althoff 2001; Sanz 2001; Twedt & Henne-Kerr 2001; and references therein).

Our results support previous findings that the number of tree weta found in artificial refuges varies considerably both over time and between individual refuges (Ordish 1992; Trewick & Morgan-Richards 2000; Spurr & Berben 2004; Powlesland et al. 2005). We did not, however, find that tree species significantly affected the likelihood of finding weta. This is possibly because our study was not primarily designed to investigate this. Instead, the number of trees of different species used in our study reflected the composition of tree species at each site. Many of the less common trees were therefore represented only once or twice, which reduced the sensitivity of the analysis. The proportion of refuges containing weta did, nevertheless, vary greatly between different tree species. Field & Sandlant (2001) reviewed factors that affect the occupation of holes in trees by tree weta and concluded that there seemed to be little preference for specific tree species. They also listed the wide variety of tree species in which tree weta have been found, as well as other locations, such as in holes in logs or between flax leaves. Field & Sandlant (2001) found that holes in trees that are suitable for tree weta show a clumped distribution, because most trees lack such holes; furthermore, the chances of a weta finding a suitable hole are low, and therefore weta require a long search time to do this. It also seems likely that the time that elapses before an artificial refuge is occupied by weta may depend on whether the tree it is attached to contains holes and whether weta occupy them. This has not yet been investigated, so we suggest that a large number of single-gallery refuges should be used and placed on every tree along a transect line, as recommended by Trewick & Morgan-Richards (2000).

We showed that at most locations the number of tree weta found in artificial refuges did not vary substantially with height above ground; however, this has not been investigated sufficiently to understand why height affects occupancy in some areas and not others. Only one other study (Rufaut & Gibbs 2003) has addressed height up trees in relation to occupancy by weta, although Trewick & Morgan-Richards (2000) did consider that it was important. Rufaut & Gibbs (2003) reported that the height of natural galleries occupied by *H. crassidens* in trees on Nukuwaiata Island (Chetwode Islands, Pelorus Sound) varied in response to the presence of ground-living predators. Here the mean height of natural galleries occupied by this weta species showed a consistent reduction from c. 1.8 m to 1.2 m during the first 3 years after kiore (*Rattus exulans*) and weka (*Gallirallus australis*) were eradicated. The only other relevant study showed that in an area of the Tararua Ranges, North Island, weta were present in up to 47% of artificial refuges placed on the ground on tree trunks (Spurr & Berben 2004). Thus, at least at this site, good numbers of weta did occupy low artificial refuges. Overall, however, height above ground clearly may affect occupancy by tree weta in some situations, so we recommend that refuges be placed wherever possible at a uniform height above the ground and that this height is chosen so that the refuges can be accessed conveniently by staff conducting monitoring.

In this study, no significant difference was detected between the probability of finding weta in refuges placed near the edge of the forest and those well within the forest. This contrasts with the findings of Trewick & Morgan-Richards (2000), who reported that very few weta were found in four refuges that were placed in a dark portion of Mohi Bush where low vegetation was sparse. They suggested that distance into a forest might influence refuge occupancy, because these same refuges became occupied soon after they were moved near to the bush edge. This suggests that tree weta may respond to artificial refuges at the edge and interior of a forest in different ways at different sites.

The distribution of weta in refuges in the Turitea catchment, averaged over the study period, was more dispersed than would be expected if the weta had entered the refuges entirely at random. This would result if weta were more likely to be found in refuges that had been occupied previously, or if the weta were spatially clumped. Moller (1985) reported that marked *H. crassidens* returned to the same galleries after leaving them, and such site fidelity to galleries is now well established, especially for adult tree weta (see reviews by Field 2001; Field & Sandlant 2001). In contrast, small immature weta disperse more (Ordish 1992). Spatial clumping is supported by the findings of both Field & Sandlant (2001) and this study, where the distribution of weta found in refuges on each sampling occasion was sometimes overdispersed. The fact that weta show site fidelity and have a patchy distribution, combined with the likelihood that adult tree weta have a small home range and disperse slowly (Moller 1985; Trewick & Morgan-Richards 2000), further supports the previous recommendation that monitoring should be done using a large number of simple refuges (Trewick & Morgan-Richards 2000).

5. Recommendations

We recommend that a large number of single-gallery refuges be used to monitor populations of tree weta, in preference to fewer multi-gallery refuges. Refuges can be attached at any height that is convenient for subsequent inspection, although we recommend that they are all set at a uniform height as discussed above. They should be set out for as long as possible before they are used for monitoring; we recommend a period of at least 1 year, especially where tree weta are less common.

A simple weta refuge, which is easily constructed, is likely to be as effective as a complex refuge, which may be more difficult and time-consuming to make. We do not recommend that a sheet of clear material such as Perspex is incorporated into the design to facilitate inspection unless the refuge is to be accessed by the general public for demonstration purposes. Instead, we recommend that the depth of the gallery (from the surface that is normally covered) is increased. This allows the weta to move further away from the light when the refuge is opened and thus reduces the probability that they will leave the gallery.

6. Acknowledgements

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Appendix 1

VEGETATION ON SAMPLE LINES

Vegetation descriptions for each sample line where artificial refuges were set. Specific names of the plants are given in Appendix 4.

SITE		CANOPY/SUB-CANOPY			UNDERSTOREY		GROUND COVER	
	HEIGHT (m)	COVER (%)	DOMINANT SPECIES		COVER (%)	DOMINANT SPECIES	COVER (%)	DOMINANT SPECIES
Ruahine Range	6–30	75–90	Rimu, mahoe, pepper tree		5–20	Hange-hange, tree fern	5	Bush rice grass, hook grass, round-leaf fern, kiwakiwa fern
Lake Papaitonga Reserve	6–15	40–90	Kohekohe, mahoe, tawa, karaka		15–90	Kohekohe, nikau, kawakawa	5–30	Karaka, hen & chicken fern, kohekohe
Pureora Forest	6–30	15–95	Miro, rimu, hinau, tawa, five-finger, kamahi		5–90	Tawa, five-finger, ponga	5–50	Bush rice grass, hook grass, crown fern, tawa, hen & chicken fern, kiwakiwa fern, kohukohu
Tongariro National Park	6–30	45–80	Miro, rimu, kamahi		25–85	Ponga, crown fern, pepper tree	5–80	Bush rice grass, hook grass, crown fern
Kaweka Range (rodent control)	6–25	10–90	Beech spp., totara		15–90	Totara, pepper tree	5–95	Crown fern *Astelia*, *Lycopodum*
Turitea	6–20	30–85	Pine, wineberry		10–95	*Coprosma grandifolia*, ponga, hange-hange	45–55	Bush rice grass, hook grass, round-leaf fern, hen & chicken fern

Appendix 2

INFORMATION RELATING TO REFUGES USED IN THE FIELD

The weta species present, approximate NZMS position of the sample lines, the date refuges were set out, number of different-sized refuges used at each location and the date when rodent control commenced are presented for each site.

SITE	SPECIES	POSITION	DATE	NUMBER OF REFUGES			RODENT
				SMALL	MEDIUM	LARGE	CONTROL
Ruahine Range	*H. thoracica*	T23 618 189	25 Aug 1999	14	4	0	None
	H. crassidens	T23 620 186	25 Aug 1999	14	4	0	None
Lake Papaitonga	*H. thoracica*	S25 986 002	24 May 2000	10	2	0	None
Reserve	*H. crassidens*	S25 989 596	24 May 2000	10	2	0	None
		S25 988 602	24 May 2000	10	2	0	Oct 1998
		S25 987 598	24 May 2000	10	2	0	Oct 1998
Pureora Forest	*H. thoracica*	T17 434 935	16 Nov 1999	10	2	0	Oct 1998
		T17 443 934	16 Nov 1999	10	2	0	None
		T17 443 923	16 Nov 1999	10	2	0	None
		T17 432 932	16 Nov 1999	10	2	0	None
		T17 374 028	16 Nov 1999	10	2	0	Dec 1995
		T17 337 014	16 Nov 1999	10	2	0	Dec 1995
		T17 303 023	16 Nov 1999	10	2	0	Dec 1995
		T17 303 025	16 Nov 1999	10	2	0	Dec 1995
		T17 363 039	16 Nov 1999	10	2	0	Dec 1995
		T17 363 041	16 Nov 1999	10	2	0	Dec 1995
		T17 363 044	16 Nov 1999	10	2	0	Dec 1995
		T17 361 046	16 Nov 1999	10	2	0	Dec 1995
Tongariro National	*H. thoracica*	S20 147 017	6 Feb 2000	10	4	2	None
Park		S20 139 009	6 Feb 2000	10	4	2	None
		S20 155 015	6 Feb 2000	10	4	2	None
		S20 156 014	6 Feb 2000	10	4	2	None
		S20 163 141	6 Feb 2000	10	4	2	None
		S20 163 140	6 Feb 2000	10	4	2	None
		S20 166 146	6 Feb 2000	10	4	2	None
		S20 165 146	6 Feb 2000	10	4	2	None
Kaweka Range	*H. thoracica*	U20 075 019	16 Feb 2000	10	4	2	None
	H. trewicki	U20 075 036	16 Feb 2000	10	4	2	None
		U20 081 046	16 Feb 2000	10	4	2	None
		U20 087 075	16 Feb 2000	10	4	2	None
		U20 059 079	16 Feb 2000	10	4	2	Jul 1997
		U20 061 083	16 Feb 2000	10	4	2	Jul 1997
		U20 060 088	16 Feb 2000	10	4	2	Jul 1997
		U20 074 088	16 Feb 2000	10	4	2	Jul 1997
Turitea catchment	*H. crassidens*	T24 396 825	14 July 2000	25	40	10	None
		T24 394 822	14 July 2000	25	40	8	None

Appendix 3

TREE SPECIES TO WHICH REFUGES WERE ATTACHED

Numbers of artificial refuges attached to different species of tree and the mean numbers of tree weta found in the refuges.

TREE	NO. REFUGES	NO. WETA	
		MEAN	SEM
Black mamaku	2	0	0
Broadleaf	7	0.429	0.679
Celery pine	1	0	0
Coprosma colensoi	2	0	0
Dead fallen branch	14	0.059	0.154
Dead fern	4	0.188	0.239
Dead tree	44	0.071	0.198
Five-finger	3	0	0
Golden tree fern	2	0	0
Hangehange	4	0.218	0.305
Haumakoroa	1	0	0
Hinau	14	0.064	0.096
Houhere	2	0.375	0.53
Kamahi	43	0.035	0.169
Kanono	23	0.436	0.566
Kanuka	12	0	0
Karaka	2	0	0
Kawakawa	11	0.06	0.118
Kohekohe	21	0.044	0.097
Kohukohu	3	0	0
Lancewood	4	0.063	0.125
Large seed *Coprosma*	3	0.056	0.096
Lowland peppertree	3	0	0
Mahoe	16	0.079	0.138
Manuka	23	0	0
Marble leaf	17	0.037	0.072
Matai	1	0	0
Miro	10	0.102	0.156
Mountain beech	20	0.017	0.051
Mountain celery pine	10	0.033	0.07
Mountain totara	3	0	0
Myrtle	2	0.084	0.118
Pepper tree	32	0.038	0.108
Pigeonwood	1	0	0
Pine	12	0.361	0.688
Poataniwha	1	0	0
Ponga	39	0.032	0.083
Rangiora	4	0.15	0.139

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Appendix 3—continued

TREE	NO. REFUGES	NO. WETA	
		MEAN	SEM
Raukawa	5	0.068	0.093
Red beech	4	0.05	0.1
Red matipo	2	0	0
Rimu	6	0	0
Seven-finger	20	0	0
Tawa	42	0.113	0.191
Totara	9	0.019	0.056
Wavy-leaved *Coprosma*	15	0.271	0.48
Weeping mapou	4	0	0
Wheki	22	0.058	0.139
Wineberry	35	0.676	0.696
Unknown	7	0	0

Appendix 4

SPECIFIC NAMES OF PLANTS

Specific names of plants referred to in this report. Most names follow Nicol (1997).

COMMON NAME	SPECIES
Black mamaku	*Cyathea medullaris*
Broadleaf	*Griselinia littoralis*
Bush rice grass	*Microlaena avenacea*
Celery pine	*Phyllocladus trichomanoides*
Crown fern	*Blechnum discolor*
Five-finger	*Pseudopanax arboreus*
Flax	*Phormium tenax*
Golden tree fern	*Dicksonia fibrosa*
Hangehange	*Geniostoma rupestre*
Haumakoroa	*Pseudopanax simplex*
Hen & chicken fern	*Asplenium bulbiferum*
Hinau	*Elaeocarpus dentatus*
Hook grass	*Uncinia* spp.
Houhere	*Hoheria sexstylosa*
Kamahi	*Weinmannia racemosa*
Kanono	*Coprosma grandifolia*
Kanuka	*Leptospermum ericoides*
Karaka	*Corynocarpus laevigatus*
Kawakawa	*Macropiper excelsum*
Kiwakiwa fern	*Blechnum fluviatile*
Kohekohe	*Dysoxylum spectabile*
Kohukohu	*Pittosporum tenuifolium*
Lancewood	*Pseudopanax crassifolius*
Large seed *Coprosma*	*Coprosma macrocarpa*
Lowland peppertree	*Pseudowintera axillaris*
Macrocarpa	*Cupressus macrocarpa*
Mahoe	*Melicytus ramiflorus*
Manuka	*Leptospermum scoparium*
Marble leaf	*Carpodetus serratus*
Matai	*Prumnopitys taxifolia*
Miro	*Prumnopitys ferruginea*
Mountain beech	*Nothofagus solandri* var. *cliffortioides*
Mountain celery pine	*Phyllocladus alpinus*
Mountain totara	*Podocarpus hallii*
Myrtle	*Neomyrtus pedunculata*
Pepper tree	*Pseudowintera colorata*
Pigeonwood	*Hedycarya arborea*
Pine	*Pinus radiata*
Poataniwha	*Melicope simplex*
Ponga	*Cyathea smithii*

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Appendix 4—continued

COMMON NAME	SPECIES
Rangiora	*Brachyglottis repanda*
Rauk awa	*Pseudopanax edgerleyi*
Red beech	*Nothofagus fusca*
Red matipo	*Myrsine australis*
Rimu	*Dacrydium cupressinum*
Round leaf fern	*Pellaea rotundifolia*
Rye grass	*Lolium perenne*
Seven-finger	*Schefflera digitata*
Tawa	*Beilschmiedia tawa*
Totara	*Podocarpus totara*
Wavy-leaved *Coprosma*	*Coprosma tenuifolia*
Weeping mapou	*Myrsine divarivata*
Wheki	*Dicksonia squarrosa*
Willow	*Salix alba*
Wineberry	*Aristotelia serrata*