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Distribution and ecology of the Banks Peninsula Tree Weta,
Hemideina ricta.

A thesis presented in partial fulfilment of the requirements for the degree of
Masterate of Science in Ecology at Massey University.



Adult male *Hemideina ricta* on tree stump,
Fishermans Bay, Banks Peninsula.

Jacqueline Anne Townsend
1995

Acknowledgements

I thank the following people for their input and advice, not necessarily in order. Firstly to my supervisors at Massey University, Drs Ian Stringer and Murray Potter, who helped with field work, and contributed knowledge, constructive criticism and assistance where necessary. To the people at the Department of Conservation, Drs Greg Sherley and Ken Huey and Euan Kennedy, for their advice, assistance and for providing funding which was crucial for the project. Thanks also to the local Dept. of Conservation staff at Akaroa, Alastair Hutt and Robin Burley for their assistance and help with local knowledge. Thanks to the countless landowners for their willingness to allow us access to their land and for their keen interest in the survey.

I appreciate the assistance from Dr Larry Field and Peter Johns of Canterbury University, for their help at the inception of the study, and for their advice and continued interest.

To Barbara Brown for her much needed assistance and good humour, during the summer survey, and her partner Geoff Spearpoint for their hospitality. A big thanks to Hugh Wilson and the Maurice White Native Forest Trust, who were able to provide local accommodation and advice, and to Tim Galloway and Sara Kooy for their hospitality also.

Thank you to my parents who have proof read and provided help and support both financial and other. To Guy Vickers for his assistance in the field, and continued encouragement and support throughout the whole thesis. Also to the many friends who managed to visit the Peninsula while I was there.

Thank you to the numerous people who provided assistance with statistics: Drs Alastair Robertson, S Ganeshanandam and Russell Death, and Dale Towers. Thanks also to Liz Grant for the elegant drawings, Jens Jorgensen for the construction of the artificial retreats, Petra van Kan and Erica Reid for their help with formatting of the thesis.

Abstract

Comparative morphology. *Hemideina ricta* and *H. femorata* were assessed for their morphological similarity. *H. ricta* adults were found to have significantly longer and wider heads in both sexes and longer cerci in adult males. The tibial length of adult female *H. femorata* was significantly longer than in *H. ricta*. Thorax width, thorax length and ovipositor length did not differ significantly between the two species.

Habitat and distribution. *H. ricta* and *H. femorata* are predominantly allopatric on Banks Peninsula, with *H. ricta* being found on the outer eastern portion of Banks Peninsula and on the inner Akaroa Harbour while *H. femorata* is located on the inner Akaroa Harbour and westward from here. The two species overlapped altitudinally, but *H. femorata* was not found above 450 m asl whereas *H. ricta* was discovered from 20 m to 806 m asl. *H. femorata* showed a strong preference for kanuka habitat whilst *H. ricta* had a broader preference for kanuka, mixed broadleaved hardwoods, fallen totara and broadleaf logs and old fenceposts.

Refuge occupation. The refuges where *H. ricta* and *H. femorata* rested during the day were assessed for their similarity. Both species preferred galleries formed by beetle larvae as these probably offered the greatest protection from predators. Weta were also found in splits, under the bark of trees, in rotten logs and in the forks of trees. Significantly more galleries were occupied by *H. ricta* adults, compared to juveniles, that occupied areas under bark and in splits. There was no significant difference in the refuges occupied by adult and juvenile *H. femorata*.

Behaviour. The nocturnal behaviour of *H. ricta* in captivity and in the field was investigated. Their activity in captivity was significantly greater. *H. ricta* were observed moulting, ovipositing, mating and fighting in captivity whereas in the field none or only a few of these activities were recorded. *H. ricta* in captivity also spent more time perching on logs and foliage compared to field situations. It is probable that temperature influenced this result because *H. ricta* showed elevated activity and a greater variety of activity with increased temperature in the field.

Feeding preferences. The comparative feeding preferences of *H. ricta* and *H. femorata* were assessed on five commonly located mixed broadleaved hardwood tree species. *H. ricta* and *H. femorata* consumed significantly different amounts of the selected plants as did juvenile and adult weta. More *Parsonsia* was eaten by *H. ricta* and more *Pittosporum* was eaten by *H. femorata*. In addition, significantly more *Parsonsia* was consumed by adult male *H. ricta* compared to juvenile males. There was no significant difference between preferred plant between the sexes.

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Chapter one

Introduction

The Banks Peninsula tree weta, *Hemideina ricta* is the rarest of New Zealand's six tree weta species¹. Prior to 1992, *H. ricta* was listed as highly endangered by the Department of Conservation's protected species ranking system (Molloy and Davis, 1992). It is therefore illegal to handle, collect or kill these tree weta without a permit.

Much of my thesis attempts to address basic questions relating to their distribution, habitat requirements, population status, biology and behaviour. The knowledge gained as a result of this study has resulted in a re-evaluation of the protection status of *H. ricta*, which has now been lowered to a class 'B' invertebrate (Tisdall, 1994). *H. ricta*, remains, however, highly restricted in distribution and is found only on the outer eastern portions of Banks Peninsula (Brown and Townsend, 1994).

H. ricta shows a number of similarities to the alpine tree weta, *H. maori*, which are addressed in relevant chapters of this thesis. The common Canterbury tree weta, *H. femorata*, is a close neighbour of *H. ricta* and the distribution of these two tree weta species was found to overlap to a limited degree (see chapter 3). These two species are similar in appearance except for the presence of prominent black transverse bands on the abdomen which are present in *H. femorata* but not *H. ricta* (Ramsay and Bigelow, 1978). However, problems arose in distinguishing these species when weta that appeared intermediate between *H. ricta* and *H. femorata* were found in a small area of sympatry and indeed two hybrid weta between these species were discovered (Morgan-Richards and Townsend, in prep). Chapter two therefore contrasts morphology to aid the critical identification of these species in the field.

¹. Until further information on the genetic identity has been published, I recognised the following six species of tree weta: *H. crassidens*; *H. thoracica*; *H. femorata*; *H. ricta*; *H. maori*; and *H. crassicuris*.

Chapter 3 details a comprehensive survey of *H. ricta* and *H. femorata*'s distribution in the Herbert and Akaroa ecological districts of Banks Peninsula (McEwen, 1987). The Department of Conservation required information on the distribution and habitat preferences of *H. ricta* as the limited knowledge previously available suggested that *H. ricta* was extremely restricted in distribution and this contributed to its ranking as highly endangered. Chapter 3 identifies habitat preferences and altitudinal relationships that affect *H. ricta* and *H. femorata*'s distribution and identifies areas where *H. ricta* are found in high density and therefore need protection.

In chapter four, the refuge use by *H. ricta* is compared to that of *H. femorata*. This chapter also examines the interspecific sharing of refuges and identifies niche differences between life stages of weta within the same habitat. Here the question: "does *H. ricta* possibly face a gallery shortage?" is addressed.

The behaviour of *H. ricta* is investigated in chapter five. Comparisons are made between the captive and field behaviour of this species as an important requisite for the correct interpretations of the behaviour of these weta in captivity, and as aid to captive rearing programmes.

A food preference experiment involving both *H. ricta* and *H. femorata* is presented in chapter 6. This compares the preferences of *H. ricta* and *H. femorata* for five commonly located mixed-broadleaved hardwood tree species. This was undertaken to help understand possible competitive interactions that may exist between these two species in the area of sympatry.

An overall synthesis of the thesis is presented in chapter seven and recommendations are proposed for the conservation of *H. ricta*.

Chapter two

Comparative morphology of two neighbouring tree weta species, *Hemideina ricta* and *H. femorata* (Orthoptera: Stenopelmatidae) on Banks Peninsula, South Island, New Zealand.

2.1 Introduction

Hemideina ricta was described by Hutton in 1896. He remarked that it resembled *H. femorata* but that *H. ricta* had smooth rather than rough gynae and males had larger heads than *H. femorata*. Hutton made no mention of colour differences between the two species. Salmon (1950) considered that *H. ricta* was a sub-species of *H. thoracica*, and referred to it as *H. thoracica figurata*. Wise (1950) regarded *H. ricta* as a synonym of *H. thoracica figurata*, but subsequent work by Ramsay and Bigelow (1978) reinstated *H. ricta* as a separate species.

A recent genetic analysis suggested that *H. ricta* is more closely related to the alpine tree weta *H. maori* than to *H. femorata* (Morgan-Richards pers. comm.). This is despite *H. ricta*'s current distribution overlapping with *H. femorata* on Banks Peninsula and not at all with that of *H. maori* which is found in the Southern Alps and some eastern isolated mountain ranges in the South Island (Field, 1993). Field (1993) describes two morphological traits that are "exclusively" found in both *H. ricta* and *H. maori*: one is the large number of stridulatory pegs and the small size of their femoral pegs; the second is the lack of retrolateral apical spines on the hind femur. *H. ricta* also shows some similar behavioural traits to *H. maori* such as an inverted defence posture when disturbed (Field, 1993) and both species can be found in rock crevices and under rocks at higher altitudes (see chapter 3).

Despite this apparent phylogeny, several weta that were found during a distributional survey of weta on Banks Peninsula had characteristics which appeared intermediate between *H. ricta* and *H. femorata* (Brown and Townsend, 1994). Allozyme analysis

showed that at least two of these weta were hybrids of these two species (Morgan-Richards and Townsend, in prep). The other weta were genetically distinct, but their morphology appeared variable. The conservation status of *H. ricta* and *H. femorata* differ greatly with *H. ricta* having a very localised distribution (Brown and Townsend, 1994) and *H. femorata* being widely distributed and numerous. The ability to correctly distinguish between *H. ricta* and *H. femorata* in the field is therefore of considerable importance to conservation managers.

The two species of weta exist mainly allopatrically on Banks Peninsula but their distributions overlap to a small extent (see chapter 3). Both species can be found on the eastern side of Akaroa Harbour but generally *H. femorata* is found west and *H. ricta* north and east of the harbour.

The aim of this chapter is to compare and contrast morphological features that can be used to distinguish *H. ricta* and *H. femorata* in the field.

2.2 Methods

Study site

Banks Peninsula (approx. 100,000 ha) is situated on the east coast of the South Island, New Zealand. The Peninsula was covered in bush until last century when timber was extracted from most of the area (Wilson, 1992). Much of the peninsula is now pasture, with small isolated stands of kanuka (*Kunzea ericoides*) and mixed broadleaved hardwoods making up a total of approximately 9000 ha, with an additional 800 ha of original forest remnants (Wilson, 1992).

Extraction of weta from holes

Weta were found during daytime searches of holes, under the bark of trees, in old fenceposts and in logs. A small torch was used to explore possible weta refuges. When weta were discovered they were invariably oriented head first in their hole. A

bent wire was inserted to tap the head of the weta and encourage them to reverse out. Occasionally the entrances of galleries had to be enlarged slightly with a chisel to facilitate extraction. A hand drill was also carefully used on 5 occasions to reach the blind end of a hole. In many cases the wood was too hard to chisel and weta were too deep within their galleries to gain access to them. In these situations no further effort was made to extract the weta for fear of damaging them or destroying their habitat.

After weta reversed from their galleries they would frequently drop from the trees into the surrounding vegetation or try to walk up the tree. A plastic bag was therefore held under the galleries to catch them. The weta were measured using vernier callipers, and were immobilised during this process by holding them in the plastic bag. This protected them from damage and kept the measurer from being bitten.

Measurements

Measurements were taken of the length and width of the head and prothorax, and the length of the cerci, the tibia and, in females, the ovipositor. Weta weights were recorded initially but later abandoned due to the inaccuracy of the spring balance and error caused by the wind blowing the equipment. The number of retrolateral and prolateral spines on the hind tibia were also recorded for some of the weta.

Male and female measurements were examined separately to ascertain size differences associated with instar and sex. Whenever possible measurements were made to determine the growth increments associated with juvenile moults. This was done by marking weta with silver ink and noting the holes they occupied. These weta were then checked regularly and when the silver ink marking disappeared, presumably during moulting, the weta were remeasured. A limited number of weta were also kept in captivity where measurements were taken regularly to determine instar durations and sizes.

Identification of species

The following characteristics were used to identify each species: the degree of abdominal banding; the presence of any markings on the prothorax; and markings on the hind femora. In particular I concentrated on the amount of striping on the abdominal tergites as this was initially the most evident feature. *H. femorata* had dark striping on the anterior and posterior of the abdominal segments and black markings on the prothorax and on the hind femora. The overall colouration of *H. ricta* varied in adults from a dark red-brown to a light golden-brown. Juvenile weta were more difficult to identify due to the presence of darker colouration on the prothorax and abdomen. Weta of intermediate appearance were discovered in an area of sympatry. These weta had fine markings on the hind femora, slight dark markings on the prothorax, and abdominal striping. The identification of these weta was confirmed as *H. ricta* with allozyme analysis (Morgan-Richards and Townsend, in prep).

Identification of adult weta

Adult males were identified by the length and the curvature of their cercus. In juvenile weta the cerci were small and straight. Another way in which adults were identified was by using a hand lens to determine whether two small black hooks were present on the last abdominal segment (P. Johns pers. comm.). Adult females were identified by characteristics of the ovipositor. The ovipositors of sub-adult and juvenile females were soft and flexible whereas the ovipositors of adult weta were shiny and hardened.

Statistical analyses

Morphometric measurements were plotted as scatter plots and all measurements were plotted against prothorax width. Measures of head width and length, and the tibia, cerci and ovipositor lengths were compared to prothorax width. Student *t* tests were used to determine whether there were any significant differences between the species and between the sexes.

2.3 Results

A total of 211 *H. ricta* and 71 *H. femorata* were extracted and measured in the entire survey. More *H. ricta* males were measured (119) than females (92) and 46 *H. femorata* females were extracted and measured compared to 25 males. Very few small nymphs (1st and 2nd instar) of either species were located. The occasional small nymphs that were found were difficult to identify because of their pale colouration and small size.

Two colour morphs of *H. ricta* were discovered, the predominant morph was a homogenous red-brown colour (see Plate 2.1) while the other was a pale ochre with stripy appearance (see Plate 2.2). Several sites were located where this pale weta with a light golden appearance and darker striping or stippling were found. At these sites the darker red-brown weta were also present. The colouration characteristics of these weta forms (the pale form of *H. ricta* is slightly intermediate in appearance with *H. femorata*) are given in Table 2.1. Two hybrid weta were also located behind Akaroa (see Plate 2.3).

Table 2.1 Difference in morphological features between *H. ricta* and *H. femorata*.

Characteristic	<i>H. ricta</i>	<i>H. ricta</i> (intermediate appearing)	<i>H. femorata</i>
Prothorax	no markings	slight 'butterfly'	dark markings
Femora markings	absent	light brown	dark (black)
Abdominal bands	absent	stippled on posterior dark on anterior of tergite	dark on posterior of tergite
Body colouration	homogenous red-brown	pale fawn with stippling, appears banded	banded black and fawn

The number of retrolateral and prolateral apical spines on the hind tibia were counted on 44 specimens of *H. ricta* and 24 *H. femorata*. No retrolateral (inside) apical spines were ever recorded in *H. ricta* but *H. femorata* always had spines (Table 2.2).

The following duration of stadia in captivity were recorded: second to last nymphal instar: 101 and 120 days (n=2); sub-adult stadia 112, 197, and 202 days (n=3); and



Plate 2.1 Adult female *H. ricta* perching on a hollow tree stump above Fishermans Bay, showing typical colouration of this species.



Plate 2.2 Shows an adult female *H. ricta* with the pale colouration and stripy intermediate appearance.



Plate 2.3 Adult male hybrid weta, extracted from a kanuka refuge behind Akaroa. Note the prominent banding on abdomen but slight femora markings.

length of adult life was 211 and 137 days (n=2). In the field, however, one sub-adult male remained marked for nine months before it moulted.

Table 2.2 Frequency of occurrence of different combinations of retrolateral and prolateral apical spines of the hind tibia of *Hemideina* species on Banks Peninsula.

Spine	<i>H. ricta</i>		<i>H. femorata</i>		Hybrid	
	n	%	n	%	n	%
2 Retro/2 Prolateral	0	0	18	75	1	50
2 Retrolateral only	0	0	2	8	0	0
1 Retro/2 prolateral	0	0	0	0	1	50
2 Prolateral only	32	72	4	16	0	0
1 Prolateral only	3	7	0	0	0	0
No spines	9	21	0	0	0	0

Weta were observed moulting on 12 occasions, three times in the field and nine times in captivity. Different appendages grew at different rates. The cerci and ovipositor showed larger increases between moults than the head and thorax length and width (Table 2.3).

Table 2.3 Mean \pm standard error, of measurements for known instars of *H. ricta*.

Male	Adult (n=3)	Sub-adult (n=4)	2nd to last nymphal instar (n=3)
Head W	11.58, (0.81)	9.58, (0.16)	8.75, (0.13)
Head L	19.06, (1.61)	16.15, (0.69)	13.41, (0.64)
Thorax W	11.43, (0.66)	10.0, (0.20)	9.39, (0.31)
Thorax L	7.50, (0.21)	6.83, (0.14)	6.65, (0.18)
Tibia L	19.17, (0.36)	16.78, (0.11)	15.67, (0.58)
Cerci L	6.78, (0.16)	5.34, (0.39)	4.05, (0.20)
Female	(n=1)	(n=2)	(n=2)
Head W	9.4	8.46, (0.25)	8.12, (0.02)
Head L	14.2	12.60, (0.1)	11.92
Thorax W	11.3	9.87, (0.44)	9.44, (0.06)
Thorax L	7.5	7.26, (0.05)	6.92, (0.12)
Tibia L	19.6	17.78, (0.28)	16.51, (0.51)
Cerci L	2.9	2.40, (0.30)	1.78
Ovipositor	21.0	16.25, (0.70)	14.08, (1.58)

Morphometric characters

There were differences between the morphometric measurements of adult male and female weta both within and between species. The cerci length and head length and widths (Fig 2.1 a, b and c) were significantly larger in males than in females of both species (Table 2.4). No difference was found in tibial lengths between male and female weta of either species (Fig 2.1.d).

In males, head lengths and widths, and cerci lengths, increased allometrically. In females, this growth was geometric.

Table 2.4 *t* tests between morphometric measures of adult male and female *H. ricta* and *H. femorata*.

Body measure	<i>H. femorata</i>	<i>H. ricta</i>
Cerci L	T=-5.05, df=11, p=.0004	T=-29.3, df=31, p<.0001
Tibia L	T=1.31, df=18, p=.2	T=0.17, df=57, p=.87
Head W	T=-4.68, df=15, p=.0003	T=-14.05, df=36, p<.0001
Head L	T=-5.99, df=11, p=.0001	T=-14.10, df=28, p<.0001
Thorax W	T=-2.07, df=16, p=.055	T=-4.79, df=51, p<.0001
Thorax L	T=-0.4, df=16, p=.69	T=0.18, df=61, p=.86

Differences between species, adults and sub-adults

Male *H. ricta* had significantly longer cerci and wider and longer heads (Fig 2.2.a,b, and c respectively) than male *H. femorata*. In male adult *H. ricta*, cerci were more curved than those of adult male *H. femorata*. The hybrid male's cerci appeared intermediate in length and curvature (Fig 2.3). There was no significant difference between tibial lengths or thorax lengths and widths (Fig 2.2.d).

Adult female *H. ricta* also had significantly longer and wider heads than *H. femorata* (Fig 2.4.a and b). There was no significant difference between the lengths of cerci or ovipositors from adult and subadult females of either species (Fig 2.4.c and d).

Tibial lengths, however, were significantly longer in *H. femorata* females than in *H. ricta* females (Fig 2.4.e).

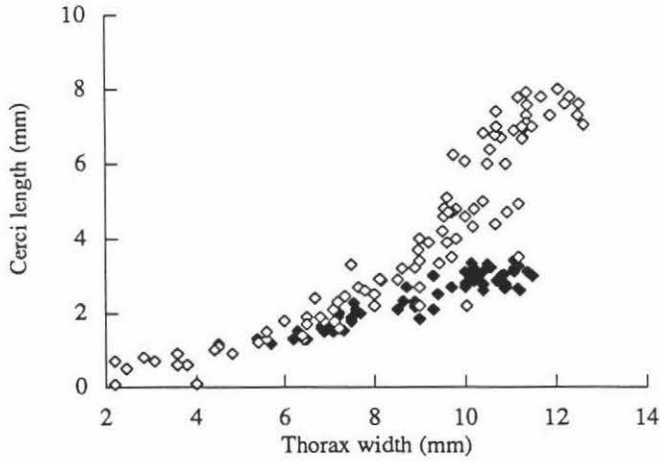
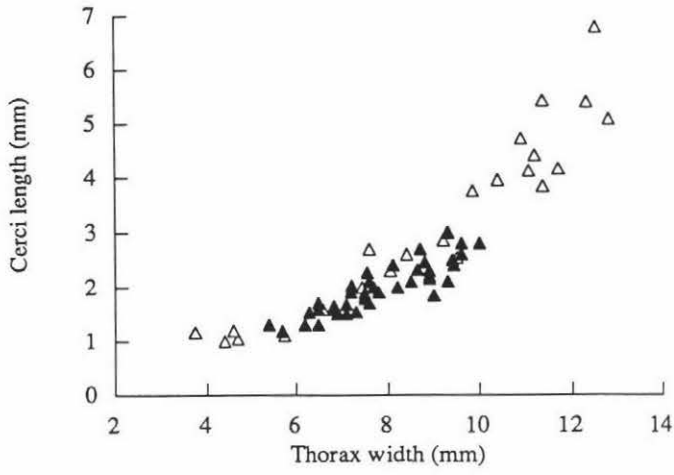


Fig. 2.1 (a) A comparison of cerci lengths (mm) of male and female weta.
 Top = *H. femorata*, open triangles = males and closed = females.
 Below = *H. ricta* with open diamonds = males and closed = females.

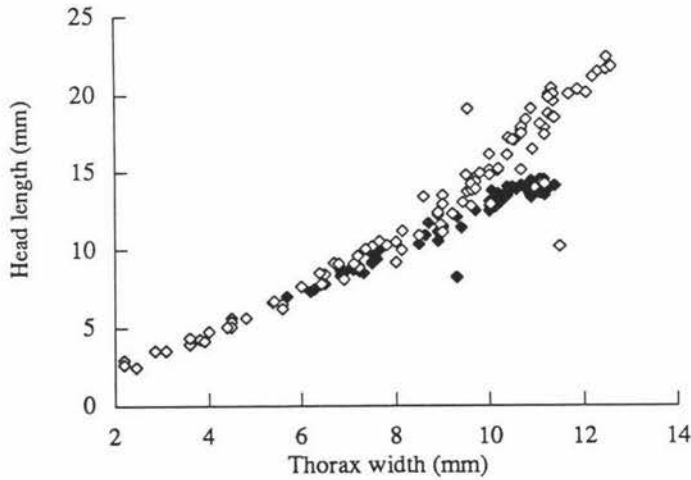
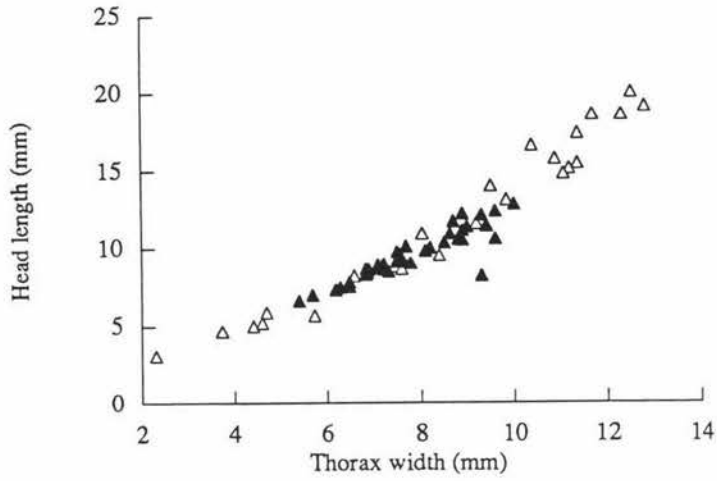


Fig. 2.1 (b) A comparison of head lengths (mm) of male and female weta.
 Top = *H. femorata*, with open triangles = males and closed = females.
 Below = *H. ricta* with open diamonds = males and closed = females.

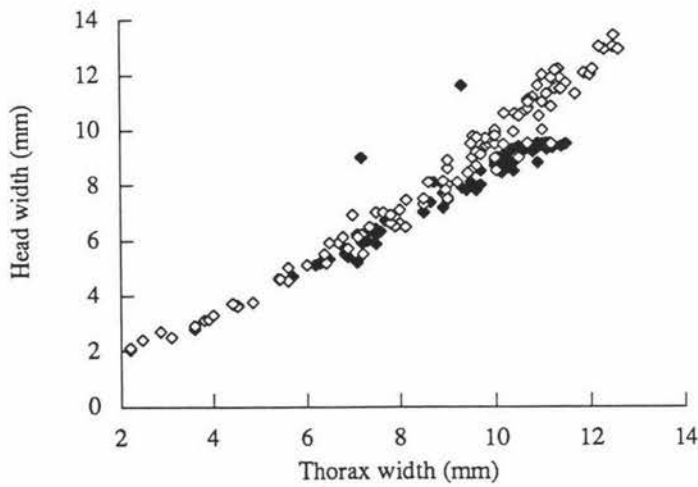
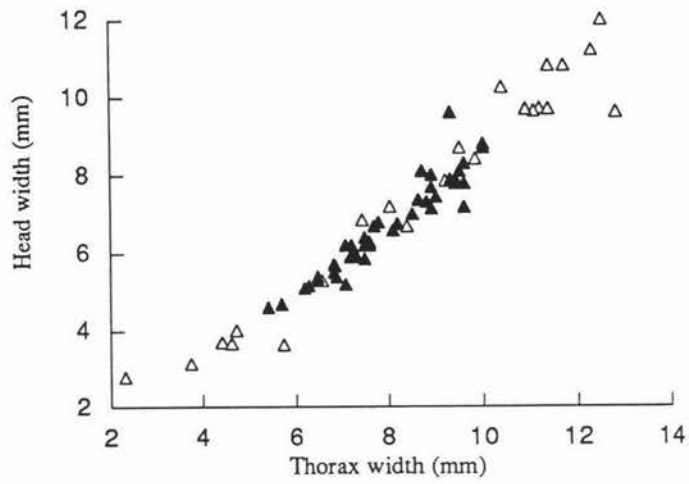


Fig. 2.1 (c) A comparison of head widths (mm) of male and female weta.
 Top = *H. femorata*, with open triangles = male and closed = females.
 Below = *H. ricta* with open diamonds = males and closed = females.

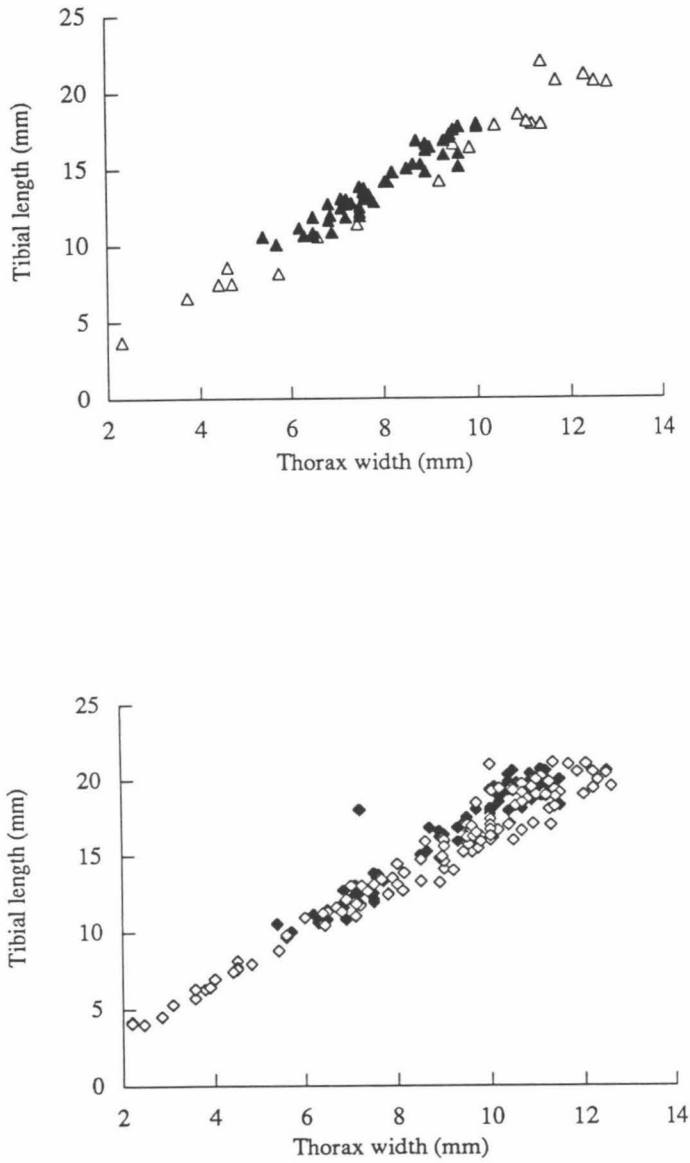


Fig. 2.1 (d) A comparison of tibial lengths (mm) of male and female weta.
 Top = *H. femorata*, with open triangles = male and closed = females.
 Below = *H. ricta* with open diamonds = male and closed = females.

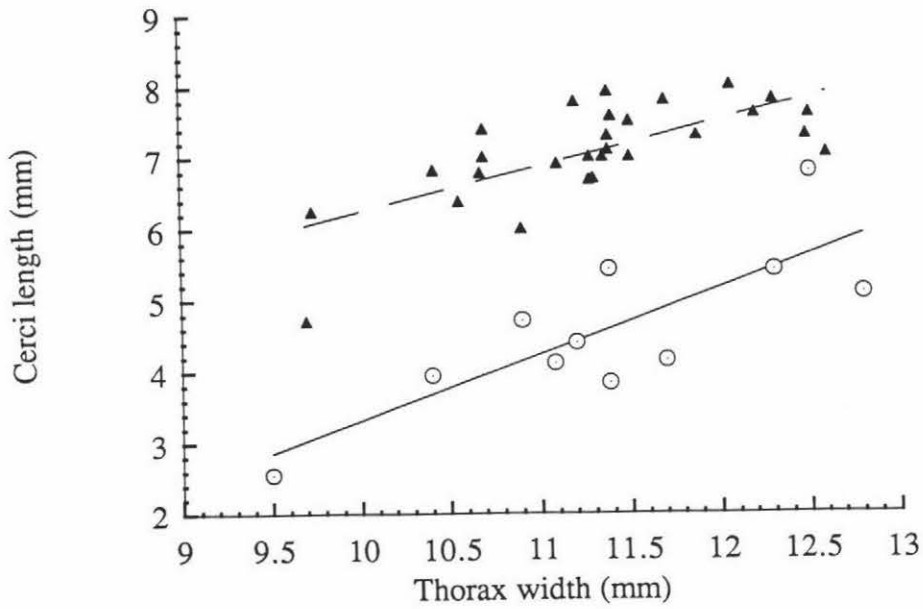


Fig. 2.2 (a) Cerci length plotted against prothorax width of adult and sub-adult male weta. Black triangles = *H. ricta*, open circles = *H. femorata*. Regression equations: $y = -0.12 + 0.64x$ ($r = 0.69$) and $y = -5.9 + 0.92x$ ($r = 0.80$) respectively.

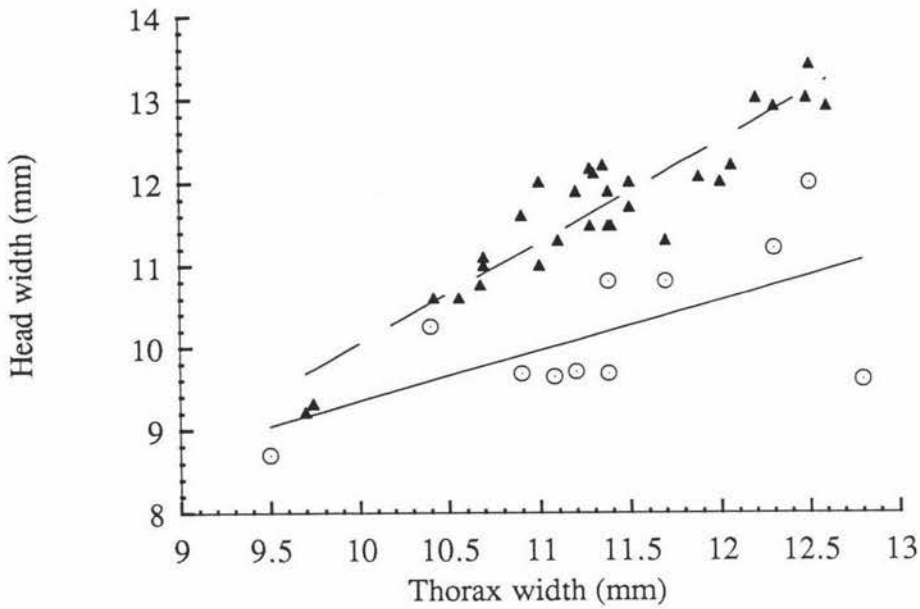


Fig. 2.2 (b) Head widths plotted against prothorax width of adult and subadult male weta. Black triangles = *H. ricta*, open circles = *H. femorata*. Regression equations: $y = -2.18 + 1.22x$ ($r=0.93$) and $y = 3.2 + 0.61x$ ($r=0.63$) respectively.

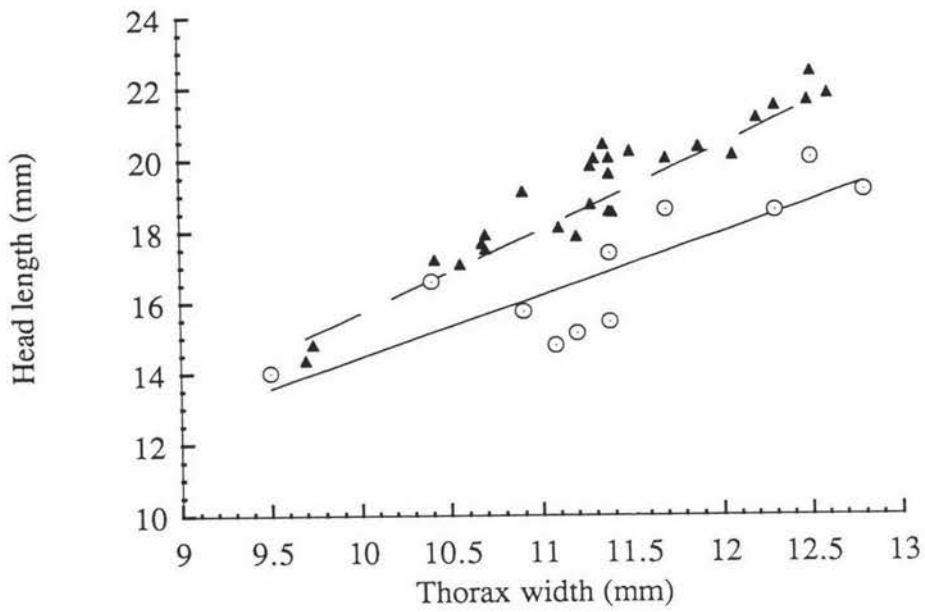


Fig. 2.2 (c) Head lengths plotted against prothorax width of adult and sub-adult male weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = -7.8 + 2.3x$ ($r=0.69$) and $y = -3.11 + 1.75x$ ($r=0.84$) respectively.

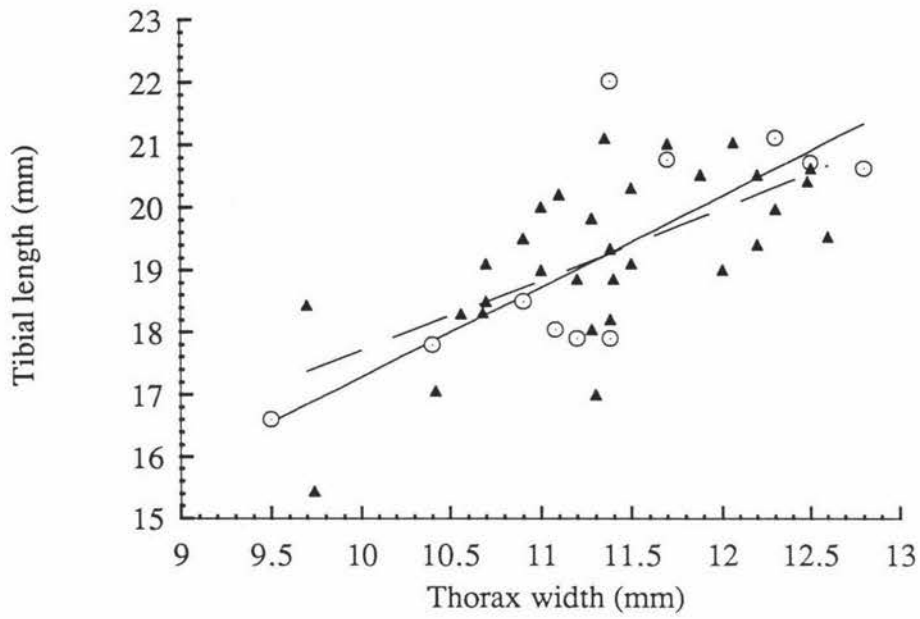


Fig. 2.2 (d) Tibial lengths plotted against prothorax width of adult and sub-adult male weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 6.4 + 1.13x$ ($r=0.65$) and $y = 2.8 + 1.44x$ ($r=0.77$) respectively.

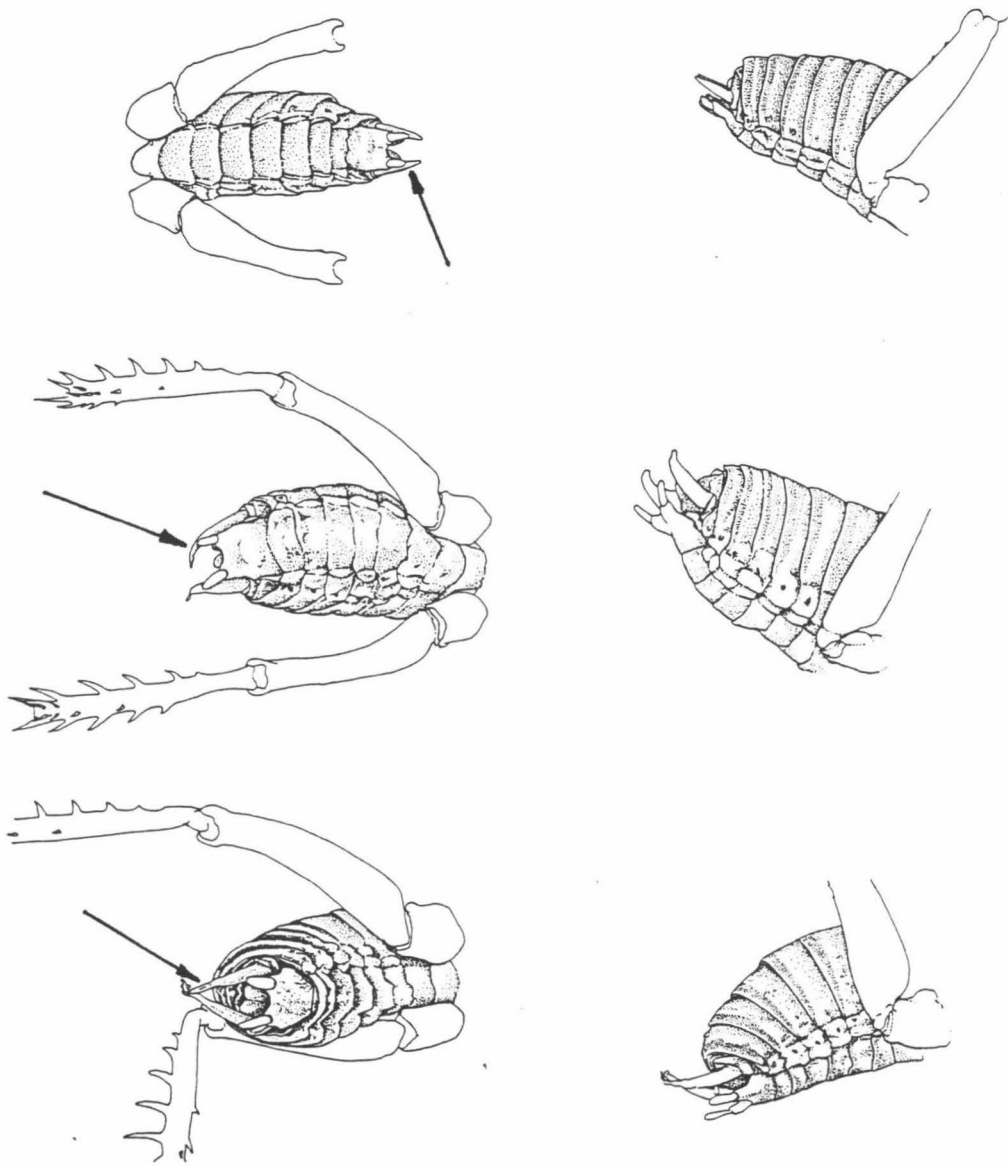


Fig. 2.3 Drawings on left show the ventral surface of adult male *H. femorata* (top), hybrid (middle) and *H. ricta* (bottom). Note the difference in cerci length (arrow) between the three weta. On the right, side views show the differences more clearly, with the weta in the same order.

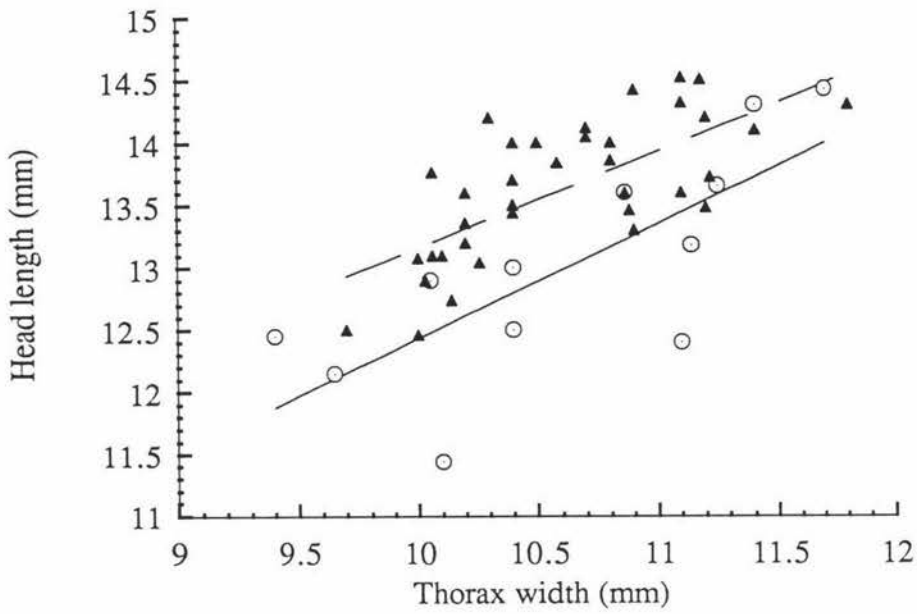


Fig. 2.4 (a) Head lengths plotted against prothorax width of adult and sub-adult female weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 5.5 + 0.77x$ ($r=0.69$) and $y = 3.2 + 0.92x$ ($r=0.76$) respectively.

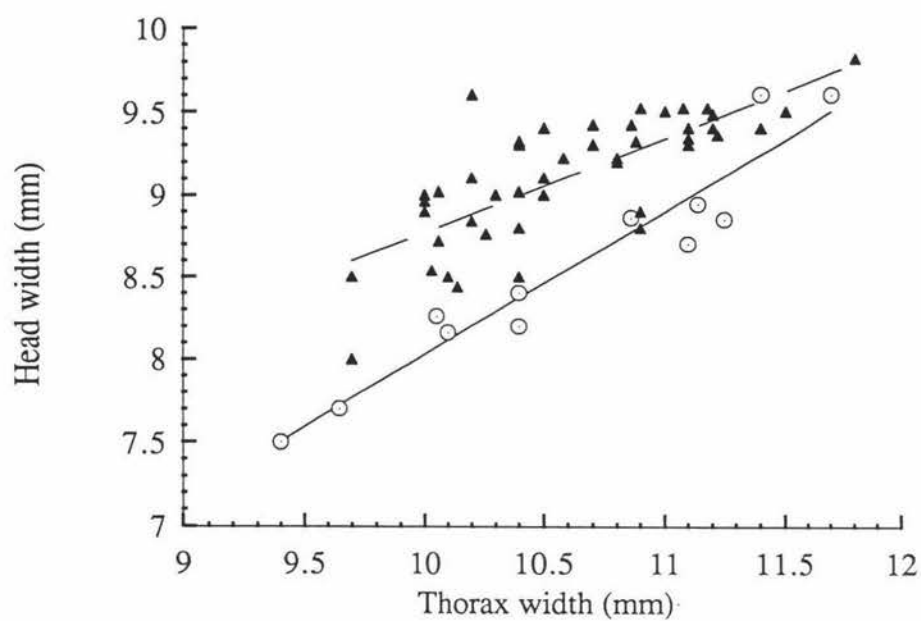


Fig. 2.4 (b) Head widths plotted against prothorax widths of adult and sub-adult female weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 3.1 + 0.57x$ ($r=0.76$) and $y = -0.65 + 0.87x$ ($r=0.96$) respectively.

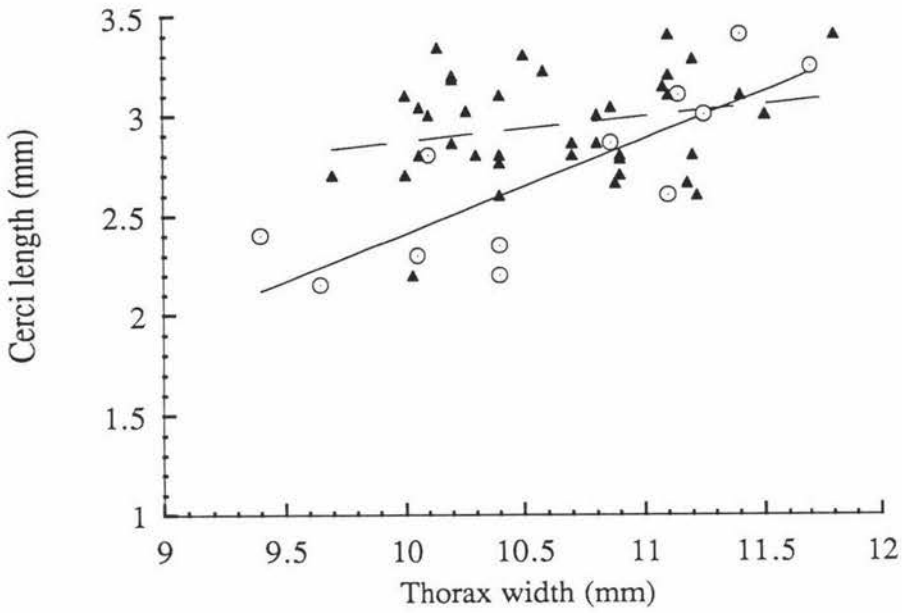


Fig. 2.4 (c) Cerci lengths plotted against prothorax widths of adult and sub-adult female weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 1.64 + 0.12x$ ($r=0.24$) and $y = -2.3 + 0.47x$ ($r=0.81$) respectively.

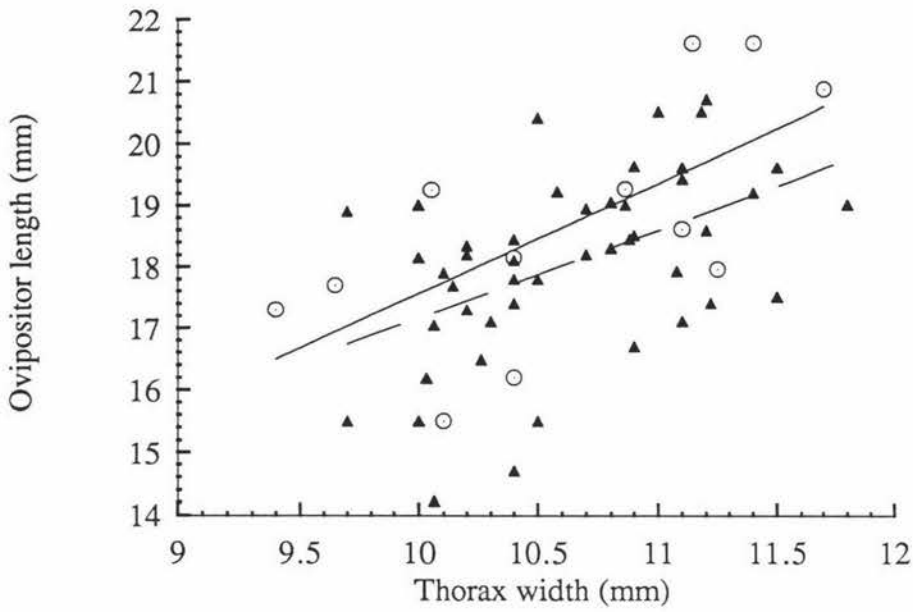


Fig. 2.4 (d) Ovipositor lengths plotted against prothorax widths of adult and sub-adult female weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 2.8 + 1.4x$ ($r=0.49$) and $y = -0.24 + 1.8x$ ($r=0.66$) respectively.

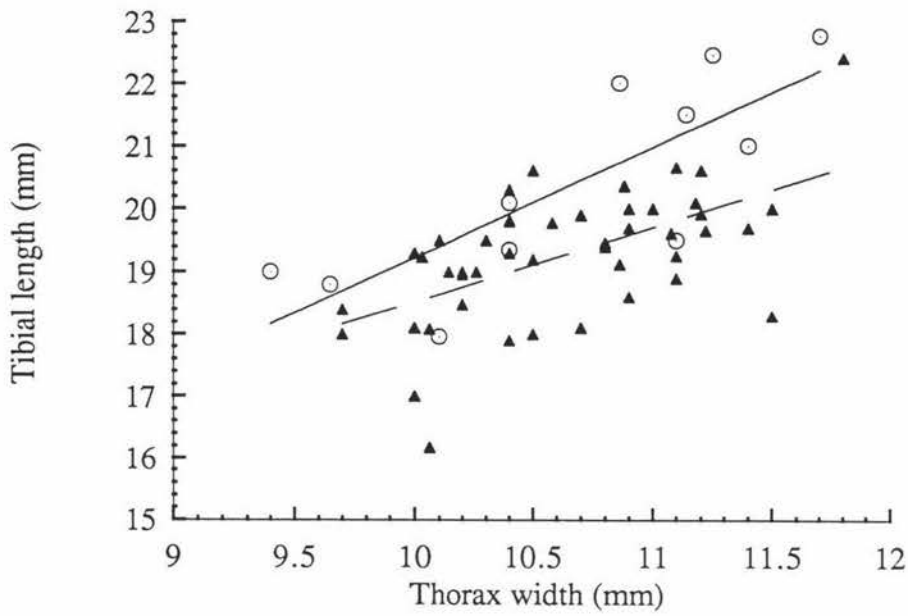


Fig. 2.4 (e) Tibial lengths plotted against prothorax widths of adult and sub-adult female weta. Black triangles = *H. ricta* and open circles = *H. femorata*. Regression equations: $y = 6.7 + 1.2x$ ($r=0.58$) and $y = 1.6 + 1.8x$ ($r=0.80$) respectively.

A summary of the above differences between adult *H. ricta* and *H. femorata* males and females is given in Table 2.5.

Table 2.5 *t* tests between morphological measurements of species.

Body measure	Female	Male
Cerci	T=-1.89, df=13, p=.081	T=-6.34, df=11, p<.0001
Tibia	T=2.17, df=12, p=.05	T=0.23, df=11, p=.82
Head L	T=-2.34, df=13, p=.036	T=-2.83, df=16, p=.012
Head W	T=-2.82, df=12, p=.015	T=-4.08, df=15, p=.001
Thorax L	T=0.45, df=12, p=.66	T=1.59, df=21, p=.13
Thorax W	T=-0.03, df=13, p=.98	T=0.16, df=12, p=.87
Ovipositor	T=1.0, df=14, p=.33	

2.4 Discussion

In general it was possible to distinguish between *H. ricta* and *H. femorata* by the degree of banding on the abdominal tergites. *H. femorata* appeared to have yellow and black stripes on the abdomen whereas *H. ricta* were only slightly striped or lacked stripes entirely. Ramsay and Bigelow (1978) reported that *H. ricta* is similar to *H. femorata* but its colouration is much more uniform, and it also lacks the dark pigmentation of *H. femorata*. In addition, all *H. femorata* found also had strong black markings on the prothorax and hind femur. *H. ricta* adults had two colour morphs, a homogenous red-brown colour and a pale stippled form. Field (1993) has similarly described the presence of two morphs of *H. maori*, one being a pale "race" and the other a melanistic "race".

When intermediate weta were discovered, they were mostly juvenile, and difficult to identify because they were generally darker in colour. The characteristics previously used to identify species were insufficient to distinguish these individuals. A more reliable characteristic that could be used in the field is therefore required. Butlin *et al.* (1992) suggest that for *Chorthippus parallelus* (Acrididae, Orthoptera) the most discriminatory morphological character is the stridulatory peg number, and this characteristic may apply to some other Orthoptera. In Acrididae, two common diagnostic features are stridulatory peg number and ovipositor length (Ferris *et al.*

1993). The stridulatory peg number is not practical for field identifications of *H. ricta* and *H. femorata* as it requires a microscope to detect the ridges. In addition, it would be difficult to count the stridulatory pegs of a live insect. The ovipositor length was not significantly different between *H. ricta* and *H. femorata* and perhaps there is a minimum length of ovipositor required to deposit the eggs and prevent them from desiccating in the soil.

Bigelow (unpublished data) counted the retrolateral and prolateral apical spines of the hind tibia of New Zealand tree weta. He concluded from these data that most *H. femorata* had both retrolateral and prolateral apical spines on the hind tibia and most *H. ricta* had only a prolateral spine. The retrolateral and prolateral apical spines is a useful morphological feature even though not all weta were consistent within a species. 20.5% of *H. ricta* found had no apical spines, while all *H. femorata* discovered had at least the prolateral or retrolateral spines. However, most of the weta conformed to having both spines present in *H. femorata* and only the prolateral apical spine in *H. ricta*. Of the two hybrid weta discovered, one had both spines and the other had both retrolateral spines but only one prolateral apical spine on the hind tibia. This suggests that these hybrids were therefore more similar by this trait to *H. femorata* than *H. ricta*. Leong and Hafernik (1992) similarly reported that hybrid damselflies of the sympatric species, *Ischnura denticollis* and *I. gemina* in California, were more similar to the common species than to the rare one.

The difference in length of adult male cerci was the best morphological character to distinguish *H. ricta* from *H. femorata* and this was a useful diagnostic tool to apply to adult males. In *H. ricta* cerci were quite curved and long while in *H. femorata* they remained shorter and straight throughout all instars. There is some evidence that cerci may aid copulation in these insects. When captive *H. ricta* were observed mating the male cerci seemed to aid in pushing down the females' sub-genital plate (personal observation). The mating behaviour of *H. femorata* has been described by Field and Sandlant (1983). They noted the presence of a pair of "recurved hooks",

which were presumably cerci, which possibly aided in reflecting the females subgenital plate or were perhaps genitalic locking devices. Sherley and Hayes (1993) observed the Mahoenui giant weta, *Deinacrida* n. sp, during mating and reported that the "cerci were inserted under a subgenital plate located ventrally and anteriorly to the attachment of the ovipositor to the abdomen". The differential size of cerci between *H. ricta* and *H. femorata* may possibly be acting as a partial reproductive isolating mechanism by inhibiting interspecific copulations. The reproductive morphology of *H. femorata* was studied by Sandlant (1981) and he described the presence of "a pair of paraprocts posterior and ventral to the phallus, together with a pair of long curved cerci" and he suggested they "were probable adaptations for gripping the female during copulation". If indeed cerci are mechanically used to grasp the female during copulation then the size differences found may act as isolating mechanisms, inhibiting male *H. femorata* from gripping female *H. ricta*.

In juvenile instars of *H. ricta* and *H. femorata* cerci lengths overlapped in size and therefore this characteristic could not be used to distinguish species. As the instars progressed toward adult, the size differences between the two species became more apparent. Sandlant (1981) found that age characteristics based on size were not a reliable measure in *H. femorata* but classed all weta greater than 30mm to be adult. It was not possible to gauge instar increments, as there was considerable overlap between instars. Perhaps if more weta were measured a clustering would have been observed around instars. It is interesting that the durations of stadia vary considerably when comparing field with captive weta. In captivity weta do not experience the seasonal temperature fluctuations during winter which would slow their activity. Weta housed at constant temperature should therefore show a shorter life span and instar duration compared to field weta.

Intraspecific variation in size between adults is generally accounted for by sexual selection for larger males. Presumably during intraspecific male aggressive interactions, a larger male will have an advantage over a smaller competitor. Field and Sandlant (1983) describe levels of aggression where one male wins by enclosing

the opponents mandibles in their own jaws. In this case a larger mandibular gape would be an advantage and hence the largest male would win the gallery and any female occupants.

H. ricta had a more pronounced allometric growth rate than *H. femorata*. Male weta of both species showed an allometric increase in the length and width of the head and cerci length but adult *H. ricta* males were significantly larger than adult *H. femorata* males. Little (1980) similarly showed that male *H. maori* have larger heads than male *H. femorata*. *H. maori* live in refuges on the ground and this behaviour characteristic is also found in some *H. ricta* (Chapter 3). Perhaps their larger mandible sizes compared to *H. femorata* is a reflection of their potential predators, such as skinks and geckos encountered in this environment. Field (1993) also suggested that the inverted defence posture exhibited by *H. ricta* and *H. maori* is an outcome of the predators they meet on the ground.

Conclusions

H. ricta and *H. femorata* could be distinguished by the degree of banding on the abdominal tergites. In addition the following features were good at discriminating weta that appeared darker and intermediate in banding: an absence of marks on the prothorax and femora; and an absence of any retrolateral apical spines on the hind tibia indicate *H. ricta*; and adult males of this species can be distinguished from *H. femorata* by the length and curvature of their cerci.

Chapter three

Distribution and habitat preferences of *Hemideina ricta*, and its association with *H. femorata*, on Banks Peninsula.

3.1 Introduction

Little is published on the distribution or habitat requirements of the Banks Peninsula tree weta, *Hemideina ricta*. This weta was discovered by Hutton (1887) who described it as closely resembling *H. femorata*. He gives no collection locality other than Banks Peninsula and South Canterbury. Prior to the current survey it was known to exist in only two locations on Banks Peninsula: Okains Bay (R. Bigelow, pers. comm.) and in totara logs below Purple Peak (P. Johns, pers. comm.). *H. ricta* was ranked at the top of the protected species list (Molloy and Davis, 1992) because it had a very confined distribution and so little was known about its population status.

The objectives of this study were therefore to map the distribution of both *H. ricta* and *H. femorata*, and to identify areas where *H. ricta* were found in high densities.

This detailed survey of the Banks Peninsula for *H. ricta* and *H. femorata* encompassed the Herbert and Akaroa Ecological districts (McEwen, 1987) of Banks Peninsula. The survey was designed to provide information to the Department of Conservation on appropriate areas of habitat that could be protected and to re-evaluate *H. ricta*'s protection status. Spatial and habitat overlap of these two tree weta species was also assessed.

3.2 Methods

Identification of weta

(refer to chapter 2)

Initial survey methods

Timed searches were done by examining all holes encountered in trees, posts and logs using a small torch with a focusable beam. Whenever a weta was discovered the search was interrupted while an attempt was made to extract it. The altitude, slope and aspect of land were recorded along with the number, species and location of all trees and bushes within 5 m of weta.

Systematic survey

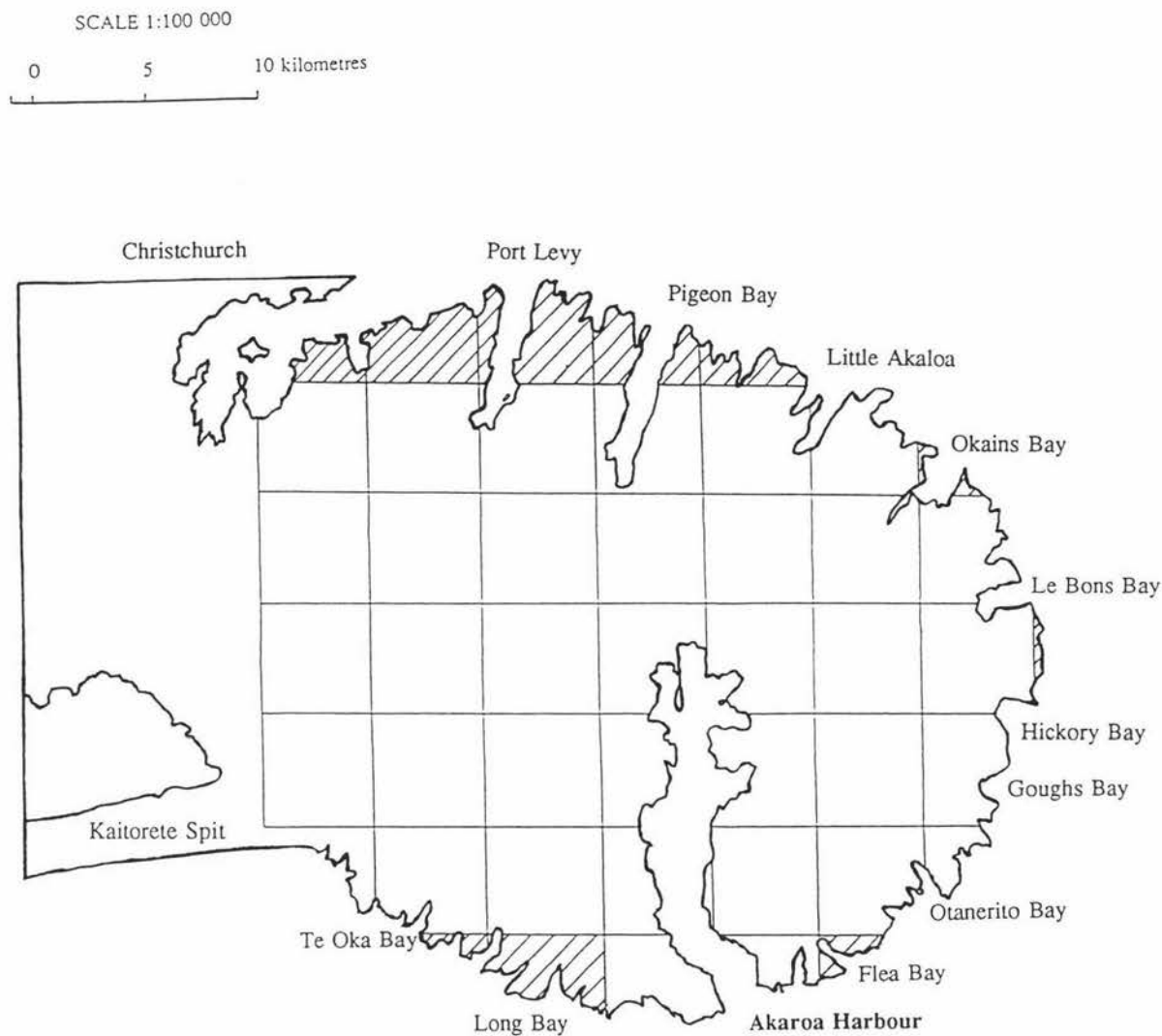
A systematic survey of much of Banks Peninsula was done by dividing it into 35 five-kilometre square areas (Fig 3.1). Areas not surveyed were mostly sea cliffs or bare farmland (hatched areas in Fig 3.1).

A 10 x 10 m plot was thoroughly searched within each broad habitat type within every 5 km square area. Each plot search was followed by a five minute timed search in the same habitat. The land use was recorded and categorised as unfenced farmland, fenced stock-proof farmland, roadside, private reserve and scenic reserve.

The locality of each plot was firstly selected from a map reference, secondly for access into the forested or plot area, and finally the plot was positioned by taking a random distance of up to 100 m in a random direction.

Broad habitat types corresponded to Wilson's (1992) vegetation categories of: dense stands of kanuka (*Kunzea ericoides*) forest; kanuka treeland comprising isolated or small groups of trees surrounded by pasture; mixed broadleaved hardwood forest; mixed broadleaved hardwood treeland; Podocarp; Podocarp/Mixed broadleaved hardwoods; beech (*Nothofagus* sp); exotic forest; and logs. An additional category consisted of old weathered totara fenceposts on farmland.

All trees, fenceposts and logs were searched for channels, holes and other possible weta refugia in each 10 x 10 m plot. The locations of every tree weta found were



BANKS PENINSULA

Fig. 3.1 Open squares show the location of each of the 35 five km² areas systematically surveyed for weta. Hatched squares show the areas not surveyed.

marked and an attempt was subsequently made to extract them. (see chapter 2 to describe weta extraction).

Destructive sampling of logs was kept to a minimum given the conservation status of *H. ricta*. When logs were broken the pieces were reassembled as much as possible before being left.

3.3 Results

Distribution

H. ricta and *H. femorata* in general were distributed allopatrically although there were four small areas of overlap. *H. ricta* occurred over approximately 200 square kilometres of the eastern end of Banks Peninsula. This included west facing slopes on the eastern side of Akaroa Harbour. The furthest west they were found was at Pigeon Bay (Fig 3.2). In contrast *H. femorata* occurred predominantly west of Akaroa. The distribution of both species overlapped at Nikau Palm Gully, behind Akaroa township, in an isolated stand of kanuka in Takamatua Valley and at Pigeon Bay. At the latter locality two juvenile *H. femorata* were found in the same tree as an adult female *H. ricta*. This was the only occasion where both species were found sharing the same tree. Two hybrid weta were found and these occurred together with *H. femorata* in a patch of Kanuka behind Akaroa township.

An area where *H. ricta* were found in high density, and could be regarded as a 'hot spot' for this species, was along Lighthouse Road and the adjacent farmland below Brasenose Peak, behind Akaroa. Here numerous logs, fenceposts and roadside vegetation contained this weta. The density of both weta species was estimated by averaging the number of weta found in each 10 x 10 m plot in every habitat category (Table 3.1). The density of each species was obtained by dividing the plots into areas where each species was known to occur on Banks Peninsula. Abbreviations of Table 3.1 are as follows: Mixed HW.= Mixed broadleaved hardwoods; Logs= totara and broadleaf logs; Scrub= low growing *Coprosma* and *Pseudowintera*; Podo.MHW=

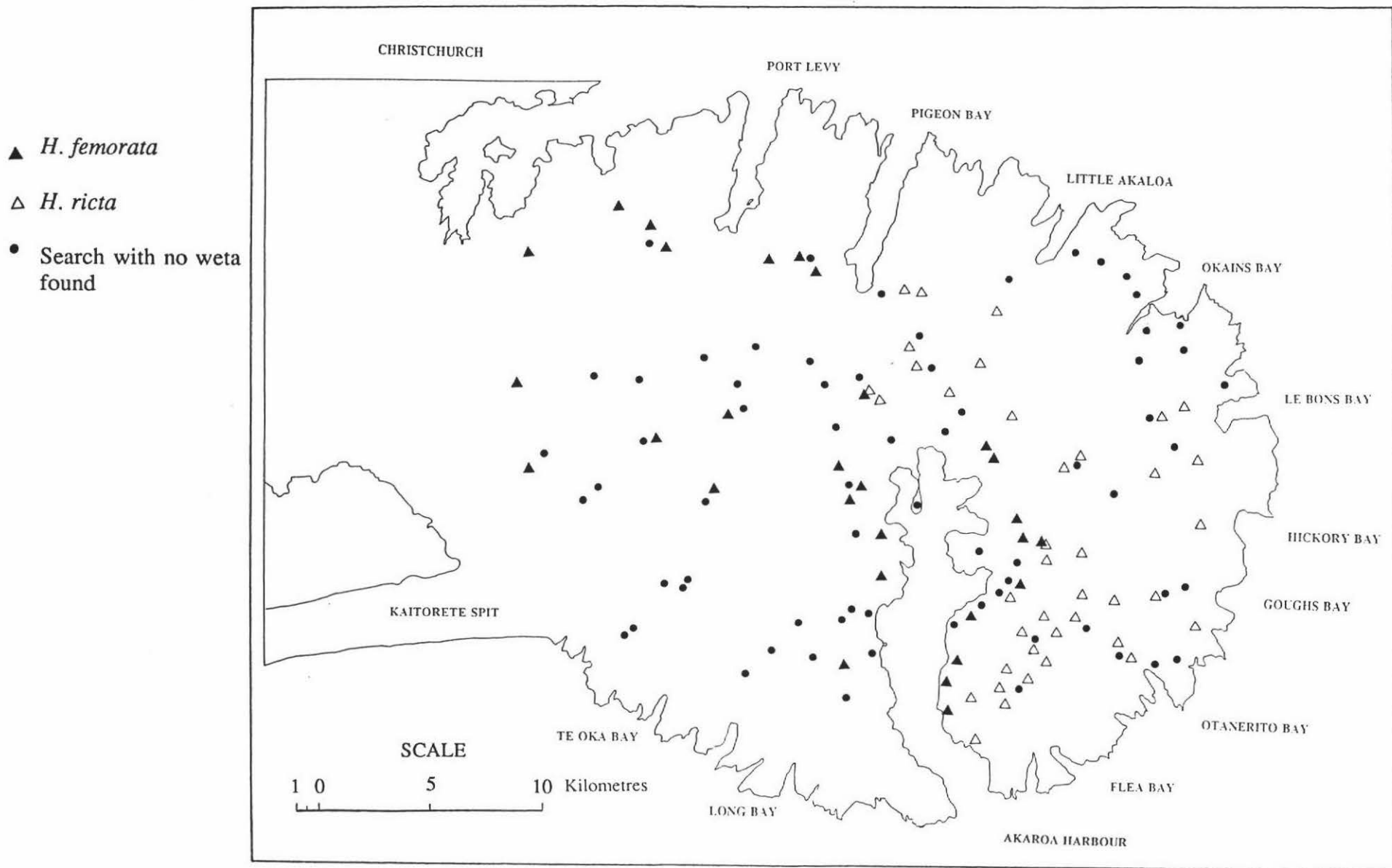


Fig. 3.2 Distribution of *Hemideina* species on Banks Peninsula.

Mixture of Podocarps and mixed broadleaved hardwood trees.

Table 3.1 The average density \pm standard error, of all weta, *H. ricta* and *H. femorata* in the 10 x 10 m plots of each habitat classification.

Habitat	Total	<i>H. ricta</i>	<i>H. femorata</i>
Kanuka	2.40, (0.59), n=35	1.67, (0.54), n=15	2.95, (0.95), n=20
Mixed HW.	1.47, (0.75), n=32	2.56, (1.29), n=18	0.07, (0.07), n=14
Logs	1.55, (0.59), n=11	2.13, (0.72), n=8	0, n=3
Fencepost	1.33, (0.88), n=3	1.33, (0.88), n=3	0,
Scrub	1.0, (1.0), n=5	1.67, (1.67), n=3	0, n=2
Beech	0, n=3	0, n=3	0
Podocarp	0, n=3	0, n=1	0, n=2
Podo. MHW.	0, n=10	0, n=2	0, n=8

All weta found were distributed according to the availability of habitat, which included isolated logs and small shrubs found in pasture. On four occasions *H. ricta* was found either under or in crevices between rocks which suggests they do not require log and tree refuges.

Altitude

All *H. femorata* were found below an altitude of 450 m, whereas *H. ricta* ranged from 40 m asl to 806 m asl (Fig 3.3). 76.9% of *H. ricta* occurred at altitudes greater than 400 m although there was no significant trend in altitudinal distribution ($X^2 = 0.951$, $df=2$, $P>0.05$). 97.1% of *H. femorata* were found below 400 m asl, ($X^2 = 13.98$, $df=2$, $P<0.005$). Where both species were located in the same habitat patches these were at the following altitudes: Nikau Palm Gully, 375 m; Takamatua Valley, 150 m; Pigeon Bay, 300 m.

Location of refuges

H. ricta was found in holes and crevices in a range of trees, posts, logs and rocks (see Plate series 3.1) whereas all *H. femorata* except one were in trees. The exception was in a log where one individual was found (Fig 3.4). *H. femorata* significantly preferred kanuka, as 94% occupied galleries in stands of kanuka, ($X^2 =$



Plate 3.1 Typical rocky habitat areas where *H. ricta* were located, (a) shows the surrounding vegetation which was bracken, and (b) shows a gallery that has been worn by an adult female which was found under a rock.



Plate 3.1 (a) Fencepost below kanuka tree, containing an adult male *H. ricta* (in central hole) and two other juvenile weta in lower galleries. (b) Old fencepost in the midst of gorse bushes and pasture grasses, contained two adult male and female *H. ricta*.

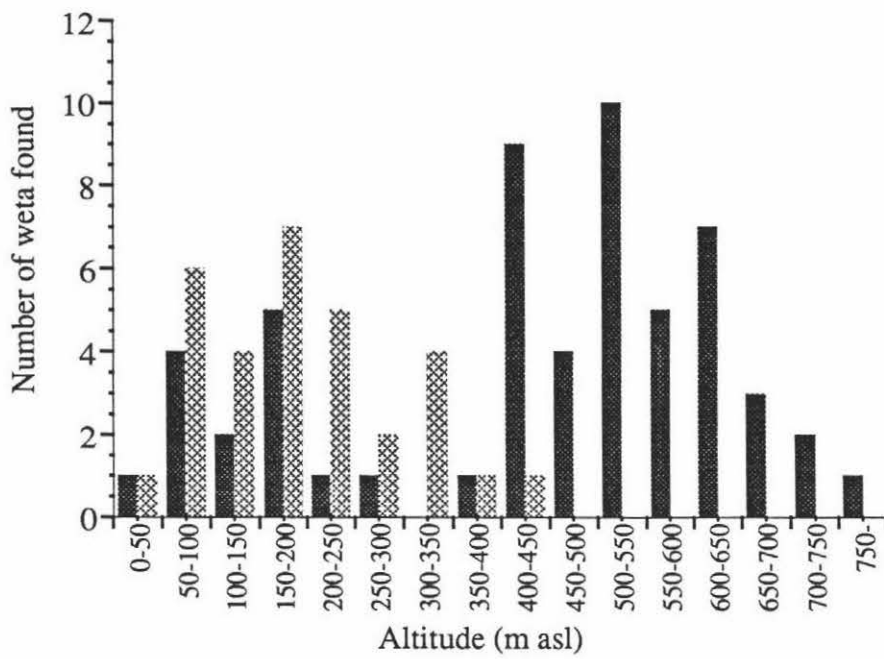


Fig. 3.3 Altitudinal distribution of *H. ricta* (solid bars) and *H. femorata* (shaded bars), on Banks Peninsula.

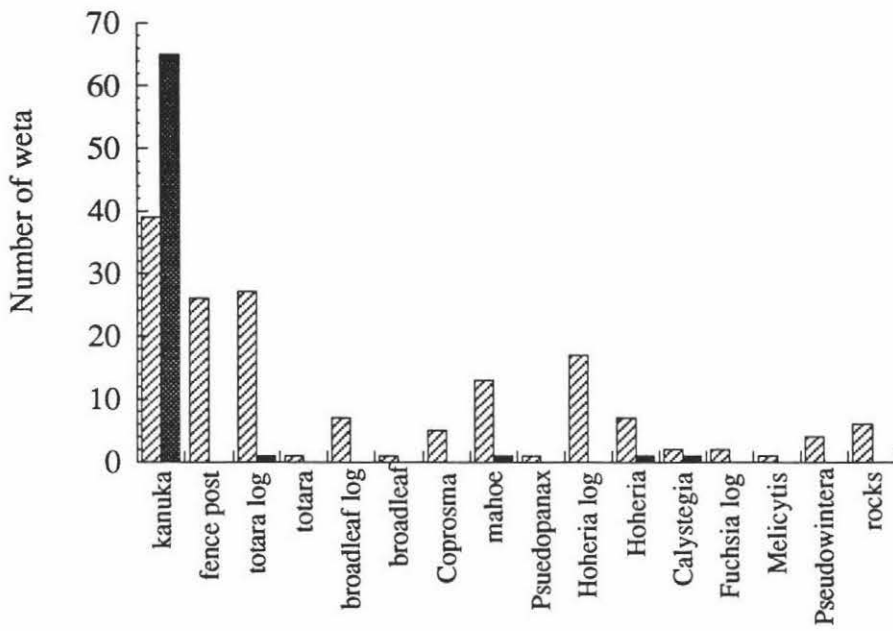


Fig. 3.4 Types of habitat and tree species where *H. ricta* (hatched bars) and *H. femorata* (shaded bars) occurred.

23.145, $df=2$, $P<0.005$) whereas the majority (40%) of *H. ricta* were located in either fenceposts or totara and broadleaf logs on the ground but this was not significant ($X^2 = 1.108$, $df=2$, $P>0.05$).

H. angustifolia and kanuka trees were preferred approximately equally by *H. ricta*. They were found in small numbers in broadleaf (*Griselinia* sp), mahoe (*Meliccytus ramiflorus*), *Pseudopanax arboreus*, *Calystegia* sp, *Pseudowintera colorata*, and *Coprosma* sp. Only one juvenile *H. ricta* was found under totara bark (*Podocarpus totara*) (Table 3.2).

Table 3.2 Number of *Hemideina* sp located in different vegetation types.

Tree species of refuges	<i>H. ricta</i>	<i>H. femorata</i>
<i>K. ericoides</i>	32	79
<i>H. angustifolia</i>	34	1
<i>M. ramiflorus</i>	13	1
<i>P. colorata</i>	4	0
<i>Coprosma</i> sp	5	0
<i>P. totara</i>	1	0
<i>P. arboreus</i>	1	0
<i>G. littoralis</i>	1	0
<i>S. digitata</i>	0	1
<i>Calystegia</i> sp	2	1
Logs	44	1
Fenceposts	26	0
Rocks	7	0

Apart from kanuka, *H. femorata* occurred in low numbers the following live trees, *H. angustifolia*, *Calystegia* sp vine, *Schlefflera digitata* and *M. ramiflorus*.

Habitat with respect to altitude

H. femorata were observed in kanuka up to 320 m asl and above that only one weta was recorded in a *Hoheria* gallery at 440 m asl. *H. ricta* were generally located in either mixed broadleaved hardwoods or kanuka up to 670 m asl but at higher elevations they were mainly found in totara or broadleaf logs and under rocks (Fig

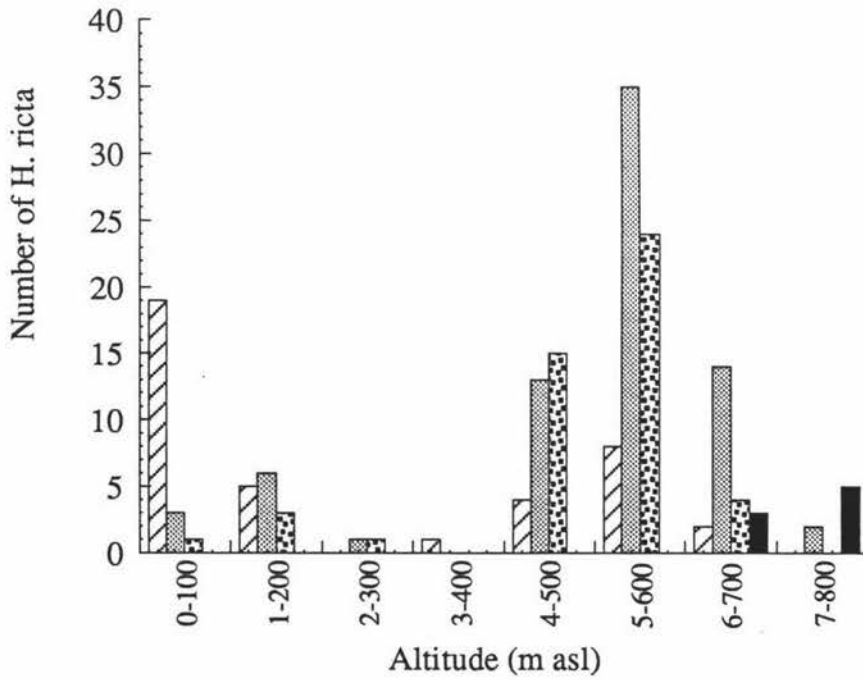
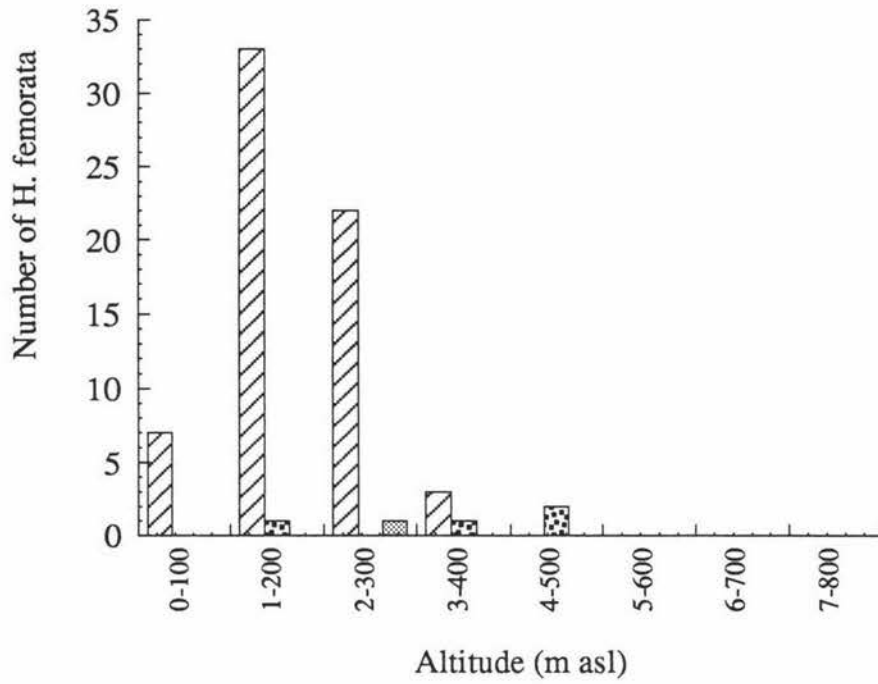


Fig. 3.5 Habitat categories and altitude where *H. femorata* (above) and *H. ricta* (below) were found. Hatched bars = kanuka, spotted bars = mixed HW., shaded bars = logs and solid bars = rocks.

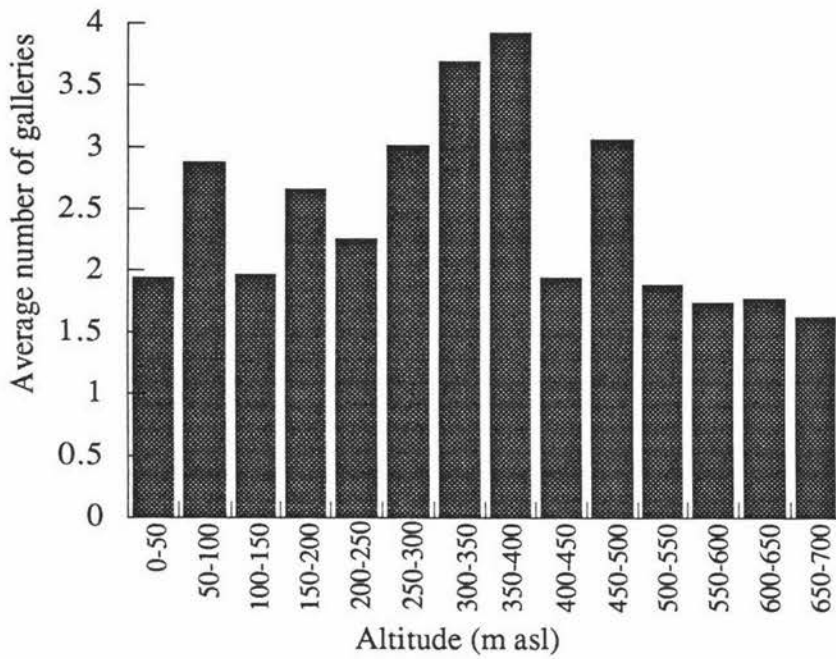


Fig. 3.6 The average number of refuges found per tree or log over the altitudinal sampling range.

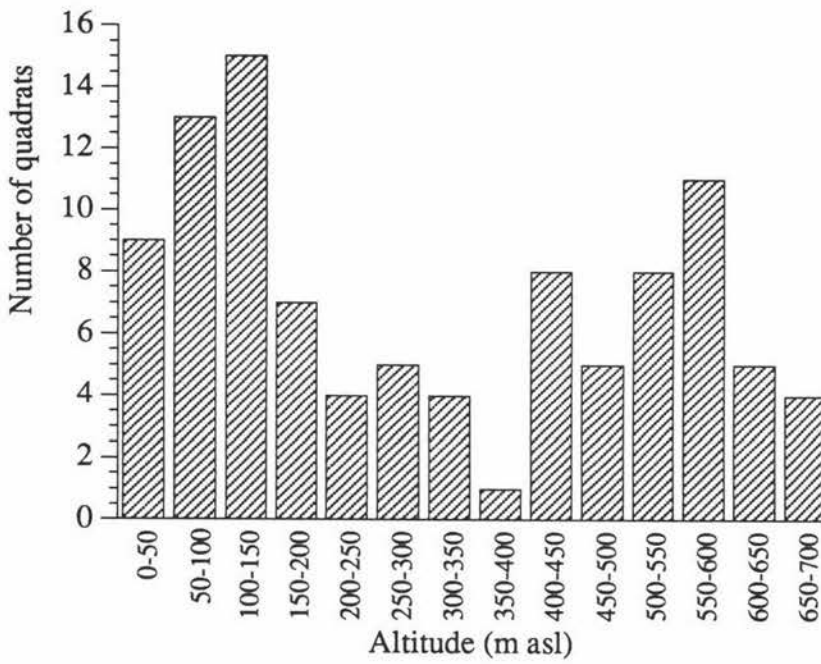


Fig. 3.7 The total number of 10 x 10 m plots sampled by altitude.

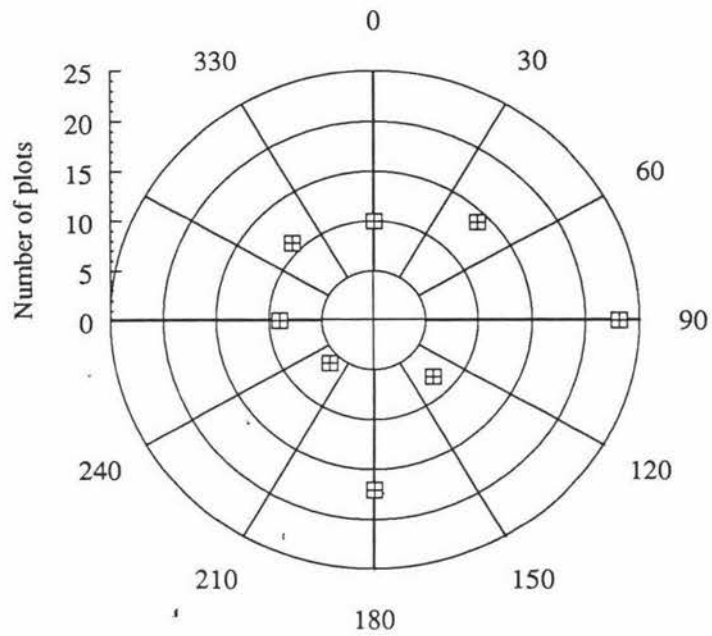


Fig. 3.8 a Aspect (direction of slope) of land of all the plots searched during the survey of *H. ricta* and *H. femorata*.

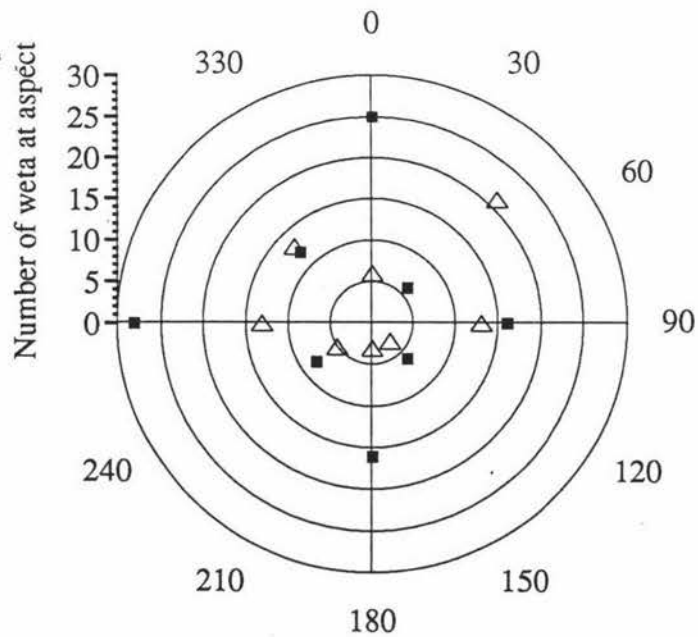


Fig. 3.8 b The number of *H. ricta* (black diamonds) and *H. femorata* (open triangles) found at the land aspects of N, NE, E, SE, S, SW, W and NW.

3.5). There was less kanuka above 400 m than below this. The number of available refuges per tree (Fig. 3.6) and the number of trees per plot did not vary appreciably with altitude. The total number of plots sampled at each 50m interval is was not consistent, with less being sampled in the mid-altitude range (Fig 3.7).

Aspect

Most areas surveyed faced eastward (Fig. 3.8a) but the majority of weta were found on west facing aspects, (Fig 3.8b). *H. ricta* and *H. femorata* were located at significantly different aspects ($X^2 = 29.407$, $df=7$, $P<0.005$). *H. ricta* were predominately on north and west facing slopes whereas *H. femorata* occurred mainly on north-east facing slopes (Table 3.3).

Table 3.3 Number of each species found at aspect of land.

Aspect	N	NE	E	SE	S	SW	W	NW
<i>H. ricta</i> (n)	25	6	16	6	16	8	28	12
<i>H. femorata</i> (n)	6	21	13	3	3	5	13	13
Total	31	27	29	9	19	13	41	25

3.4 Discussion

The distribution of vegetation on Banks Peninsula affects weta distribution because weta mainly use trees and logs for refuges. Banks Peninsula is currently a mosaic of pasture and low scrubland, with isolated stands of kanuka and mixed broadleaved hardwoods occupying the wetter gullies (Wilson, 1992). The summit road area, between an altitude of 500 to 840 m asl, is mainly farmed but decaying totara and broadleaf logs together with scattered shrubs are often locally abundant and form an important weta habitat. These scattered areas of remnant bush may be too far apart for weta to disperse between patches and may therefore limit the current distribution. No information is available on the dispersal distances of other tree weta, but some acridids have been shown to disperse distances of up to 30 m per generation (Ferris *et al.* 1993). Richards (1994) reported that Mahoenui weta (*Deinacrida* n.sp), was

usually found within 1 m of its original position when relocated after a period of one to seven months. This implies that these weta do not move great distances within their lifetimes, and hence, dispersal would be limited by the distances between patches.

All tree species present on Banks Peninsula have distributions that encompass the entire peninsula with the exceptions of red and black beech (*Nothofagus fusca* and *N. solandri*). These are restricted to small isolated stands within a small south-eastern portion of the peninsula (Wilson, 1992). However, I found no tree weta in *Nothofagus* forest. The rainfalls of Mt Herbert and Akaroa ecological districts are similar although Wilson (1992) reports that the climate of the latter has more mild, moist and oceanic conditions. These may coincide with the distribution of *H. ricta*.

There is a distinct vegetational transition at 500 m asl on Banks Peninsula. Here lowland podocarp forest changes to montane forest dominated by thin bark totara, mountain five finger, broadleaf and pepperwood (Wilson, 1992). This altitudinal change corresponds with the upper altitudinal limit of *H. femorata* on Banks Peninsula but not with the upper altitudinal limit of *H. ricta*. Kanuka was preferentially used by *H. femorata* and its distribution can be described as homogenous throughout the Peninsula (Wilson, pers. comm.). Hence the distribution of kanuka does not significantly affect the distribution of *H. femorata* even though kanuka was not surveyed as often at higher altitude on the western portion of the Peninsula.

A small number of studies have investigated the habitat use of *H. femorata*. I found that 94% of *H. femorata* were in kanuka trees whereas *H. ricta* was found to use a wide range of trees, logs and rock crevices for refuges. In a survey of *H. femorata* and *H. maori*, *H. femorata* was associated with kanuka and *Nothofagus* sp where it was found in tunnels in trunks (Little, 1980). Sandlant (1981) reported that *H. femorata* was located commonly in kanuka, lacebark, *Fuchsia* sp, mahoe, beech and

broadleaf. No *H. ricta* or *H. femorata* were located in beech or *Fuchsia* during this study, but it is not known whether they existed higher in the canopy where I did not search, although no galleries were located in the trunks at heights I was able to search.

On the western portion of the peninsula where only *H. femorata* existed, this weta was not found above an altitude of 450 m despite extensive searches and the availability of numerous suitable weta refuges. Most of the available habitat searched were totara logs and podocarp forest remnants similar to those searched for *H. ricta* at equivalent altitudes. *H. ricta* was frequently found in logs and fenceposts and less often in crevices between rocks, while only one *H. femorata* was found in a log. On Banks Peninsula, the majority of totara and broadleaf logs lay scattered above an altitude of 500 m asl and the lowest area of logs that I examined was at 300 m asl. Such a distribution of logs may also add to the greater number of *H. ricta* discovered between altitudes of 400 and 700 m asl, given that they were readily found in log refuges.

H. ricta and *H. femorata* were only found in three habitat patches that could be considered as overlapping. They were at altitudes of 375, 300 and 150 m asl. In all other instances these species were in altitudinally separate habitat patches. Richards and Trewick (pers. comm.) report that altitude is an important factor determining the species distribution of *H. thoracica* and *H. crassidens* in the Taranaki region. They found *H. thoracica* all around Mt Taranaki up to 800-900 m asl whereas *H. crassidens* occurred from 800-900 m asl up to the bush line (1100 m asl). There were also zones of overlap where both species were found. Levins and Culver (1971) and Hanski (1983) suggest that two species can coexist by occupying different patches when environments have a patchy, island-like pattern of occurrence. Each would have little effect on the other because their co-occurrence would be an extremely rare event. Granot (in Abramsky, 1981) suggested that two closely related species can co-exist if they prefer slightly different habitats or through resource partitioning, even though both species may be found at the same sites. This certainly

appears to be happening with *H. ricta* and *H. femorata* when one compares the use of refuges of these weta. *H. ricta* was found in a wide range of habitat that included live trees, logs, fenceposts and rock crevices while *H. femorata* was found predominantly in live trees. Possibly these two species have come to occupy variable niches because of competition for the same resources. The niche of a species is thought to consist of the essential resources of the species inclusive of conditions of time and space (den Boer, 1986). However, den Boer (1986) and Wissinger (1992) describe a competitive coexistence principle where taxonomically closely related species are expected to be more convergent in habitat use. They suggested that two species can coexist under favourable conditions, and while coexistence increases the pressure of competition, the niches shift to allow coexistence to continue.

I found *H. crassidens* and *H. thoracica* together in the foothills behind Palmerston North. In the Turitea Valley, *H. crassidens* occurs in logs and trees within the forest whereas *H. thoracica* occurs in fenceposts and logs in exposed areas with no canopy cover. In this case there appears to be two species co-existing and occupying varying habitat refuges some what similar to *H. ricta* and *H. femorata*. In studies of other animals the differences between two species can sometimes be very subtle. Forrester (1993) reports that two species of Curculionidae have a wide niche overlap on their host plant *Echium plantagineum*. They are able to co-exist because of temporal separation with one species hatching one month earlier than the other. A distributional study of two rodent species showed that two species were able to coexist but occupied different habitats within the area (Abramsky, 1981).

There is no information yet available on what competitive interactions occur between *H. ricta* and *H. femorata* but it is likely that the greatest competition would be for occupation of preferred gallery sites. Moller (1985) describes vigorous intraspecific disputes over gallery occupancy in *H. crassicuris* and suggested there was substantial competition for gallery space on Stephens Island. Ordish (1992) reported

that *H. crassidens* preferred dry sheltered retreats close to a suitable food source and that they jealously guarded suitable tunnels. Intraspecific aggression of *H. femorata* was studied by Sandlant (1981), and he reported that initially galleries were considered to be a limiting resource but further investigation revealed a complex interaction between gallery occupancy and male competition for females. Observations of *H. femorata* behaviour have revealed that male weta spend a lot of time roaming around inspecting galleries. There are inter-male disputes for gallery occupancy and for females contained within them (Field and Sandlant, 1983). Refuges do not appear to be a limiting resource based on numbers counted during the study of *H. ricta* and *H. femorata* (see chapter 4). Perhaps the refuges counted were an over-estimate of the number available, because many refuges eg, in broadleaf bark, never contained weta.

There were a greater number of weta found on land sloping from west to north. The majority of *H. ricta* and *H. femorata*, however, were found at significantly different aspects, with *H. ricta* being located mainly on north and west facing slopes whereas *H. femorata* was found on north-east facing slopes. Sherley and Hayes (1993) reported that the Mahoenui weta (*Deinacrida* n. sp) was also found mainly on north-east slopes at Mahoenui Reserve, King country. They suggested that Mahoenui weta preferred the warmer slopes of north-east aspect and avoided the south-east colder slopes.

The reduced numbers of *H. ricta* and *H. femorata* that were located in the mid altitude range between 300 to 450 m asl is due to the sampling regime. This occurred because more 10 x 10 m plots were sampled from lower and higher altitudes where there was better road access from either the Summit Road or the lower Main Harbour Road.

It is interesting that *H. ricta* occurred under rocks and in crevices between rocks at four sites on Banks Peninsula. Two of these were within scenic or private reserves at Ellangowen and Hinewai respectively whereas the other two were on a private

farm above Takamatua Valley off the Summit Road. *H. ricta* was found on the summit of Stoney Bay Peak (806 m asl) under rocks with the gallery tunnel in soil, (see plate series 3.1). *H. ricta* appears to show a similarity to the alpine tree weta, *H. maori*, as it too uses refuges in rock crevices and under rocks in alpine fell fields above the timberline (Field, 1993). The alpine giant weta, *Deinacrida connectens* is also found under rocks above the tree line (Field, 1980). Sandlant (1981) lists *Zelandosandrus gracilis*, *Z. maculifrons* and *Hemiandrus* as inhabiting burrows dug in soil and leaf litter. Moller (1985) described *H. crassicuris* occurring in clay bank colonies where the population density was high. It may be that where weta face a tree refuge shortage they are forced to use other refuges such as under rocks and in soil banks. Certainly where *H. ricta* was found under rocks on the summit of Stoney Bay Peak, no logs or trees were present. There was, however, thick low growing gorse bushes where weta could have taken refuge apart from under stones. Staff at Hinewai Reserve reported several sightings of *H. ricta* when clearing gorse from boundaries within the reserve but I searched and never found them in this plant.

There are a few other scenic reserves on Banks Peninsula where *H. ricta* were located. Two of them, Otepatotu and Mt Pearce Scenic Reserves, are both above 500 m altitude and encompass native bush and open tussock grassland with scattered totara logs. I believe these reserves are of high conservation importance to *H. ricta*. Both contain scattered totara and broadleaf logs with low growing vegetation as well as forested areas. In addition to this the altitudes of these reserves are above altitudes where *H. femorata* has been found, which would therefore exclude this species if it were encroaching on *H. ricta* habitat. On many of the farmed areas of the Summit Road where *H. ricta* have been located, totara and broadleaf logs are being removed for firewood and for ornamental purposes. It is therefore important to protect and extend these reserves where *H. ricta* has been found.

A recent proposal suggested introducing Weka to Hinewai Reserve. Bramley (1994) found that weka obtained prey commonly available and Orthoptera remains were

among the items in the gizzards of North Island Weka. The weta using refuges in logs on the ground and in fenceposts may therefore be at risk of being eaten by weka. Other introduced animals also pose a threat to *H. ricta*'s continued survival and are known to prey on weta. J Miles (pers. comm.) found remains of tree weta in the stomachs of stoats from the Tongariro Forest park. Wildlife Research Liaison Group (1988) reports that introduced vertebrates have a significant effect on the New Zealand arthropod fauna. Cowan and Moeed (1987) also found that possums (*Trichosurus vulpecula*) feed on weta and considered that they would be a threat to small remnant populations of slow moving, large bodied insects. Possums are prevalent in Hinewai Reserve and were seen in the paddock study area on one occasion at night. Other introduced animals such as rats, feral cats and hedgehogs also probably pose a threat to tree weta.

Conclusions

H. ricta was restricted to the eastern portion of Banks Peninsula including the inner slopes to the east of Akaroa Harbour. *H. femorata* was also found on the eastern side of Akaroa Harbour and westward from here. *H. ricta* was found in considerably varied habitats and over an altitudinal range between 20-806 m whereas *H. femorata* was only located below 500 m. The distribution of *H. femorata* was either associated with altitude or kanuka.

Chapter four

Refuge occupation by *Hemideina ricta* and *H. femorata*.

4.1 Introduction

Field (1993) suggested that *H. ricta* faced a gallery shortage because they were found in fenceposts and logs on the ground. In many instances, however, logs were the only available refuge in the area. In chapter 3 I reported finding *H. ricta* in rock crevices and under rocks at four sites on Banks Peninsula, so perhaps tree refuges were a limited resource for this weta. Sandlant (1981), however, proposed that refuges were not a limiting resource for *H. femorata* because 20% of the potential refuges were unoccupied. Instead he suggested that the females that occupied them were the subject of intense intraspecific competition between males. Field and Sandlant (1983) suggested male *H. femorata* competed for and defended galleries which were a limited resource. Male *H. femorata* also forms harem structures with multiple females in large galleries (Field, 1994). Presumably males that occupied large galleries could acquire multiple females and therefore increase their reproductive fitness.

In the area of overlap between *H. ricta* and *H. femorata*, it was possible that competition existed for gallery occupancy. *H. ricta* and *H. femorata* were found in a range of tree species, although *H. femorata* showed a strong preference for kanuka (Chapter three). The intention of this chapter was to discover whether there are any differences in refuge occupation between *H. ricta* and *H. femorata* both between instars within a species and between species.

Part of this work involved placing artificial retreats in areas of Hinewai Reserve to study colonisation in *H. ricta*. Ordish (1992) previously investigated aggregation and stridulation in *H. crassidens* using artificial retreats. Artificial retreats allow observation of the number of weta present without disturbing and destroying the natural refuge. Retreats similar to those described by Ordish (1992) were tested to determine whether they could be used to supplement natural refugia as part of a conservation management plan.

4.2 Methods

Potential weta refugia were searched and counted in the systematic survey of Banks Peninsula (see chapter 3). All refuges (categorised below) were searched both within the 10 x 10 m plots and in 5 minute searches in trees, fenceposts and logs of a range of habitat types (see chapter 3 for more comprehensive details). Refuges were categorised as follows:

- * Galleries that were tunnels in mainly live trees, generally with a single aperture and with the entrance clear of debris. These tunnels were mainly formed by larval Cerambycidae beetles and were characterised by having a well maintained approximately circular entrance.
- * Splits (greater than 5 cm) or channels mainly in logs on the ground but also formed from wounding of trees.
- * Forks where leaves and twigs had fallen into the branches and built up deposits of debris.
- * Hollows in the interior of dead trees.
- * Areas under pieces of bark where the bark had detached but was still held firmly against the trunk. Most of these were associated with kanuka but sometimes were also associated with totara, *Hoheria* and some other species.
- * Rotted wood with holes in soft, dry, logs.

Animals that occupied these potential refuges were recorded together with the type of refuge occupied. The height off ground of the refuge was recorded but I was generally limited to ranges between ground and 2 m although on some occasions I was able to search higher by climbing up the trees. When weta were extracted their head width and entrance aperture of the refuge were measured.

Thirty four artificial refuges were made from macrocarpa blocks according to Ordish (1992). These were fitted with perspex windows and aluminium covers. One of the inner channels in each box was fitted with a wedge to produce a graduated hole. The lids were attached with a screw at the top of the box.

The refuges were hooked on to branches or forks and secured with twine to tree trunks or fenceposts in Hinewai Reserve. They were positioned 0.5-2.0 m above the ground. Eleven refuges were placed in mixed broadleaf hardwood bush, 18 were put in kanuka, and five were hung on the boundary fence in an area where weta were found in fenceposts. These refuges were checked at the start and end of each fieldtrip in April, May and August 1993 and monthly during summer (Jan./Feb. 1993, Nov. 1993-Feb. 1994).

Statistical methods include X^2 tests and regression analysis.

4.3 Results

A total of 138 weta of both species were found in galleries, 83 were found in splits, 18 under bark, 3 in rotten wood, 2 in forked branches and 1 in the hollow centre of a tree. Only small nymphs of both species were found under bark of kanuka and on one occasion a juvenile *H. ricta* was found under totara bark. A greater number of *H. femorata* (76.4%) were discovered in galleries compared to *H. ricta* (46.6%) and there was a significant difference in refuge use between species ($X^2 = 26.6$, $df=2$, $P<0.005$). More *H. ricta* occupied splits though this is most probably related to the greater number of these weta discovered in weathered log refuges. Two *H. femorata* were found in forks whereas no *H. ricta* were. In contrast three *H. ricta* were located in rotten wood but no *H. femorata* were (Table 4.1).

Table 4.1 The number of weta of both species found in each refuge category.

Refuge type	<i>H. ricta</i>		<i>H. femorata</i>	
	n	%	n	%
Gallery	83	46.6	55	76.4
Split	76	43.9	7	9.7
Under Bark	10	5.8	8	11.1
Hollows in trees	1	0.6	0	0
Rotten wood	3	1.7	0	0
Branch forks	0	0	2	2.8

Juvenile *H. ricta* preferred different refugia to adults. Significantly more adult *H. ricta* were located in galleries ($X^2= 10.12$, $df=2$, $0.01 < P < 0.005$) than in splits, rotten wood, and under bark. No significant difference was apparent between the refuges occupied by *H. femorata* adults and juveniles ($X^2 = 1.21$, $df=1$, $P > 0.05$). The aperture of the refuge entrance was significantly correlated with the width of the weta heads ($r=0.507$, $P < 0.001$). The mean ratio of aperture width to head width was 2.04, ($n=55$).

There was a significant difference in the direction (aspect) of refuge entrance between *H. ricta* and *H. femorata* ($X^2= 15.22$, $df=7$, $0.025 < P < 0.05$). *H. ricta* gallery entrances were predominantly found at north to north-east aspect while *H. femorata* were mainly west (Fig. 4.1). Weta were discovered at all heights from 0 to 3.25 m but most weta were found at 0.75 to 1.0 m above ground (Fig 4.2).

Table 4.2 Number of potential refugia in different tree species.

Tree Type	Number of trees examined	No.trees without refuges	Total No. refuges counted	Average refuge/tree	Std. dev.
<i>Kunzea</i>	880	368	2610	5.12	4.79
<i>Melicytus</i>	238	67	627	3.64	3.71
<i>Hoheria</i>	152	56	346	3.01	2.02
<i>Pseudowintera</i>	139	64	175	2.39	1.87
<i>Coprosma</i>	439	287	316	2.19	1.85
<i>Pseudopanax</i>	68	35	147	4.61	5.07
<i>Griselinia</i>	38	7	148	6.35	6.30
<i>Fuchsia</i>	26	0	88	3.38	2.70
<i>Podocarpus</i>	65	25	171	2.93	1.90
<i>Macropiper</i>	130	95	70	1.94	1.30
<i>Nothofagus</i>	107	83	46	2.0	1.47
<i>Myoporum</i>	18	6	44	3.5	2.20
<i>Calystegia</i>	46	5	86	2.90	3.37
<i>Sophora</i>	37	10	97	3.48	2.40
<i>Pittosporum</i>	20	13	13	1.86	1.46
<i>Carpodetus</i>	19	7	22	1.83	1.11
<i>Pennantia</i>	20	7	25	1.92	1.44

The highest number of potential refuges per tree occurred in kanuka and broadleaf

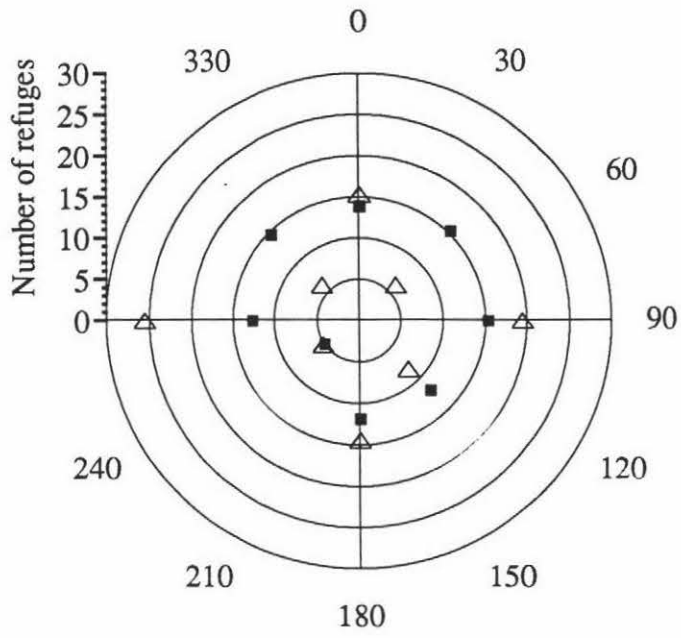


Fig. 4.1 The aspect of refuge entrance of *H. ricta* (black diamonds) and *H. femorata* (open triangles)

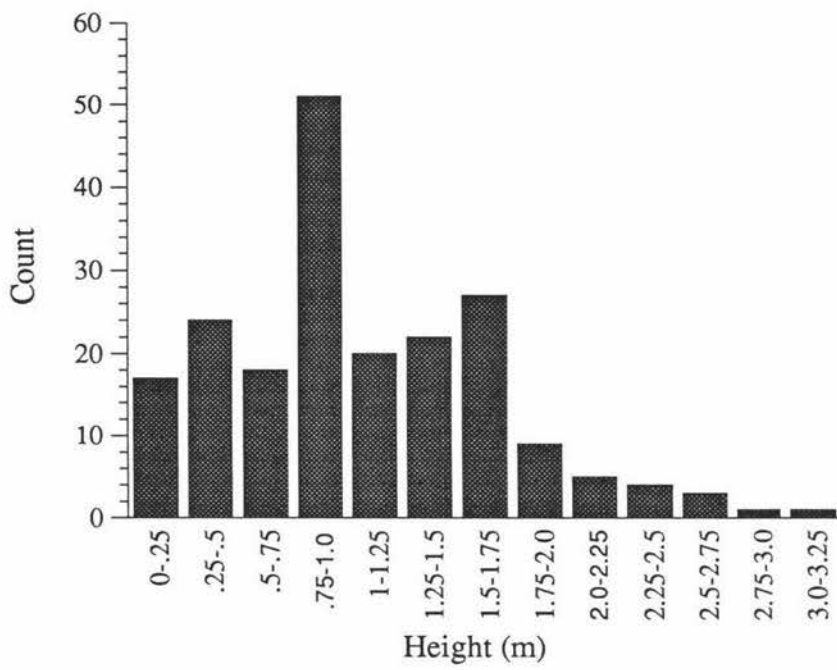


Fig. 4.2 Height off ground where weta were found in galleries.

(Table 4.2) with averages of 5.12, (sd=4.79, n=880) and 6.35 (sd=6.30, n=38) respectively. The bark of broadleaf trees contained numerous channels and crevices but no weta were ever found in them. More weta were found in trees where more refuges were available (Fig. 4.3).

1135 trees were examined that had no refuges present. 5018 possible refugia were counted in all of the trees examined and a total of 1417 of these refuges were occupied by invertebrates, including 146 refugia containing *Hemideina* sp (Table 4.3). The remaining refugia were empty.

Table 4.3 The taxa found per tree and log refuges

Taxa	Gallery	Split	Bark	Fork	Rot	Hollow
<i>H. ricta</i>	62	15	5	0	3	0
<i>H. femorata</i>	48	4	7	2	0	0
Arachnid	361	46	260	17	16	7
Rhaphidophoridae	84	17	48	3	5	0
Blattodea	13	3	23	0	3	1
Cerambycidae	11	0	3	2	1	0
Tenebrionidae	45	17	26	3	3	0
Other Coleoptera	12	3	17	0	7	0
Isopoda	51	7	33	6	3	1
Forficulidae	8	4	19	2	4	1
Slug	33	11	7	2	4	2
Snail	11	2	3	0	4	0
Formicidae	8	3	6	1	0	0
Lepidoptera	2	1	3	1	0	0
Chilopoda	0	1	8	0	2	0
Diplopoda	4	2	6	1	4	0
Platyhelminth	3	1	1	0	1	0
Opilionidae	4	2	1	0	0	1
Skink/Gecko	2	2	0	1	1	0

62.4% and 74.2% of *H. ricta* and *H. femorata* respectively were found to occupy refugia as individuals. Ten pairs of adult females and males were found sharing refugia in *H. ricta* and 8 pairs in *H. femorata*. Only once was one adult male *H. ricta* found with two adult females (Table 4.4). On one occasion a large fencepost with numerous channels and splits contained 18 adult and juvenile *H. ricta* of mixed sex and many of the weta

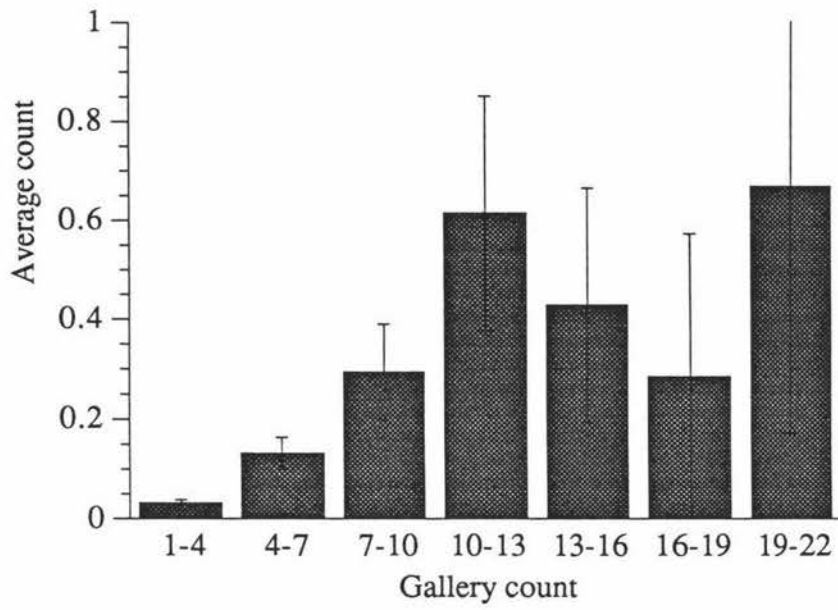


Fig. 4.3 The average (and standard error) number of weta found per tree by the number of potential refuges available per tree.

were found in the same crevices, although it was difficult to determine where the splits started and stopped.

Table 4.4 Number of weta found in artificial refuges and by survey searching.

Number of weta per gallery	<i>H. ricta</i>	<i>H. femorata</i>
Survey		
1	68	46
2	10 pairs	8 pairs
3	1	0
>3**	1	0
Artificial refuges		
1		
2		
3	3*	
4	1*	

* In separate artificial retreats on at least one occasion. In some instances for example, three weta were found in a refuge on three consecutive months of the trial.

** On one occasion a group of 18 *H. ricta* were located in a fencepost.

Refuge sharing with other animals

Weta shared galleries with the following invertebrates: raphidophorids; cockroaches; small spiders; earwigs; woodlice; tenebrionidid beetles and athoracophorid slugs. On 10 occasions weta shared galleries with the common gecko *Hoplodactylus maculatus*, and once with a skink. These latter weta were all adult or large sub-adults. Large spiders were not found occupying refuges with any other taxa but small spiders occurred together with the following invertebrates: Dermaptera; Blattodea; Isopoda; Chilopoda; athoracophorid slugs; Tenebrionidae and Carabidae beetles; Rhaphidophoridae and Stenopelmatidae weta.

Artificial refuge use

Of 34 artificial refuges only 11 were used periodically over a 14 month period by *H. ricta* (Fig 4.4). No *H. femorata* colonised the refuges because only *H. ricta* was found in Hinewai Reserve. Refuges were initially colonised by spiders but one juvenile male weta was found in one refuge after 15 days. This refuge was placed in a kanuka tree that already had weta in it. Low numbers of boxes were colonised by tree weta after

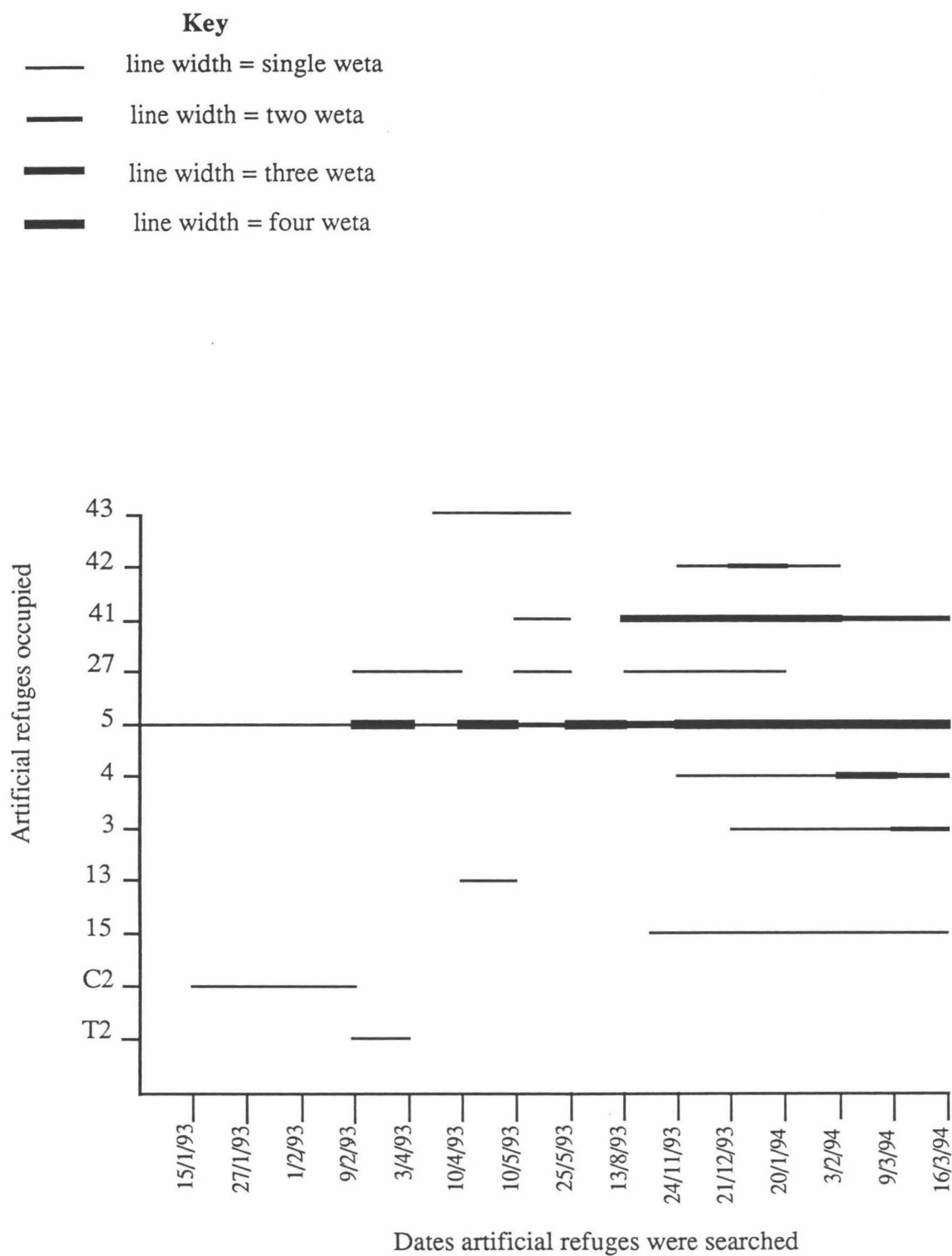


Fig. 4.4 The 11 artificial retreats that were occupied by *H. ricta*, throughout the fieldwork period. Some of the retreats (13 and T2), were only occupied by weta on one occasion, while others were colonised early and had weta in them throughout the full period. Line thickness indicated how many weta were in each box.

approximately two months in the field and the first group of weta associated with a box comprised two adult females plus one male under the box and one juvenile male in the box, were discovered after 4 months. A group of three adult female weta were discovered with one adult male weta after 13 months in the field. Prior to this, the refuge contained one male and two females for 5 months.

All three boxes placed in kanuka near the bottom of Hinewai Reserve were eventually used by *H. ricta*. One had a tree weta present from 15th January 1993 to 16th March 1994. In 50% of occasions the first weta to colonise a new artificial refuge was a juvenile male, on 21% of occasions adults or groups of adults and in 28% of cases juvenile females.

No weta were ever found in any of the boxes put in mixed hardwood forest. Eight of the 18 boxes hung in the kanuka canopy had weta in them at some stage and weta were found in 4 of the 5 boxes on the fenceline.

4.4 Discussion

H. ricta and *H. femorata* were found in a wide range of refuge types but both species preferred galleries. Tree weta did not appear to be limited by refuges because 2174 galleries, 603 splits, 1431 refuges under bark, 173 rotten areas of logs and 274 forks of branches were counted but only 146 contained weta. However, *H. ricta* may face a tree refuge shortage at altitudes above 500 m asl, and hence they occupy fallen log refuges and fenceposts instead. That does not necessarily imply that fallen logs and fenceposts form lower quality refuges than trees. In addition, at three sites on Banks Peninsula *H. ricta* were found under rocks and in rock crevices (see chapter three). No *H. femorata* were found in rock crevices and only two were located in logs on the ground. This seems to imply that *H. ricta* are highly adaptable and use refuges that are not the most preferred or perhaps do not offer as much concealment as a true gallery would.

Most weta galleries are initially formed by the Cerambycidae larvae, *Ochrocydus huttoni*

(P. Johns pers. comm.). Weta enlarge the existing tunnels and maintain clear entrances which was one of the identifying features of weta galleries. Other galleries that I searched were formed by branches falling off the trunk and leaving behind notched crevices. Large kanuka tend to have thicker bark than young kanuka and as this detaches from the trunk, refuges form under the bark. However, only juvenile weta were found under bark. It appears that juvenile weta can occupy a far greater range of refuges than adults and this may be because of their smaller size. Another possibility is that adult weta compete for the preferred galleries resulting in significantly more adult *H. ricta* occupying galleries and the juvenile weta occupy relatively more refuges under bark, in splits and in rotten wood. Adult weta presumably have a competitive advantage over juvenile weta for access to larger galleries. Moller (1985) describes vigorous disputes in *H. crassicuris* prior to dawn as weta fought for refuge space. In his study, however, gallery availability appeared to be a limiting resource. This may reflect how important these refuges are for protection against diurnal predators.

Galleries probably offer the greatest protection from predators such as birds, rodents and mustelids in contrast to open splits and under bark. It was remarkable how often *H. ricta* was found in exposed splits in fenceposts and logs that offered no concealment. Moller (1985) reported that *H. crassicuris* took refuge in very open sites on Stephens Island. They were found in hollowed out mahoe and he suggested that had rodents and mustelids been present the weta would have been more accessible to them. This may indicate the vulnerable nature of *H. ricta* to these predators, as 30% were found in refuges on the ground.

P. Johns (pers. comm.) reported that he found *H. ricta* in totara trees but I only ever found one under totara bark despite extensive searching. I found no galleries in totara, over the height range normally searched in other species of trees. However, it is possible that refuges are available high up in the branches of the canopy of these trees. Moller (1985) attempted to estimate the density of *H. crassicuris* on Stephens Island, but he suggested his estimate was limited by the possibility that weta lived high in the canopy and were never detected. Obviously my study is also limited because the

canopy of trees were not searched. However, Field (1994) suggests that most galleries that are excavated by the larval cerambycid, fall between the height range of 0-3 m, which was the general height range that I was able to search.

Large harems with multiple females were not found during this survey for either *H. ricta* or *H. femorata*. This contrasts with the numbers reported by Moller (1985) where a maximum of 9 *H. crassicuris* females were found, Sandlant (1981) with 9 *H. femorata* females and Field (1994) with 13 *H. femorata* females. The greatest number of females found with a male in my survey was three and this was under an artificial retreat. It is not known whether the density of *H. ricta* has an effect on the numbers in galleries. If the population of *H. ricta* only exists in low density, then the formation of large harems would be restricted. Little (1980) reported that *H. maori* was usually found individually under rocks but on some occasions he found pairs of adult weta. *H. ricta* and *H. maori* are similar in a number of traits (see chapter 2) and perhaps low numbers of weta in harems and low population density is another comparable feature of these two species. A density estimate of *H. ricta* was difficult to achieve because of the highly variable nature of their distribution. For example in some areas, up to 22 *H. ricta* were found in a 10 x 10m plot (see chapter 3), whereas in other plots in similar habitat and altitude no weta were located. A reliable estimate of the number of gallery inhabitants was also difficult because the sampling was non-destructive and it was often difficult to determine the total number of weta present.

Tree weta were frequently found with other invertebrates and on some occasions with skinks and geckos. Sandlant (1981) found that *H. femorata* commonly shared galleries with spiders, cave weta, cockroaches and native slugs but stated that they were never found with *Cambridgea* spiders. The large spiders *Cambridgea* and *Hexatheli* also never cohabitated artificial retreats with tree weta or any other invertebrates. Perhaps these large spiders' chelicerae are capable of penetrating the cuticle of weta. The spiders would therefore pose a threat to weta if they were in the same refuge. It is not known whether spiders can evict the weta from refuges or if weta avoid refuges with large

spiders.

Juvenile weta mainly used the boxes and were first to colonise them in 78% of occasions but adults were found in and under the refuges also. It is probable that juveniles, being highly dispersive (Ordish, 1992) are more likely to encounter these artificial retreats. Ordish (1992) states that juvenile *H. crassidens* were the first weta to colonise his artificial retreats, but adults eventually displaced them. On one occasion a juvenile male was displaced by an adult male and two females and in another instance a juvenile male weta was found in the same refuge with an adult female. Generally, however, juvenile weta continued to use the refuges without displacement. This may be because the refuges are not a limiting resource for this species in the areas they were placed. It may also be because *H. ricta* do not exist in a high density. Ordish (1992) found a maximum of 55 *H. crassidens* in ten artificial retreats in his study and census data on occupancy was instigated in 1988. It is not known, however, whether *H. crassidens* lives in highly dense populations or if the length of time he had the retreats exposed have a greater effect on the numbers he found in the retreats.

Chapter five

Field and captive behavioural activity patterns of *Hemideina ricta*.

5.1 Introduction

Little is known about the behaviour of *H. ricta*, and what is known is limited to studies in captivity. Field (1994) described mating and agonistic behaviour in *H. ricta* and investigated interspecific behaviour between *H. ricta* and *H. femorata*. He suggested that *H. ricta* appeared to display similar behavioural characteristics to other *Hemideina* species studied.

It is important to know if behaviour of captive animals is comparable to behaviour in their natural habitat because many conservation programmes are limited to captive rearing. Mahoenui weta (*Deinacrida* n.sp) showed increased levels of activity in captivity compared to natural field activity, and Richards (1994) concluded that this was most likely because the weta were not exposed to environmental conditions of frost, wind and rain. The objectives of this chapter were to study *H. ricta* in a natural environment and determine its major activity periods both seasonally and nightly, and how temperature influences their behaviour. A further objective of this study was to observe captive behaviour of *H. ricta* and compare this with their behaviour in the field.

Study sites

Site one

Study site one was adjacent to Hinewai Reserve at an altitude of 450 m. The area was within a farm paddock that was periodically stocked with sheep (*Ovis aries*). The site was of sloping topography and south-east aspect. Totara logs, low-growing vegetation and rocks were scattered throughout the paddock. Vegetation comprised totara (*Podocarpus totara*), kanuka (*Kunzea ericoides*), *Coprosma rotundifolia*, *C. rhamnoides*, *C. propinqua*, *Melicytus* sp, gorse (*Ulex europeaus*), pepperwood (*Pseudowintera colorata*), nettle (*Urtica ferox*), mahoe (*Melicytus ramiflorus*) and marbleleaf

(*Carpodetus serratus*).

Six groups of bushes (5 associated with logs) were visited regularly at intervals throughout the night. All areas were sites where *H. ricta* had been observed on bushes or within logs at some time throughout the sampling period.

Site two

Site two was located in Hinewai Reserve at a lower altitude of 40 m above sea level. It was situated on a valley floor with the valley running east-west. The vegetation at the site was predominantly kanuka with a canopy height of 3-4 m and an understorey of *C. rhamnoides*, nettle, *Calystegia* sp or bare litter. Fenceposts and roadside kanuka were included in the night searches at this site.

5.2 Methods

Light source

A variety of filters with half band width of 18 nm were placed over a visible light source and observations were made of how each affected weta behaviour. A red filter with wave length of 618 nm appeared to altered their behaviour least. The 618 nm filter was used for captive observations and red cellophane was used to cover torches for the longer observational periods in the field while normal torch light was used for initial searches of bushes. An infrared light source and night scope were also used for a period in the field but abandoned due to difficulty in detecting weta holes and viewing weta through the scope. This equipment was also cumbersome to move to, and around the study site.

Field observations

Nights were divided into two viewing sessions. During the first part of the night the hours from dusk until half way through the night were monitored. During the second night observations were made during the remaining hours until dawn. Weta were located during day searches and the locations were revisited at night to observe

behaviour. Initial searches of the study site were made early in the evening. If no weta were observed on the first occasion a repeated search was done at a later stage of the night. If no weta were observed at this stage, searching was abandoned for the night and no activity data were recorded.

Searches of the six areas within site one were conducted throughout the night at intervals of either 25 or 40 minutes depending on the length of darkness. Instantaneous scan inspections were made of all foliage, logs and ground around each of the six areas.

Categories of behaviour were formed from previous observations. Weta were categorised as either in their galleries (similar to the daytime position), in the entrances of their gallery, or on foliage of a particular species. If the weta were on foliage, the plant species was recorded along with the category of behaviour such as: stationary (perching), moving, eating or interacting (other) with other weta. The interacting category includes mating, moulting, as well as weta pursuing one another with no further outcome.

Weta were recorded as either male or female, adult, sub-adult or juvenile. A numbering system was also attempted, (see below). All other invertebrates that were found within these areas were also noted, and temperature and brief weather conditions were recorded for each night's observations.

Numbering of weta

When weta were discovered they were marked with a number to identify them for future observations. Silver pens "Pentel Paint Pen 0.5, Super Silver", were initially used but were inconvenient as pressure was required to initiate ink flow. Twink pens "Uni Correction Pen" were also used to number weta. The twink numbers wore off over a period of five nights and numbered weta then became difficult to identify, hence weta were re-numbered on many occasions.

Captive holding

Weta were permanently housed in perspex containers of approximately 0.3 x 0.3 x 0.4 m or 0.4 x 0.4 x 0.2 m dimensions. Water was provided from a vial with a cotton wick, plant food was available nightly, and dried, crushed dog biscuit was supplied periodically. Many pieces of wood and logs with drilled centres or natural channels were provided as refuges.

Weta were removed and placed in a larger cage (0.5 x 0.5 x 1.0 m) for investigations of interactive behaviour. Three walls of the cage were perspex and the back wall was wooden with a window of mesh. The floor of the cage was covered with river pebbles, a dish of soil was available for oviposition and logs were placed vertically for the weta to climb. Fresh vegetation and a water-filled vial with a cotton wick was also provided. Logs with natural channels were cut in two and held firmly against a wall of the perspex cage by leaning other logs against them. This made it possible to observe weta regularly within their galleries.

Regular inspections of the cage were done throughout the hours of darkness with either an infra-red light and night scope or a torch with a red filter of 618 nm.

5.3 Results

Observed field behaviour

Weta activity was difficult to observe in the tall canopy of trees at higher altitude (450 m asl). Twenty two observations of weta remaining in their galleries or entrances were recorded and only once was a weta discovered on kanuka trunks in the tall canopy within the reserve.

In total 155.5 hours were spent searching for and recording *H. ricta* behaviour. More hours were spent at site one where all bushes except one *C. rotundifolia* and one *C. serratus* were below 2 m and accessible.

H. ricta were found to emerge on average 2 hours and 24 minutes (S.E. 3.36 min, n=24)

after official sunset (Christchurch standard time), and could be observed at any instance throughout the hours of darkness. The weta returned to galleries on average 53 minutes (S.E. 6 min, n=10) before sunrise. More weta were observed during the second quarter of the night, however, this is affected by the time of darkness. It should be noted that even though the sun officially set at 20.14 hours in mid January in Christchurch, the sky remained light until at least 22.00 hours and this therefore influenced the time of emergence.

Activity of weta

Over the month of January 1994, 29 *H. ricta* were marked at logs and bushes within site one. Twelve of these weta were within one log and group of bushes. On 51 occasions these marked weta were relocated on the same group of bushes they were originally caught on, and on 5 occasions weta were found in different areas ranging in distance from 2 m to 15.5 m. It was difficult to assess movement for lengths greater than this time because the markings wore off and the weta became un-identifiable.

Weta were mainly recorded in their galleries or not moving on the foliage (Table 5.1). More male weta than female weta were seen out on bushes but the difference was not significant ($X^2 = 0.21$, $df=2$, $P>0.05$).

Weta activity increased significantly with increasing temperature (Fig. 5.1) ($r=0.751$, $P<0.001$). There was no difference in the number of males or females active at different temperatures (Fig. 5.2). The lowest temperature weta were discovered out on foliage was 2.0° C, and two weta were perching. The highest temperature recorded during observations was 22.2° C and 14 weta were counted. Weta spent more time perching on foliage and less time in galleries as the temperature increased and the total variety of activity increased with increasing temperature (Fig. 5.3).

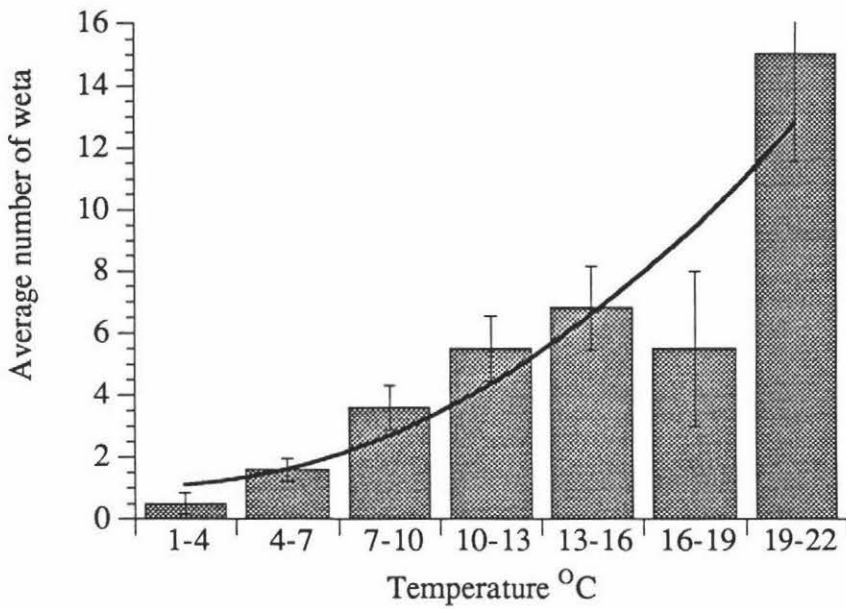


Fig. 5.1 The average number of weta found out of refuges, on bushes at site one at varying temperature. Equation of line = $0.54 * x^{1.6}$, $R=0.90$.

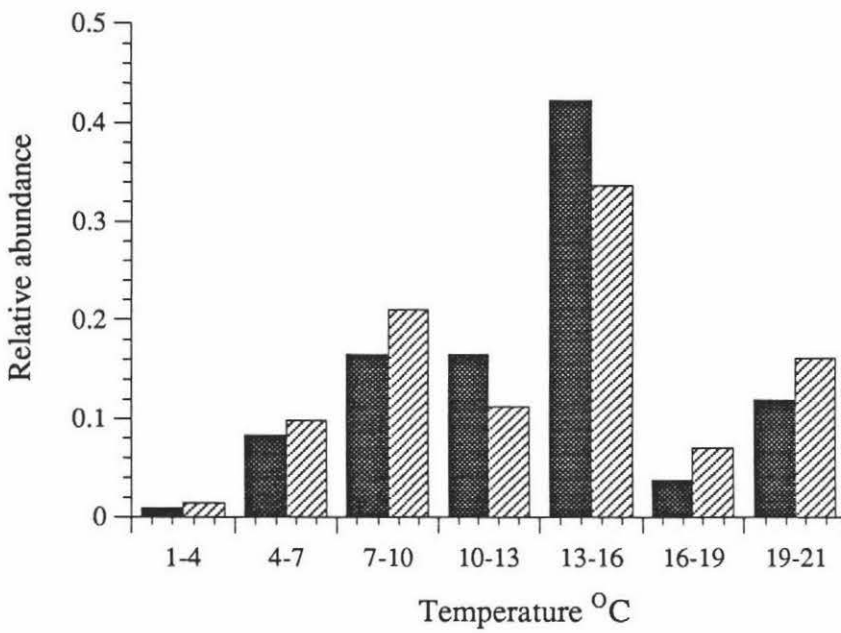


Fig. 5.2 The relative abundance of male and female *H. ricta* active on bushes at varying temperature over the months sampled. Hatched bars = male and shaded bars = female weta.

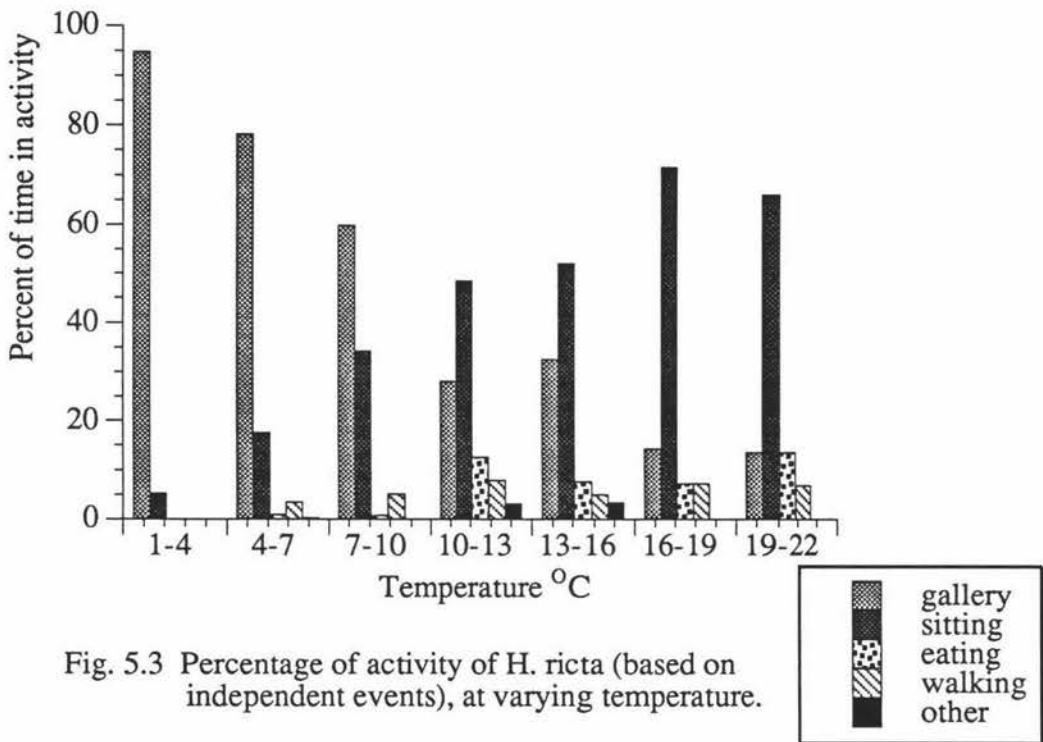


Fig. 5.3 Percentage of activity of *H. ricta* (based on independent events), at varying temperature.

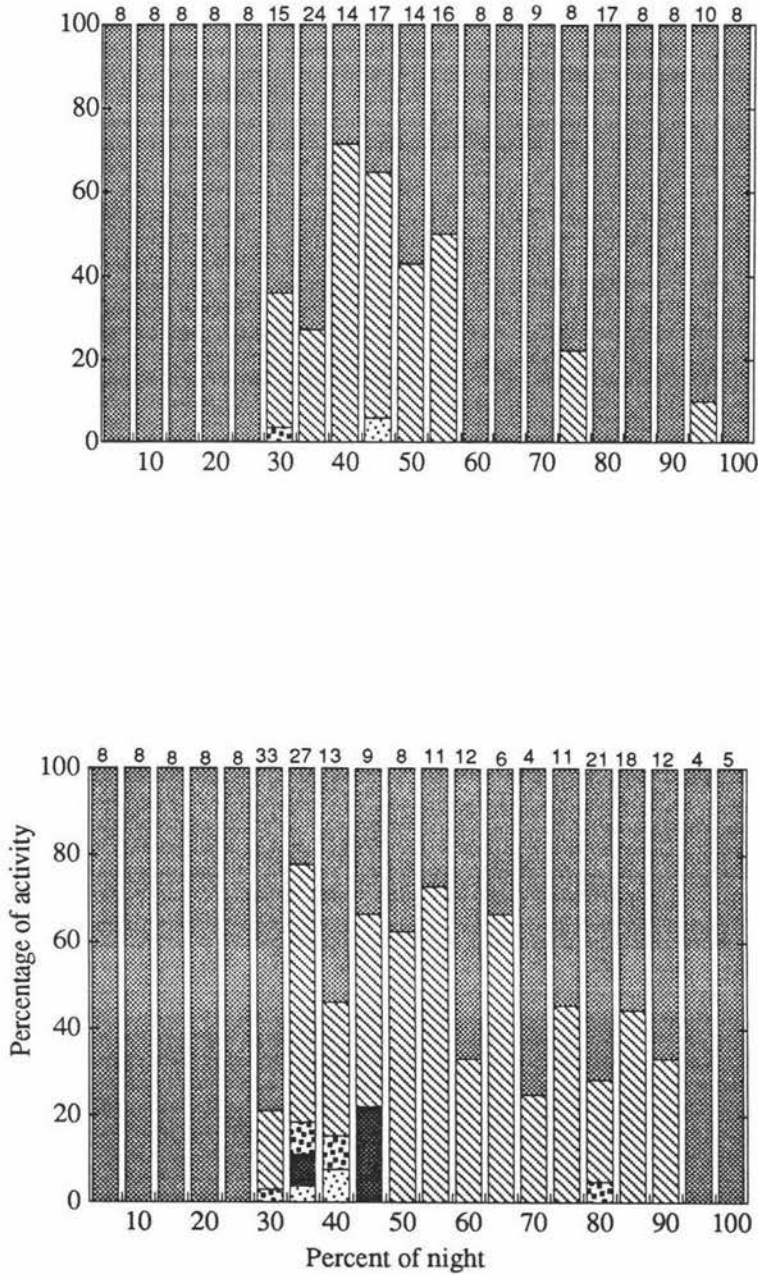


Fig. 5.4 (a) Percentage of night spent in each activity (see key), for the months of November (Above) and December (below). (n values shown above the bars).

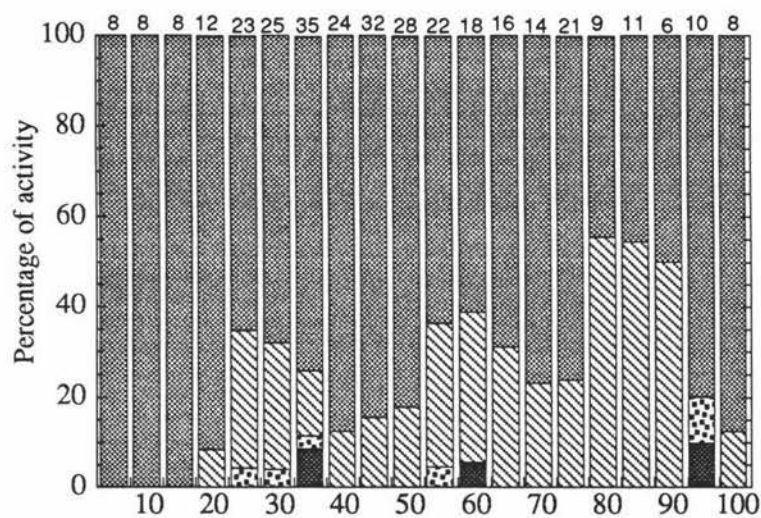
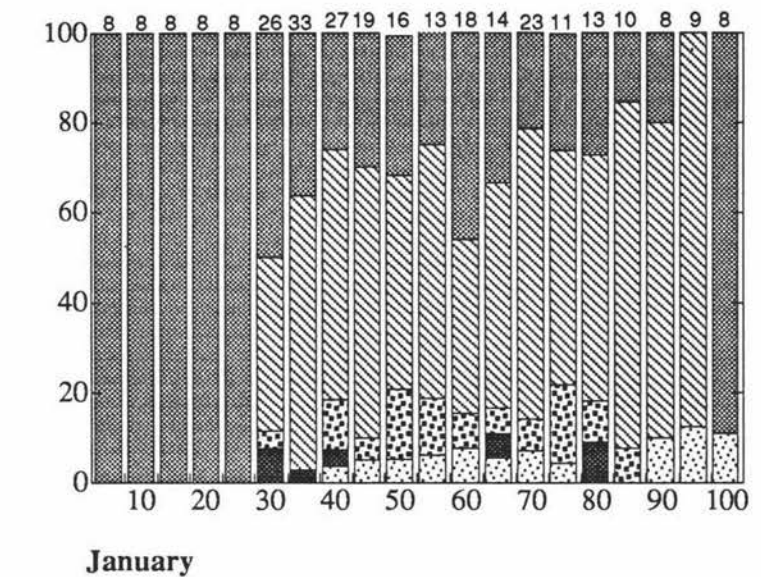


Fig. 5.4 (b) Percentage of night in each activity (see key), for the months of January (above) and March (below). (n values shown above the bars)

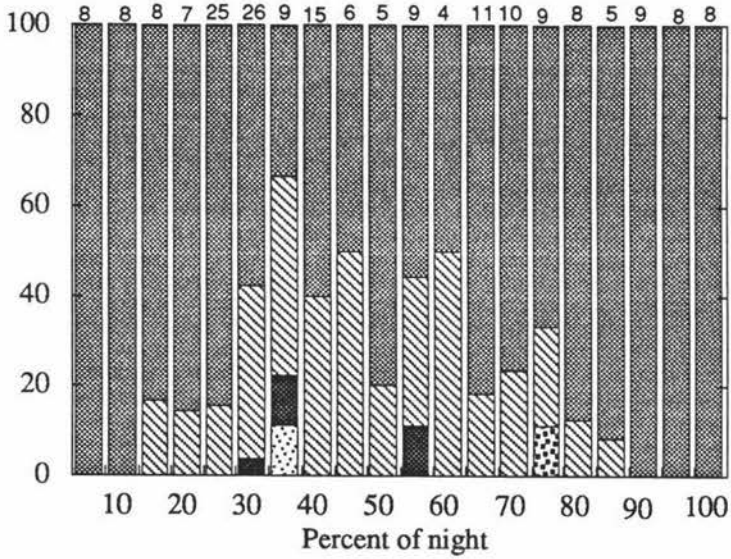
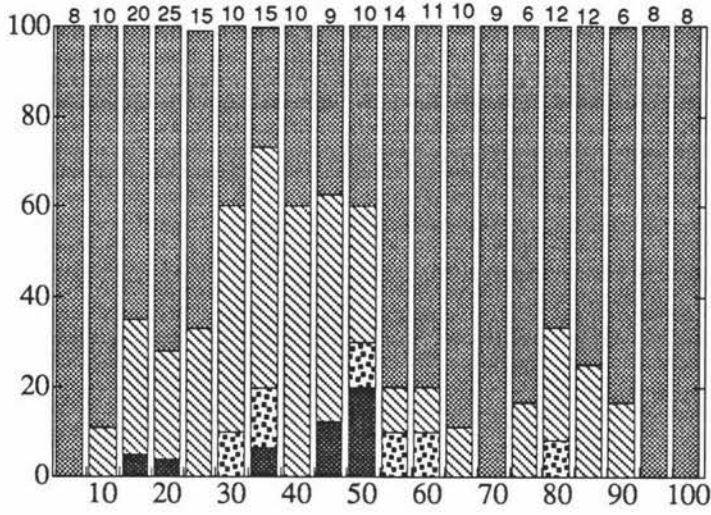


Fig. 5.4 c. Percentage of night spent in each activity (see key), for the months of April (above) and May (below). (n values shown above the bars).

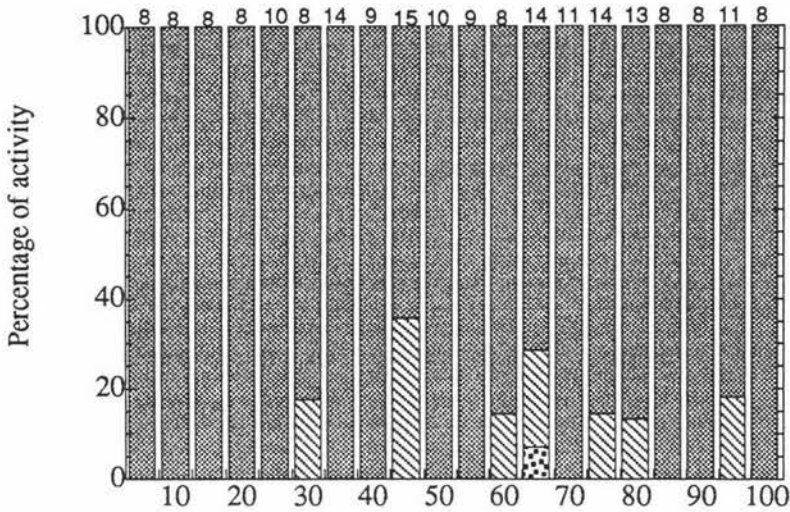


Fig. 5.4 (d) Percentage of night spent in each activity (see key), for the month of August. (n values shown above the bars).

Key

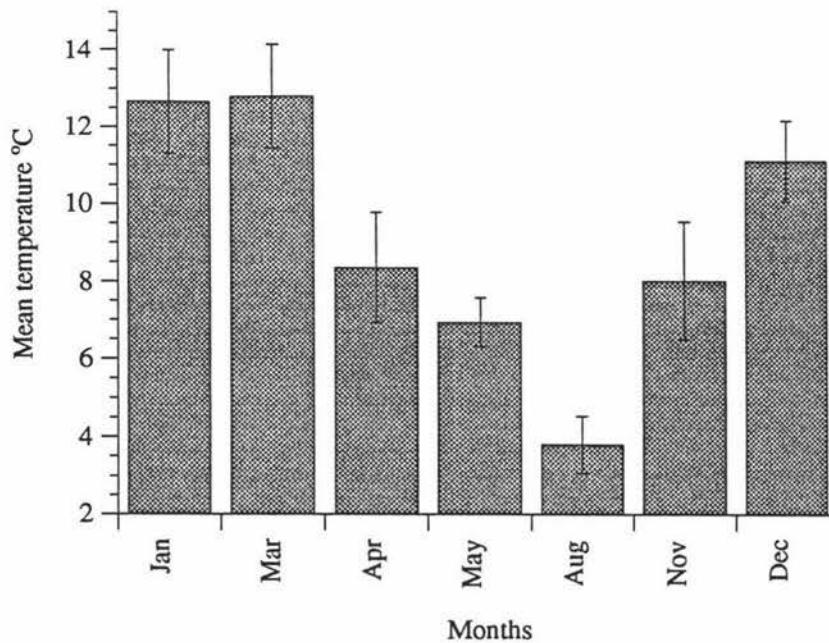
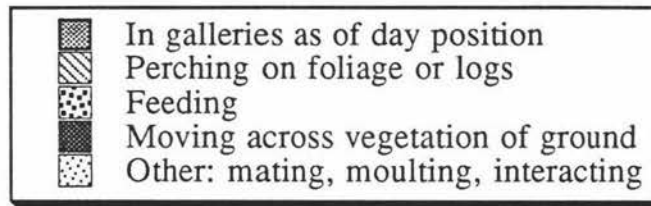


Fig. 5.5 The mean (and standard error) of monthly temperature, recorded during sampling observations.

The seasonal activity of *H. ricta* varied during the seven months sampled (Figures 5.4 a-d) (key on page 77). This was obviously affected by seasonal temperature fluctuations which ranged from 22.2 to 1.1^o C (maximum/minimum) during the total hours of observation (Fig 5.5). Weta were predominantly found in their galleries during the month of August, and were less active than in the months of December and January.

The behaviour of *H. ricta* varied significantly in captivity compared to field observations ($X^2= 54.93$, $df= 4$, $p<0.001$) (G test, captive $p<0.001$, field $0.001<p<0.005$). (Table 5.1).

Table 5.1. Field observations at Hinewai Reserve and captive observations (Palmerston North) of *H. ricta* activity. The category of "other" includes mating, fighting, pursuing without further outcome and ovipositing.

Activity	No. Observed Field	%	No. Observed Captive	%
In galleries	n= 225	44.9	n= 38	22.5
Perching	n= 216	43.1	n= 85	50.3
Moving	n= 26	5.2	n= 22	13.0
Feeding	n= 28	5.6	n= 8	4.7
Other	n= 6	1.2	n= 16	9.5

Mating

Only one pair was observed throughout the entire field observations of *H. ricta* and these copulated three times (see Plate 5.1). At site one, an isolated clump of *C. rhamnoides* was found that contained one adult male and female. Both were removed and measured then replaced back in their original positions on the bush. Fifty five minutes later the weta were perching very close and the male was waving his antennae over the female's body in pre-copulatory behaviour. The female remained stationary while the male bent his abdomen into a 'c' shape and directed it toward her abdomen. The male took on a position underneath and slightly angled away from the female, then bent his abdomen toward the female's sub-genital plate. During the next copulation the male was at an angle of approximately 90^o to the female, and this eventuated into an end-to-end position. The copulations lasted up to two minutes and no spermatophore was observed on the female when they separated.

On another occasion a male weta was heard stridulating several echemes (syllables) (Field and Rind, 1992) of sound. He was found in the entrance of his gallery which was adjacent to a gallery occupied by a female weta. In the succeeding half hour the male entered the female's gallery and continued with the stridulatory calling. It was not possible to observe the weta as the male blocked the entrance of the gallery.

Defence Behaviour

Weta defended themselves in a number of ways. Passive defence was from a number of spines on the tibia which protected them and made extraction from galleries very difficult.

Active defence involved a threat posture with hind legs held forward above the abdomen, the legs were drawn downward and the weta stridulated. Another posture was adopted when the weta was extremely agitated and involved the weta standing erect with jaws gaping and front legs held out in a horizontal position. The weta stridulated in this position also. Sometimes the weta regurgitated a brown smelly liquid from their mouths while being handled. *H. ricta* also adopted an inverted defence posture and fell to the ground and lay on its back with jaws gaping and legs splayed.

The residency of galleries and dispersal

Juvenile weta occupying galleries were prone to being displaced by mature weta and the common gecko, *Hoplodactylus maculatus*. Adult weta seemed to coexist readily with the common gecko. Two adjacent galleries in a log at site 1 were initially home to a pair of adult male and female *H. ricta*. 5 days later two adult males occupied the galleries. Subsequently, after 3 days an adult male and a juvenile male weta occupied them. However, after this adult male was removed from the tree for measurement and then returned to the gallery he had occupied, he displaced the juvenile male in the adjacent gallery. These observations may be heavily biased by my continued use of light at the galleries.

Some weta occupied the same galleries for long periods of time. One male sub-adult was in a fencepost at site 2 from January 1993 until February 1994 and during this time



Plate 5.1 Isolated clump of *C. rhamnoides*, containing adult male and female *H. ricta* at site one. The weta were observed in these mating positions, (a) female above, and (b) male twisted at an angle to the female with this position eventuating to an end-to-end position.

he moulted into an adult. Three juvenile male weta occupied the same individual galleries in a fencepost at site 1 for at least 8 months.

An attempt was made to estimate the distances weta moved throughout the night by relocating the marked weta. However, as these markings wore off continually it was difficult to assess where individuals were moving to, and whether they were the same weta. Most marked weta stayed on the group of bushes they were originally caught on, but two marked weta were found to have moved to nearby bushes 2.5 m away (across pasture). One other weta was recorded on a bush 15 m away from the original site of capture and after a two week interval.

Feeding observations

When weta were observed feeding in the field, they ate a range of plants but mostly (11 observations) *Coprosma rhamnoides*. Other plants that weta were seen eating were *C. propinqua* (6 observations), *C. rotundifolia* (4 observations), *Melicytus* sp (3 observations), and one observation of *Calystegia* sp and kanuka. They were not observed feeding at site 2 or within the reserve because of the tall canopy.

Captive behaviour

Observations were made on two pairs of adult male and female weta, two adult females, and single adult and juvenile male and female weta. Twice an adult male ate a female and once a juvenile female was eaten by an adult female. These weta were collected as pairs or found in the same area of log in the field. Further observations were therefore done using only one or two weta in the cage at a time and pairs were maintained only during observations.

Captive weta demonstrated increased moving, perching and interactive behaviour compared to field weta. Mating, grooming, fighting and oviposition were observed in captivity and only very rarely or never seen in the field.

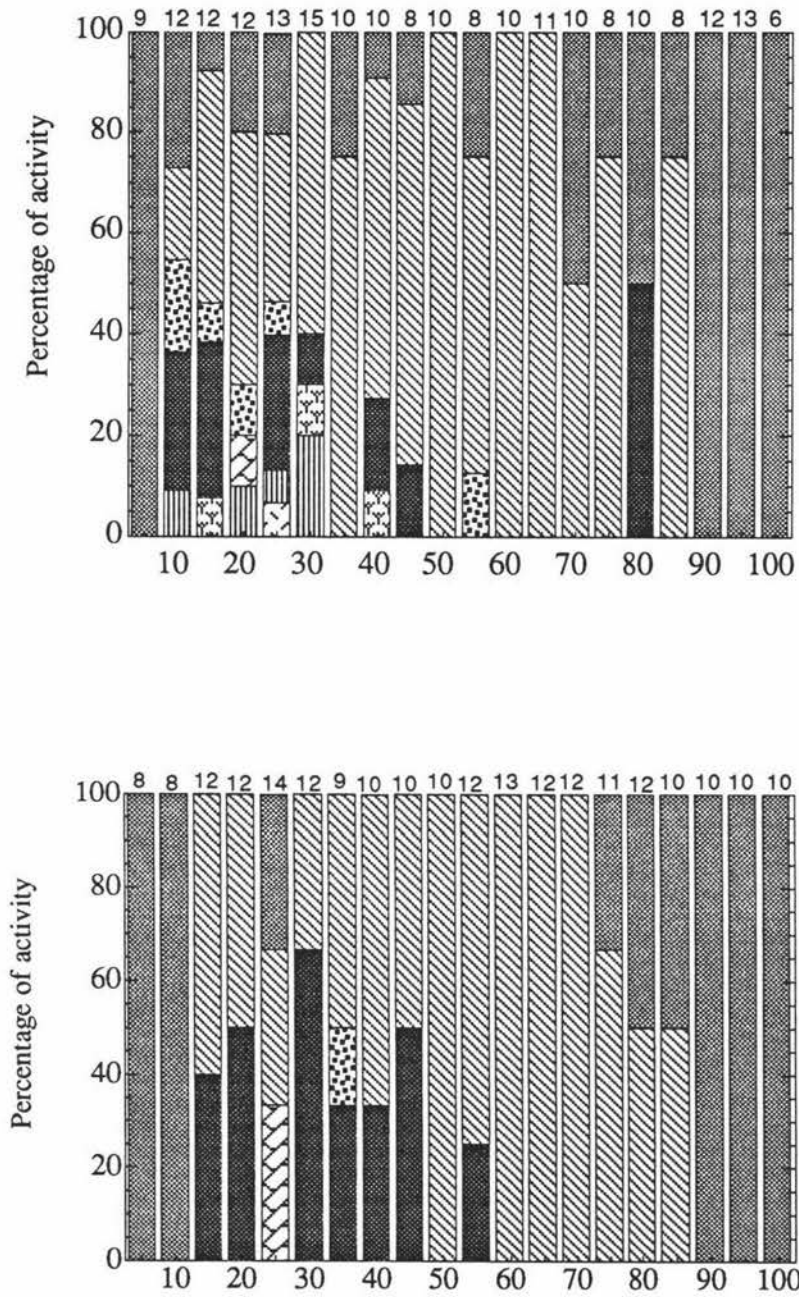


Fig. 5.6 (a) Percentage of night spent in each activity (see key) in captivity, for the months of April (above) and May (below). (n values are shown above bars).

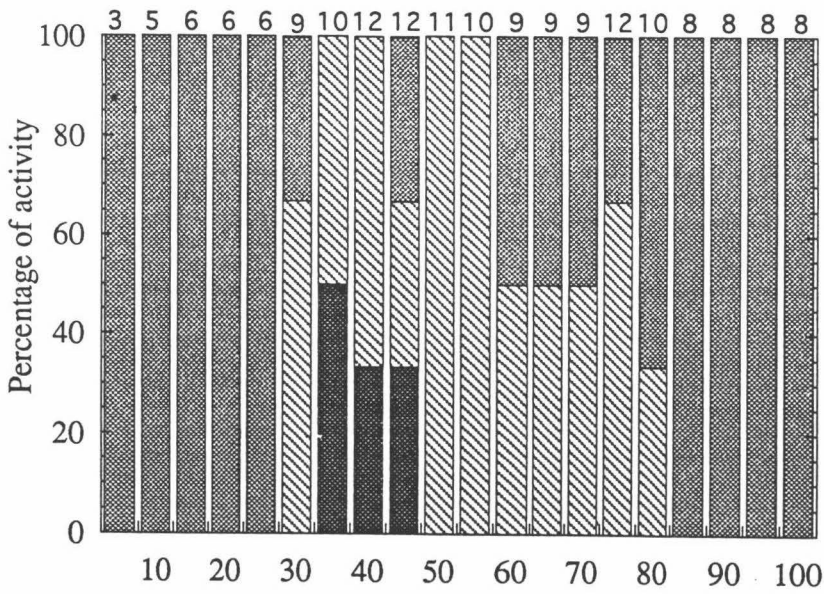
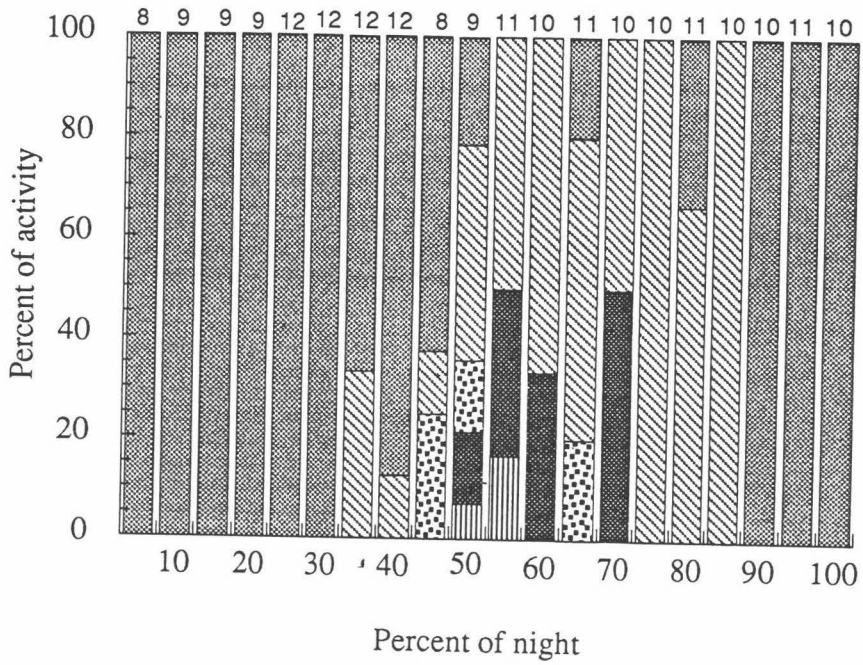
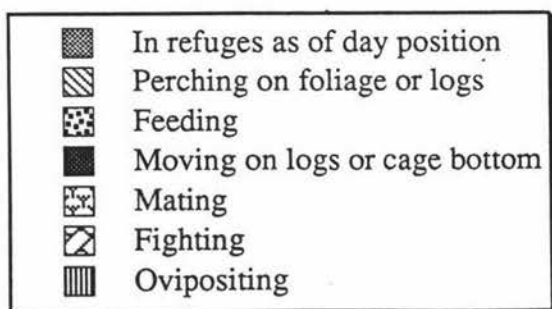
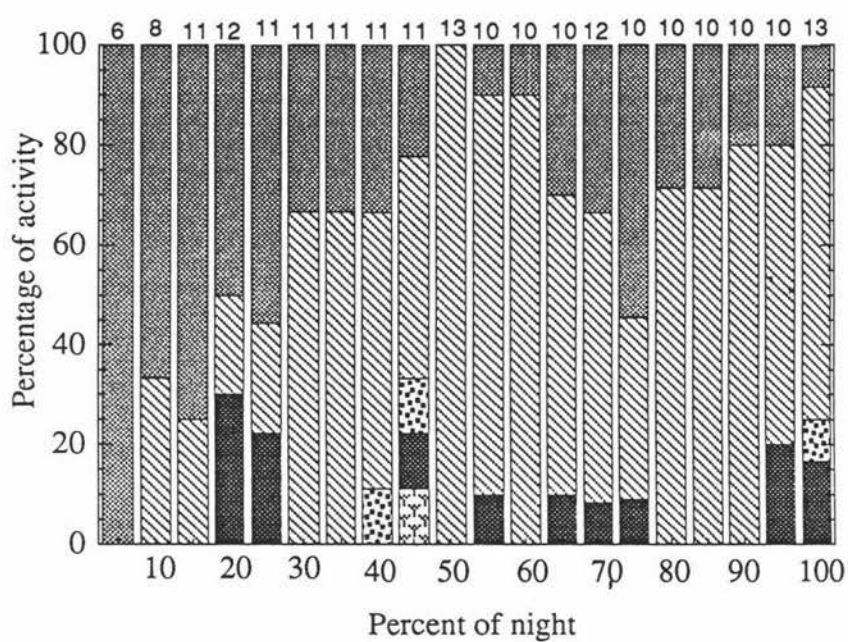


Fig. 5.6 (b) Percentage of night spent in each activity (see key), in captivity, for the months of June (above) and July (below). (n values are shown above bars).

Fig. 5.6 (c) Percentage of night spent in each activity (see key), in captivity, for the month of November. (n values shown above the bars)



Captive weta showed a decline in activity in the months of June and July when compared with April, May and November (Fig. 5.6 a-c) (key on page 84). No observations were done in August because of field work. The cages were viewed indoors where the temperature fluctuated from 8° C to 16° C.

Captive fighting

When two adult females or male and female juvenile weta were in the cage together they either moved about the cage, perching in separate areas of the cage "ignoring each other" or were seen to fight each other. They bit and kicked out at each other with their hind legs until one retreated. Juvenile weta fought viscosly, biting legs and kicking at one another until I separated them for fear that they would damage each other.

Captive oviposition

When females oviposited, they spent a lot of time testing the soil in the punnet, removing their ovipositor and re-inserting it before eventually pausing for up to 2 minutes at a time. The female's abdomen pulsed while the ovipositor was inserted in the soil, presumably ovipositing the eggs over 2 minutes.

Five adult female *H. ricta* were observed ovipositing although none of the eggs have hatched yet (Table 5.2). Four of the five weta laid on average 16.5 eggs but one female laid 53 eggs. The body weight of the female weta did not have any effect on the number of eggs laid or the weight of the eggs (Fig. 5.7).

Mating

In captivity two separate adult male weta were observed mating with females and their behaviour varied considerably. One spent a lot of time pursuing a female and attempting copulation, while the other mated and spent a lot of time perching very close to the female who sat passively. The female responded to the persistent male by retreating or kicking at him with her hind legs but the attempted copulations were successful.

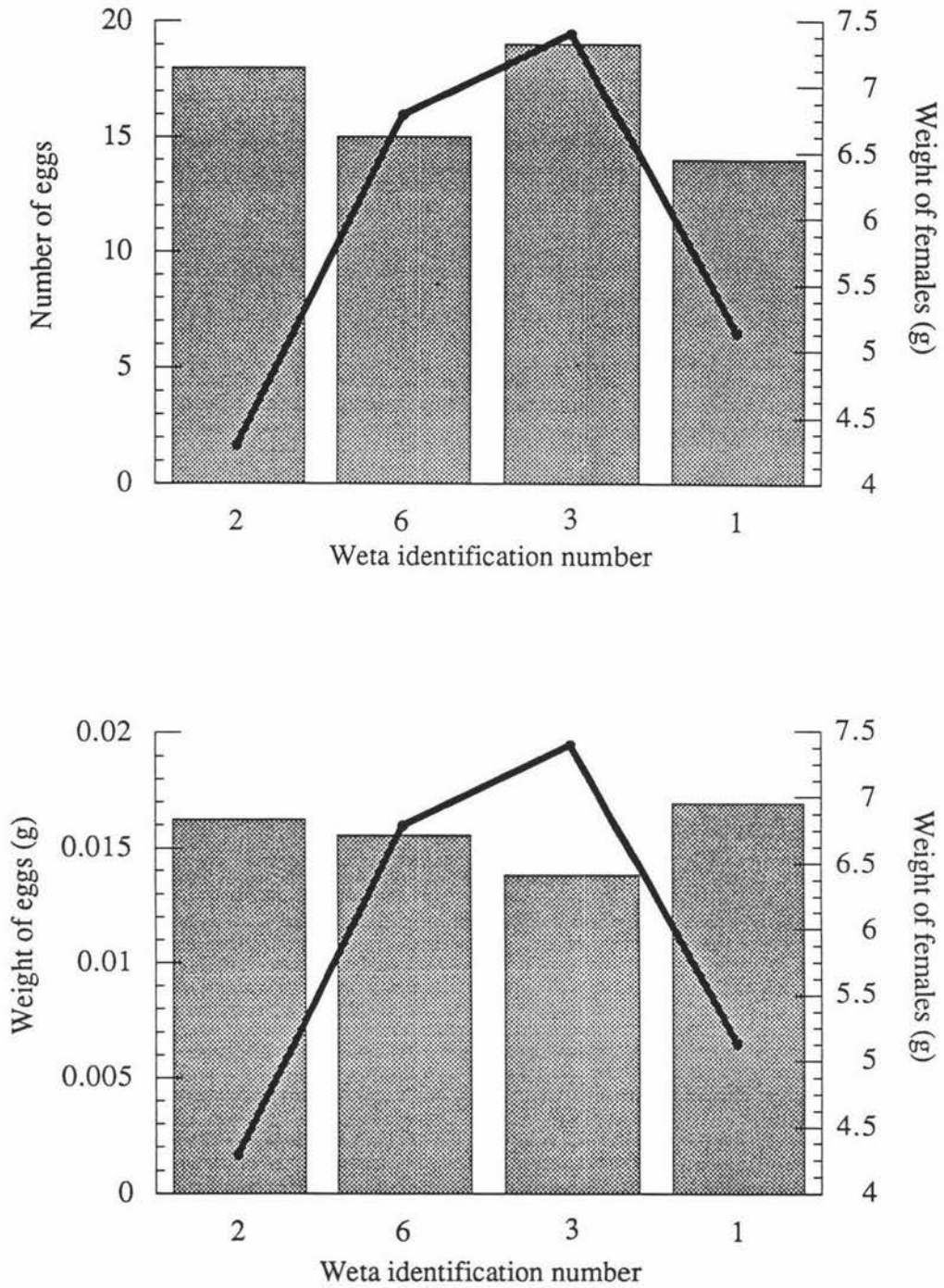


Fig. 5.7 (above) A comparison of the number of eggs laid by each female and the weight of each female *H. ricta*. (below) A comparison of egg weight and female body weight.

Table 5.2 Egg weights, lengths and number oviposited by 5 female *H. ricta* in autumn 1993.

Weta Identification number	Female wt before laying (g)	Total eggs	Average weight (g)	Maximum and minimum (wt)	Average length (mm)	Period eggs were laid over	Number laid per interval
1	5.13	14	0.01690	(0.0188) (0.0161)	6.33	30.3.93 - 26.4.93	7,7
2	4.29	18	0.01624	(0.0164) (0.0161)	5.5	3.3.93	18
3	7.40	19	0.01820	(0.0206) (0.0148)	6.02	26.3.93 - 29.3.93	7,6,2#,4
3a	5.86	53	?*	?*	?*	2.4.93 - 20.4.93	53#
6	6.79	15	0.01555	(0.0161) (0.0144)	5.85	11.3.93 - 23.3.93	5,3,7#

Eggs oviposited over a period of 20 days, absence due to field work.

* Eggs disturbed by minimal amount incase disturbance inhibited eclosion.

Males waved their antenna over the female and bent their abdomen into a 'C' shape in pre-copulatory behaviour. During this time the male tried to find the female's genitalia by applying his to the abdomen of the female. The copulatory positions observed in captivity were female on top with the male angled slightly away from the female, and end-to-end copulations. The average length of copulation in captivity was 2 min 14 sec. (n=9 full copulations observed, range 1 min-4 min). No spermatophore was ever observed after copulation but once a female appeared to be eating a spermatophore as she was seen with her head curled under her abdomen towards her genitalia and her mandibles were moving.

Usually the male initiated a copulation by perching close to the a female and applying his antenna to her body. Once, however, a female was seen to initiate copulation by advancing toward a male, the male then directed his abdomen to the females genitalia and copulation proceeded. Copulation ended by the female retreating.

5.4 Discussion

Clear behavioural differences existed between *H. ricta* in the field and in captivity. In captivity weta emerged early and spent long durations perching on logs or foliage. When pairs of weta were in the cage together, perching and feeding were interrupted by periods of fighting or mating depending on the age and sex of the weta. It is difficult to infer whether the differences between captive and field observations are typical of insects in these two situations. As weta were never seen fighting during field observations, presumably, the confined space in the captive environment caused this. Therefore, if weta are to be kept in cages together, I recommend large cages with numerous logs and refuges where individuals can retreat to. In field observations, weta were often seen perching within distances of 10 to 50 cm of each other with no further interaction occurring.

P. Barrett (pers. comm.) suggested weta used pheromones to orient themselves in their surroundings and find their way back to their galleries and Ordish (1992) suggested that

weta guide themselves by pheromones in their faeces. Perhaps in a new environment the weta allocate time dispersing new pheromone trails throughout the cage, and hence increase their activity. Richards (1994) suggests that in captivity, weta experience temperatures that are warmer than ambient and this may increase their activity. In addition, there is no effect from frost or wind. These diminished environmental factors may lead to heightened activity in captivity.

In the field, insects are strongly influenced by climatic factors both seasonally and diurnally. *H. ricta* was less active during the cooler months of May and August than during December - March. Ordish (1992) reported that male *H. crassidens* would tolerate other males in their galleries during the cooler months for extra insulation and also because they are too lethargic to evict them. Roberts (1978) describes torpor as being typically induced by short periods of adverse weather. This occurred during the summer and autumn months when cool southerly conditions prevailed and resulted in reduced activity of *H. ricta*. Throughout the cooler winter months their activity could be described as quiescent. Quiescence is directly induced or terminated by surrounding environmental conditions (Roberts, 1978). *H. ricta* therefore showed quiescent activity patterns with their nightly activity correlated with environmental temperature. Ramsay (1978), however, describes Stenopelmatidae and Rhabdiphoridae as seasonal because they lay eggs in summer and autumn, which hatch the following spring. The Stenopelmatidae have overlapping generations and hence juvenile and adult weta can be found at any time of the year which means that they can overwinter in a less active state.

Field (1993) investigated captive behaviour of *H. ricta* in relation to their stridulatory behaviour. He described preliminary mating behaviour of males which used their mandibular and maxillary palps to antennate the female's bodies. I observed this behaviour in captive *H. ricta* but not in the field. Field (1993) described the only mating stridulatory behaviour as being produced by the male when a female rejected his copulatory attempts. In my captive weta, I heard no stridulating when the female kicked at the persistent male. Only once was an adult male *H. ricta* heard stridulating in the

field. This was most likely a mating stridulation as the male was seen entering a female's gallery. No further observations could be made however, because the male blocked the entrance. Field (1993) also experimented with male *H. ricta* and female *H. femorata* to determine whether they would mate. No copulation was observed but initial attempts with males antennating the female were made and one male formed the 'C' shaped abdomen. I found two hybrids of *H. ricta* and *H. femorata* behind Akaroa (Morgan-Richards and Townsend, in prep) so interspecific copulation between these two species does occur to a limited degree.

Richards (1973) describes the following four mating positions in *Deinacrida heteracantha* and *D. fallai*: male and female angled at 45° to 90° to each other; male on female with abdomen curled under to meet females genitalia; end-to-end; and on their sides. Three mating positions were observed in *H. ricta*. One was the male angled slightly away from the female with his abdomen curled to meet the females genitalia, with his legs holding the females body. The second was the female above the male with the males abdomen curved upwards. Thirdly, after an initial side on position an end-to-end position was acquired. No observations were made of male weta extracting females by their tibia from galleries as all matings were either on bushes in the field or on logs in captivity. Field and Sandlant (1983) describe most *H. femorata* copulations as occurring at the gallery entrance and if a male finds a female in a gallery, extraction is necessary as it is impossible to mate within the confines of the gallery. They suggested male *H. femorata* usually remained in the gallery with the female. In captivity one *H. ricta* adult pair perched together for at least five hours after copulation. Field and Sandlant (1983) proposed that defence of galleries against other males was a post-copulatory guarding technique. The male strategy of mating then perching close by the female for long durations could perhaps be considered as post-copulatory guarding by the male. Likewise the attempts of a captive *H. ricta* male to continually mate with the female could be considered as the male making sure he was the last male to mate with her prior to oviposition.

One suggestion for the dispersal of insects occurs in the juvenile instars as a mechanism

to prevent predation and cannibalism. Southwood (1962) discusses dispersal behaviour in spiders and other insects and suggests it is desirable for young spiders to disperse from the egg mass. However, he only discusses the migration of Acrididae in relation to food requirements. The Western Horselubber grasshopper (*Taeniopoda eques*) emerges from the egg pod and stays with conspecific hatchlings until dispersal at the first moult. Cannibalism was noted as one of the reasons for the dispersal at first instar (Whitman and Orsak, 1985). No information was obtained on the dispersal stages of *H. ricta*, and only limited data were gained of marked weta moving distances of between 2.5 and 15 m over a month sampling period. Generally the weta were found on the same group of bushes they were originally located on. Weta dispersal distances were unobtainable due to the identification markings wearing off on some weta, over a period of a week. In addition, marked juvenile nymphs would be difficult to track as the numbers would be lost with the exuviae. Radio tracking the weta's movement would also have been difficult because *Hemideina* species exhibit thigmotaxis (which means they like contact) (Field, pers. comm). This means they force themselves into tight spaces where a transmitter may be lost or destroyed or the weta may become trapped within a refuge. In addition, weta wore numbers off from abrasion against the gallery. I suggest small bird leg bands in colour combinations would be more suitable for the permanent marking of adult weta. Perhaps marking juvenile weta on the tibia would have less abrasion than the body against the gallery. Moller (1985) investigated weta movement with capture re-capture experiments of *H. crassicuris* on Stephens Island. He discovered that there was no difference between male and female movement. One male weta moved a distance of 11.6 m and he suggested that these weta were adverse to moving across the ground. *H. ricta* are found frequently in channels of logs on the ground (see chapter three). They were seen on nine occasions moving or perching on or close to the ground which must increase the likelihood of predation. Moller (1985) reported only 3 of the pellets from tuatara faeces contained weta remains but suggested that predation from rats, stoats, cats and hedgehogs may have more influence on their behaviour.

Chapter six

Comparative feeding preferences of *Hemideina ricta* and *H. femorata* in captivity.

6.1 Introduction

Hemideina weta are polyphagous, eating a wide variety of different plants (Barrett, 1991). They are also omnivorous as native bee, beetle larvae and dipteran fragments as well as plant material have been found in *H. femorata* and *H. maori* faeces (Little, 1980). Barrett (1991) suggests that weta be regularly supplied with a variety of insects along with their fresh plant matter. He also suggests that some *Hemideina* species for example, *H. maori* are more carnivorous than others.

One aspect of interest is whether different species of tree weta prefer different plants. In this chapter I investigate whether *H. ricta* and *H. femorata* would compete for the same food resources, given a situation of limited food supply.

6.2 Methods

Initially weta were provided with the following selection of plants: kanuka (*Kunzea ericoides*); totara (*Podocarpus totara*); gorse (*Ulex europeus*); broadleaf (*Griselinia littoralis*); seven finger (*Schefflera digitata*); *Parsonsia heterophylla*; titoki (*Alectryon excelsus*); *Coprosma robusta*; lemonwood, *Pittosporum eugenioides*; mahoe (*Melicactus ramiflorus*); five finger (*Pseudopanax arboreus*); *Hebe* sp; gum (*Eucalyptus* sp); peach; pepperwood (*Pseudowintera colorata*); kawakawa (*Micropiper excelsum*); nettle (*Urtica ferox*); dandelion (*Taraxacum officinale*); dock (*Rumex obtusifolius*); sowthistle (*Sonchus oleraceus*); and clover (*Trifolium repens*). Some plants were eaten in large amounts with much of the leaf area consumed, whereas others were only nibbled at or rejected completely. A lot of the sowthistle and dandelion were eaten also, but this appeared to give the weta scours when consumed in large amounts.

The plants finally selected for the food choice comparison between *H. ricta* and *H. femorata* were all found in mixed broadleaved hardwood forests, and were typical of the vegetation encountered as understorey plants in the survey and comprised: *C. robusta*, Mahoe, lemonwood, five finger and *P. heterophylla*.

The feeding experiment was conducted in a constant temperature room at 18^o C and under a 12 hour light/dark cycle. Weta were housed in perspex cages of approximately 0.3 x 0.3 x 0.4 m or 0.4 x 0.4 x 0.25 m volume. Equal numbers of adults and juveniles, and male and female *H. femorata* were used. However, only 2 male and 4 female *H. ricta* were available for this trial.

Each cage contained logs and refuges and the weta were provided with a vial of water with a cotton wick and were periodically supplied with crushed dog biscuits. All existing plant material was removed from the cages during the food preference trial. The experimental design consisted of a latin square matrix of 6 weta (2 replicates), 3 nights of feeding and three different plants being tested per trial. All combinations of the five selected plants resulted in 10 separate trials. On any given night each weta had a choice of two possible plants and these combinations were changed over the three nights of the trial.

		Weta		
		1 and 2	3 and 4	5 and 6
Night	1	<i>Coprosma/Parsonsia</i>	<i>Coprosma/mahoe</i>	<i>Parsonsia/mahoe</i>
	2	<i>Coprosma/mahoe</i>	<i>Parsonsia/mahoe</i>	<i>Coprosma/Parsonsia</i>
	3	<i>Parsonsia/mahoe</i>	<i>Coprosma/Parsonsia</i>	<i>Coprosma/mahoe</i>

An effort was made to supply the weta with approximately the same amount of leaves for each trial but no information was obtained on whether these plants were nutritionally equivalent. All weta were treated to the same conditions prior to the set of experiments and given the same selection of foods.

To assess the amount of plant material eaten the leaves were photocopied prior to being

given to the weta. The stems were inserted into vials containing water, through drilled holes in the lids, to prevent dehydration. After a night's experiment the plants were removed and the areas eaten were drawn around on the photocopy, to estimate the surface area consumed. The area eaten was then cut out, weighed and converted to cm^2 by comparing it with a cm^2 of paper. Leaf weight consumed was calculated by weighing a square cm of each species of leaf, then multiplying it by the total cm^2 eaten from the cut out area of photocopied leaf.

Statistical analysis consisted of analysis of variance.

6.3 Results

It was difficult to assess the amount (weight) of gorse and kanuka eaten because the leaves were very small and the controls lost more water overnight than the trial samples. No gorse leaves or prickles were eaten, but the calix and petals of the flower were readily consumed. Only very small amounts of kanuka were eaten but no quantitative values exist. No feeding was recorded for the following: Gum; nettle; titoki; totara; and *H. ricta* only ate slight amounts of *Hebe*, kawakawa, pepperwood, dock, clover and peach. Dandelion and puha were consumed readily but seemed to be too rich.

In captivity weta ate a range of ground dwelling plants and they were seen on the ground on nine occasions during night field observations but were not seen feeding.

H. ricta and *H. femorata* showed the following preferences from the five plant choice test: *Parsonsia heterophylla* > *Coprosma robusta* > *Pittosporum eugenioides* > *Melicytus ramiflorus* = *Pseudopanax arboreus* (Table 6.1). Adult *H. ricta* ate more plant matter than juvenile weta, but adult and juvenile *H. femorata* consumed approximately the same total amount (Fig. 6.1). There was no significant difference in the amount of plant eaten between males and females of either species, but *H. ricta* females ate more *Parsonsia* than males. (Fig. 6.2). Adult *H. ricta* consumed more *Parsonsia* and *Coprosma* than

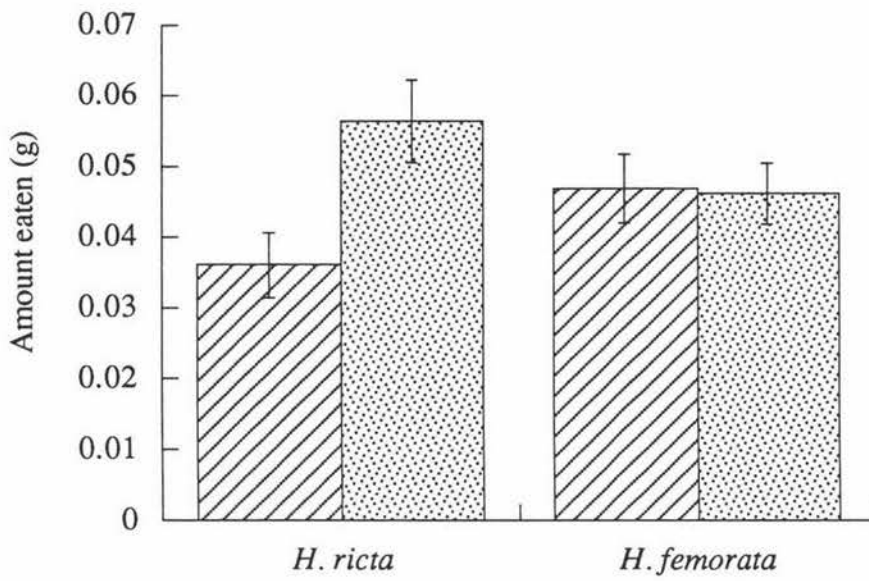


Fig. 6.1 The amount (and standard error) of all plants consumed in the trial by adult (shaded bars) and juvenile (hatched bars) weta of both species.

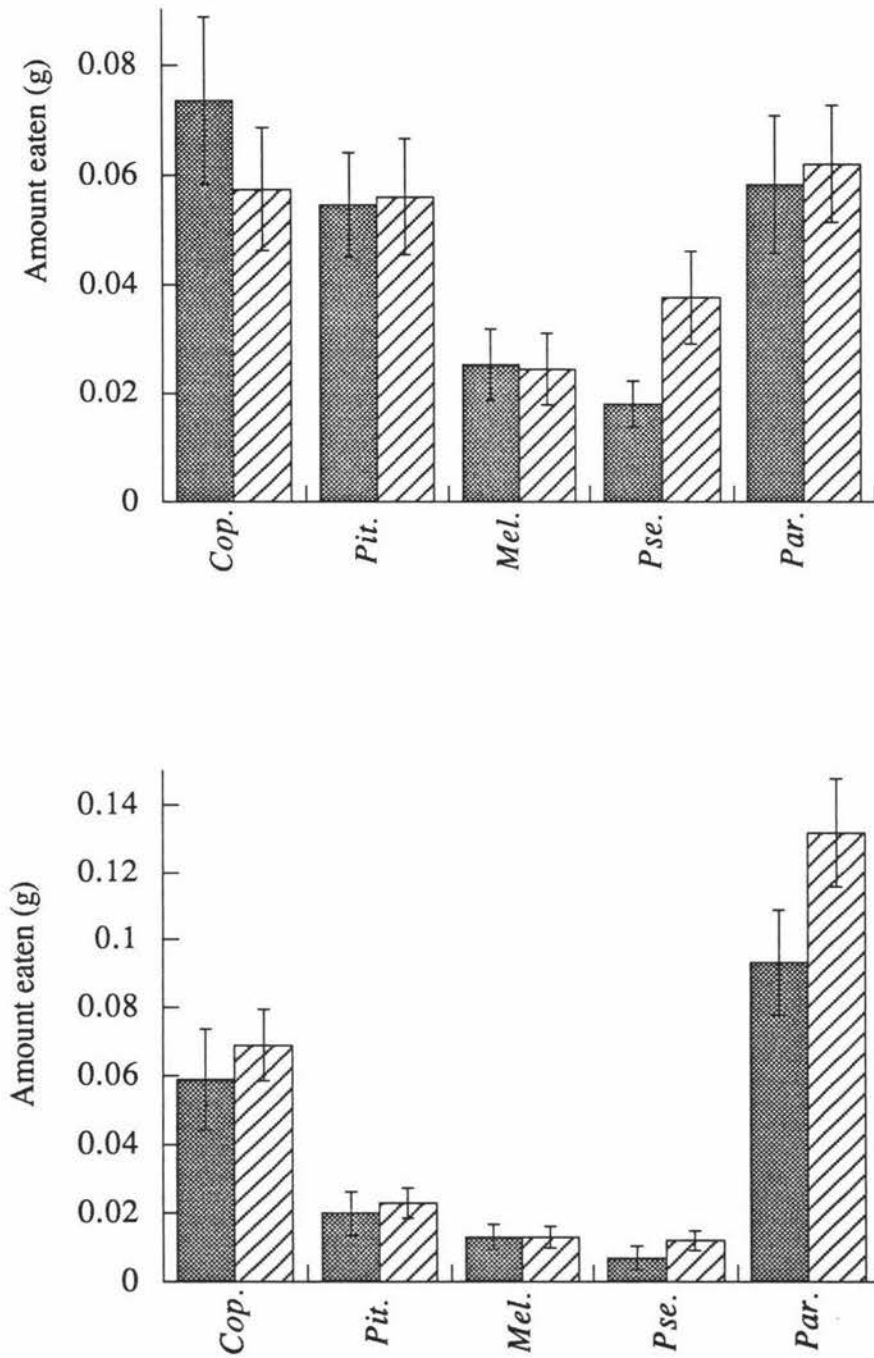


Fig. 6.2 The average amount (weight) and standard error, consumed per night, by male and female *H. femorata* (above) and *H. ricta* (below). Shaded bars = male and hatched bars = female *H. ricta*.

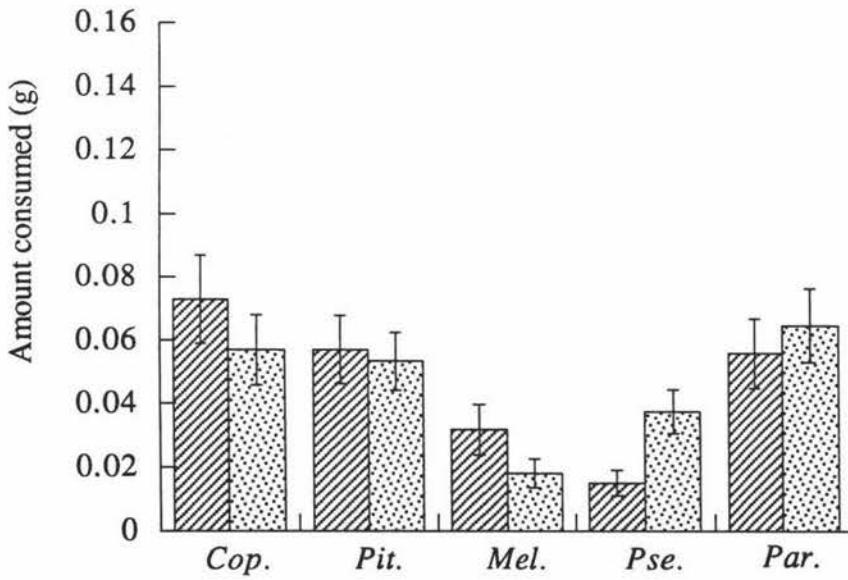
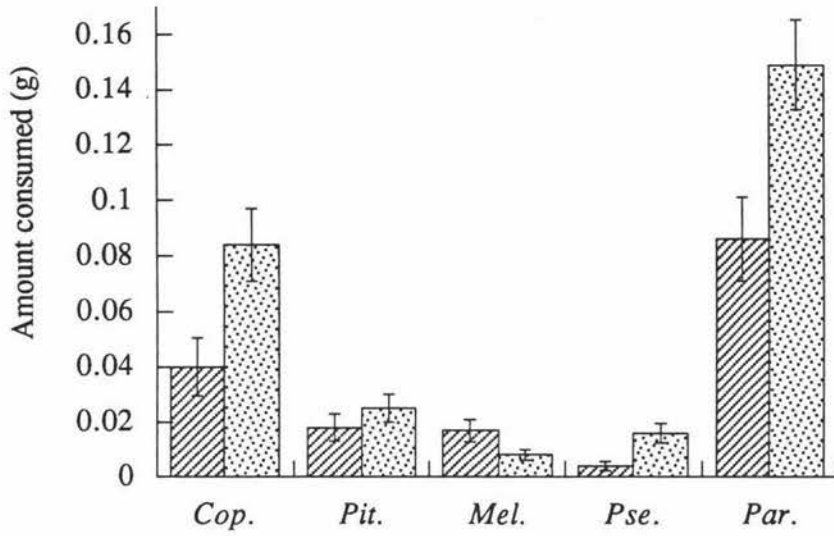


Fig. 6.3 Amount of plant consumed in the trials, by adult (shaded bars) and juvenile (hatched bars) weta of *H. ricta* (above) and *H. femorata* (below).

juveniles, but there was no difference in the amount consumed between adult and juvenile *H. femorata* (Fig 6.3).

Table 6.1 The total amount (g), of each plant eaten by both species in food preference trials.

	Total	<i>H. ricta</i>	<i>H. femorata</i>
<i>P. heterophylla</i>	13.36	8.75	4.61
<i>P. eugenoides</i>	5.49	1.51	3.98
<i>C. robusta</i>	9.66	4.88	4.79
<i>P. arboreus</i>	2.57	0.75	1.82
<i>M. ramiflorus</i>	2.85	0.96	1.88

The weight of plant material consumed was influenced significantly by the age of the weta and by the species of plant offered (Table 6.2). Significant interactive effects existed between weta species and age, weta species and plant species, and weta species, weta age and plant species.

Table 6.2 ANOVA tests on difference between species, sex and age of weta in their selection of five plants in the trial.

Source	DF	Mean Square	F value	Pr>F
Species	1	0.004	1.11	0.293
Sex	1	0.007	2.11	0.147
Age	1	0.018	5.24	0.022
Plant	4	0.118	35.15	0.0001
Spp*sex	1	0.003	0.93	0.336
Spp*age	1	0.022	6.53	0.011
Spp*plant	4	0.038	11.41	0.0001
Sex*age	1	0.010	2.88	0.090
Sex*plant	4	0.002	0.52	0.721
Spp*sex*age	1	0.006	1.81	0.180
Spp*sex*plant	4	0.003	0.87	0.482
Spp*age*plant	8	0.008	2.38	0.016
Error	688	0.0034		

There was no discernible decrease in the amount of plant eaten over the duration of trial but *Parsonsia* was initially consumed in increasing amounts and this later declined (Fig. 6.4).

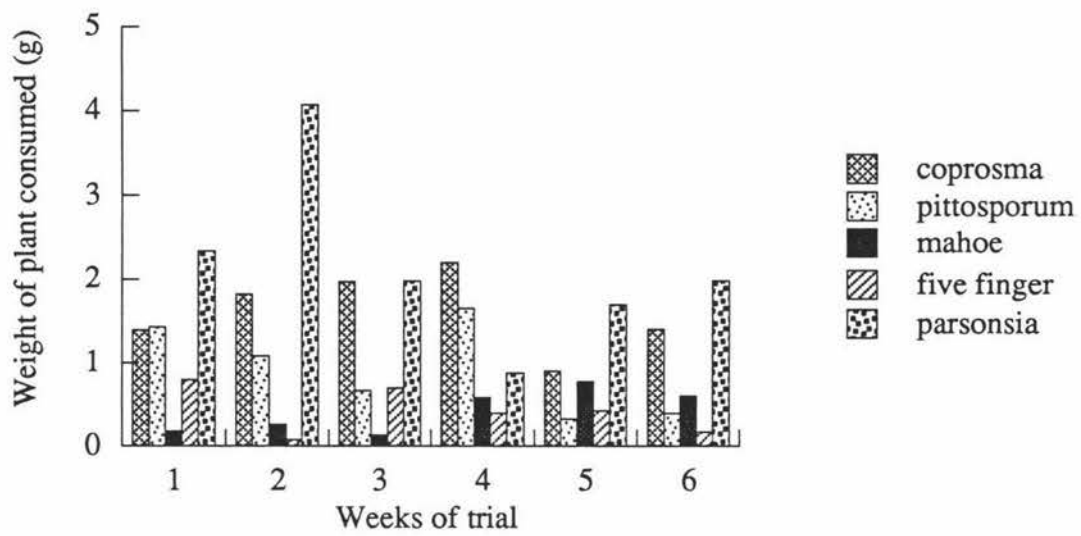


Fig. 6.4 Total amount (weight) of plants consumed by both species throughout the experiment.

There was a noticeable cessation of feeding by juvenile weta prior to moulting which resulted in several nights with no feeding by these individuals.

6.4 Discussion

The species of plant had the greatest effect on how much plant material was consumed by both species of weta. There are many characteristics of a plant that affect its selection by an insect, for example the nutrient content, the digestibility, toxic substances and feeding stimulants and deterrents (Bernays, 1992). The species of weta did not have an effect on the amount of plant material eaten, but it did have an effect in combination with plant species and weta age. *H. ricta* adults consumed approximately twice as much *Coprosma*, *Parsonsia* and *Pittosporum* than juveniles, but adult and juvenile *H. femorata* ate approximately the same amount of these plants. Adult *H. ricta* and *H. femorata* consumed nearly twice and four times the amount respectively of *Pseudopanax* than juvenile weta and juvenile weta of both species consumed about twice as much mahoe than adults. Supposedly the differences observed arise from the contrasting nutrient needs of adult and juvenile insects. Therefore, if captive experiments are typical of field situations, these two species would not compete strongly for the same plant foods if there was ever a limited supply.

It is not known whether some of the plants chosen for the trial contain higher amounts of feeding attractants or stimulants while others may have contained deterrents. The nutritional content of the plants was also not known. However, an attempt was made to equalise the amounts of all the plant material offered so as to balance the amount of chemical signal each may give off. Bernays (1992 b) describes plant feeding preferences as difficult to assess due to the presence of toxic substances, feeding stimulants, and feeding deterrents all of which affect the amount of plant consumed.

Some plants release kairomines (antifeedants) into their sap after they have been damaged (Metcalf and Metcalf, 1992). Hence, continued cropping of the plant (the samples were all removed from the same bushes throughout the trial) to get samples for

the experiment, may possibly have caused more antifeedants to be released into the sap during the experiment. This would therefore impinge on the consistency throughout the experiment. There was no noticeable decline in the amounts of any plant eaten, except that *Parsonsia* was initially consumed in increasingly large amounts but the amount consumed then declined and levelled off. Bernays (1992a) suggests that insects forage to gain optimum nutritional intake and prefer novel tastes, which may explain the heightened intake initially with *Parsonsia*. However, Bernays (1992b) suggests that it is impossible to determine whether a reduction in feeding results from a lack of phagostimulants in the food or the post-ingestive effects of eating the food.

These *Hemideina* are polyphagous and are similar in this respect to the locust, *Taeniopoda eques*. This locust is a generalist feeder, switching frequently between foods in the field and eating up to eight different foods in the same meal (Bernays, 1992a). The plant species that this locust feed on regularly, become progressively less acceptable, and they seek out novel tastes (Bernays, 1992a). Grasshoppers and locusts have been shown to orient to food by photo (light) or anemotaxis (wind), and plants are selected for stimulants such as sugar, amino acids, lipids and vitamins (Metcalf and Metcalf, 1992).

The differences in physical properties of the plants selected may also have an effect on the amount consumed. Little (1980) suggested that *H. femorata* found kanuka and manuka (*Leptospermum scoparium*) very hard to digest whereas *Pseudopanax* and *Coprosma* were easily digested by them. Based on their appearance alone, I inferred that there was no real difference between the physical nature of the selected plants. Waxes were obviously present (due to the shiny nature of the surface) and abundant in *Coprosma*, *Pittosporum* and *Pseudopanax* but to a lesser extent in Mahoe and *Parsonsia*. Perhaps weta choose plant material on their ability to digest them, as well as their initial chemical stimuli. The food selected may also be dependent on what foods have previously been eaten by the weta, because of the ability to store amounts in its crop. Additionally, if an insect has been deprived of a specific nutrient, it will favour this nutrient when available (Bernays, 1992b). To alleviate the problem of weta storing food

in their crops all were treated identically and given the same foods prior to the experiment.

Possibly the type of food consumed has an effect on the longevity of an insects life. Horton and Redak (1993) found diet significantly affected growth or consumption in insects. In addition, some plants directly affect the growth by altering the amount of ecdysone within the insect causing premature moulting (Russell, 1977). This would therefore influence the selected foods of juvenile insects but not adults in this situation. Little (1980) suggested that *H. femorata* found kanuka and manuka difficult to digest but numerous weta of both species were found in kanuka stands or isolated kanuka trees. Weta leave their refuges at night and ascend to the canopy to feed which suggests these weta consume predominantly kanuka. Obviously in some situations vines like *Parsonsia* and *Calystegia* exist in the canopy but frequently kanuka trees were the only plant available for feeding. The sub-adult male *H. ricta* that was marked for a period of nine months prior to ecdysis (see chapter 5), was situated below a kanuka tree. If this weta was feeding on kanuka only, this may have slowed the duration of stadia because of the difficulty involved with digestion of kanuka.

When weta moulted they showed reduced food intake and they sometimes did not eat for the entire three nights of the food trial. The process of ecdysis and the production of new cuticle requires considerable outlays of energy and nutrients (Bernays, 1992b). She reported that many insects ate increasing amounts of food up to mid stadia, and subsequently food intake declined until they moulted. This may explain the associated differences in food preference between adult and juvenile weta. A juvenile weta may require greater protein for example than an adult weta. Bernays (1992b) also suggests that changes in food requirements during a stadium are both quantitative and qualitative. She assessed the quantitative requirements of *L. migratoria* throughout growth. During the first half of stadia, 5th instar nymphs incorporated lipids and proteins into the body whereas later stages of the instar, body carbohydrates and glycogen stores were increased in the fat body.

Many *H. ricta* were found in fenceposts and the only other vegetation around them was pasture grasses, and others were found in posts in the midst of gorse bushes (Chapter 3). They readily ate puha, dock, dandelion, clover and gorse flowers in captivity so this implies these weta either travel long distances to feed or eat pasture species and gorse (presumably flowers) when seasonally abundant.

Chapter seven

Discussion and recommendations

Hemideina ricta and *H. femorata* are distributed predominantly allopatrically on Banks Peninsula, although small areas of sympatry exist on the eastern inner slopes of Akaroa Harbour. One of the main concerns during this survey was to correctly identify each species in this area of sympatry. These concerns were heightened with the discovery of weta that appeared to be intermediate and were hence difficult to assign to species. Juvenile weta of both species are more similar than adult weta because of darker markings on some *H. ricta*. Hence the most useful trait in these situations was to use the retrolateral and prolateral apical spines on the hind tibia. If retrolateral apical spines were present, the weta was definitely *H. femorata*, if only the prolateral apical spines were present then the weta was most likely *H. ricta*. Otherwise the most prominent feature was the stripy appearance of *H. femorata* compared with *H. ricta*.

There are a number of interesting similarities between *H. ricta* and *H. maori*. Morphologically these two species share the character of only the prolateral apical spine on the hind tibia, and both species have two colour morphs. Comparably, *H. ricta* and *H. maori* are both larger tree weta, having wider and longer heads than *H. femorata*. *H. femorata* was seldom found in refuges on the ground whereas *H. ricta* and *H. maori* are, perhaps this is a reflection of the predators that *H. ricta* and *H. maori* encounter in this environment. The similarities between *H. ricta* and *H. maori* are problematic, however, as their present distributions are quite separate, but I presume they are from closely related genetic stock.

Field (1993) suggested that *H. ricta* may face a gallery shortage because they were found in refuges on the ground and in splits of old fenceposts. If this is so and given that they are found in similar areas, then surely *H. femorata* would face the same gallery shortage too? However, although I searched numerous fallen totara logs on the western

portion of Banks Peninsula (Mt Sinclair and Mt Fitzgerald), only two *H. femorata* were found in logs on the ground. *H. femorata* were not found above 450 m asl on Banks Peninsula, and was found to have a strong preference for kanuka trees. Perhaps, given that tree refuges were not as abundant above this altitude, refuge availability may have limited this species' distribution. It is still uncertain whether *H. ricta* in fallen log and fencepost refuges are there because of limited tree refuges at high altitude (>500 m asl). Perhaps these weta exist in logs because deep channels form naturally as the wood slowly decays, therefore logs may provide good shelter from diurnal predators. The fenceposts, however, do not seem to render much protection as weta in these posts can readily be seen, which is one of the concerns raised by introducing weka to Hinewai Reserve.

I suggest that resource partitioning has some influence on the current distributions. *H. femorata* showed a strong preference for kanuka whereas *H. ricta* was found in kanuka, *Hoheria*, totara and broadleaf logs and mixed hardwoods. If these two species have co-existed for many thousands of years, then perhaps their niches have shifted slightly to allow continued co-existence.

It is generally assumed that *H. ricta* evolved from a mainland tree weta ancestor when Banks Peninsula was an island. If so, then it is therefore an endemic to Banks Peninsula. Presumably once Banks Island re-joined the mainland at some unidentified ice age, *H. femorata* supposedly began invading the Peninsula. Perhaps the current distribution of *H. ricta* suggests that it has been forced to the outer reaches of Banks Peninsula, but this is unknown at this stage and can only be determined from a subsequent survey in perhaps five or ten years time. Such a survey would hopefully determine whether *H. ricta*'s population is increasing, stable or declining and if its distribution is changing, by comparison with the distribution presented here.

A population estimate was difficult to achieve because of the heterogeneity of the habitat and also because of the erratic nature of *H. ricta*'s distribution. For example, in some

areas as many as 22 *H. ricta* per plot were located, but no weta were found in other plots that appeared to be otherwise similar. Many of the areas searched were in what I considered to be ideal weta habitat (logs and trees with refuges and vegetation) and yet I did not locate any tree weta. Perhaps there are other features of the weta habitat (humidity or soil chemistry for example), that I did not record in our study, that affected where weta occur.

The current distribution of tree weta on Banks Peninsula may be heavily influenced by man. Early maori settlers had removed about one third of the forest on Banks Peninsula by fire and more recently, since 1850, much of the forest has been cleared for timber and to produce pasture (Wilson, 1992). This has created large habitat breaks that may halt any large scale dispersal of either weta species. In addition, when timber is felled from areas and transported about, this may allow one species to extend its distribution unnaturally. Even on the small scale when farmers remove firewood from one area, and transfer it to home, there is the possibility that weta are relocated into new areas. A classic example of humans intervening with a species distribution is the spread of *Vespula* wasps throughout the world. The German wasp *Vespula germanica*, has spread quickly through areas of South Australia, and it was discovered that the wasp had been transported into South Australia by timber consignments from New Zealand then passively and accidentally around South Australia in motor vehicles (Crosland, 1991).

Only about 2066 hectares of Akaroa and Mt Herbert districts on Banks Peninsula have some form of land protection (Wilson, 1992), and only the following scenic or private reserves are known to have *H. ricta*: Otepatotu; Ellangowen; Mt Pearce; Stoney Bay; Nikau Palm Gully and Hinewai. However, there are numerous other small areas on private farms which are either fenced off or left as stock shelter that are significant areas regarding *H. ricta*'s total area of distribution.

Much of *H. ricta*'s current distribution extends over private farmland and the continued existence of this species therefore lies in the hands of these landowners. There are many directions that landowners can take to improve *H. ricta*'s chances of survival. A

major impact on large areas of land does occur from 'slash and burn' clearing techniques which may not be legal but do occur in some areas. Fires are destructive to all existing plants and animals and also pose a threat of becoming unmanageable. It is understandable that farmers desire as much pasture as possible on their land. Perhaps where some regeneration has occurred in gullies, this could be left as is and it would allow stock shelter and, in addition permit small pockets of native bush to remain even though understorey plants would not regenerate because of grazing. This is already occurring on many properties throughout the Peninsula, and some landowners have protected areas of native bush with stock-proof fences as well. The removal of long established kanuka and old totara logs for firewood and also for wood-turning and craft work may be detrimental to *H. ricta*'s population, as these trees and logs form a significant portion of *H. ricta*'s habitat. Perhaps when trees and logs are removed, any weta discovered in them should be returned to the area or similar habitat. Fenceposts that are old and falling apart are readily used by *H. ricta* and possibly when these fencelines are replaced, farmers could leave the old posts in order to provide refuges.

High numbers of *H. ricta* did not colonise the artificial refuges compared to the numbers of *H. crassidens* obtained by Ordish (1992). It may, however, be that *H. ricta* do not live in dense populations as *H. crassidens* seem to. In addition, this study was limited to about 14 months of potential colonisation whereas Ordish (1992) has monitored the weta present in the artificial retreats in his garden since 1988. The fact that *H. ricta* readily colonised these artificial retreats is still of value. Perhaps, in years to come, the need will arise to provide such artificial retreat in a species recovery plan. Even now, it may be an advantage to consider depositing logs and kanuka with holes drilled in them in some areas where *H. ricta* has been found in high density.

It is difficult to suggest pest management plans that would benefit *H. ricta* when these involve considerable time and effort. Also, I found no evidence of predation in this study. It is known however, that stoats, ferrets, cats, possum and hedgehogs may prey on weta (chapter 3) and all inhabit the Peninsula. These animals, exempting the

hedgehog, are already the target of many pest management strategies and therefore may not need additional attention. I am also concerned that the South Island Buff Weka should not be introduced into new areas such as Hinewai Reserve on Banks Peninsula. J Dugdale (*pers. comm*) suggested that significant numbers of Chatham Island invertebrates could not be found on the main island and only barely on Pitt Island where weka inhabit. It seems bird conservation has priority over existing fauna even when these birds survive in reasonable populations elsewhere. It has been argued that weka previously occupied Banks Peninsula and therefore would not interfere with *H. ricta*'s population. However, weka were not present on the Peninsula with the additional threats of rats, stoats, cats, possum and reduced habitat. Such an introduction of weka may therefore be more harmful than first anticipated.

The greatest threat to *H. ricta* is still, I feel, the removal and destruction of its existing habitat. Many people do not understand the aim of conserving something unless it has some value or use. It needs to be understood that conserving a species is a worthy cause in its own right because of the species own intrinsic value. Wells *et. al* (1983) suggests that invertebrate conservation ensures the sustainability of species and ecosystems which may support rural communities, but more so, to preserve genetic diversity. More often than not, peoples' reaction to weta is avoidance and dislike and it takes a lot of effort to persuade them to think otherwise. However, I consider it important to educate school children and landowners about the significance of *H. ricta*, that it is only found on Banks Peninsula, and therefore special to the area. Any efforts to encourage landowners to avoid destruction of *H. ricta*'s habitat would be beneficial also.

Recommendations

1. I consider the gravest threat to be destruction of *H. ricta*'s habitat, and some of the following measures could be taken to avoid this predicament:

Limit the cutting of kanuka for firewood.

Stop the removal of logs from the Summit Road area of Banks Peninsula which are currently being removed for ornamental purposes and as firewood.

Abolish or severely limit fire as a land clearing practice where *H. ricta* occurs.

As many of the areas surveyed containing *H. ricta* were on the roadside, perhaps leaving these verges intact and as free of herbicide sprays as possible would also enhance this as habitat. *H. ricta* was found in a high density in fenceposts, logs and vegetation, along the roadside verge of Lighthouse Road at an altitude of 500 m and above, and in logs on farmland below Brasenose Peak. Protection of these areas would assist in the conservation of this species.

Placing logs with drilled holes in areas of the roadside or Summit Road area where *H. ricta* are known to occur in high number and where natural refuges are scarce would be of possible benefit to this species.

2. Education:

Inform children about interesting local insects, perhaps with a conservation theme at school. This will promote awareness at a young age.

Familiarise land owners with *H. ricta* and its habitat requirement, and suggest ways they can conserve this insect. For example, retaining old fenceposts when replacing the fences and keeping the removal of trees and logs to a minimum.

3. Thorough study prior to introducing possible new threats to *H. ricta*:

The introduction of weka should be very carefully investigated prior to any releases as the impact of these birds on ground dwelling weta has not yet been studied.

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