Ecology and behaviour of the Mahoenui Giant weta

(*Deinacrida* nov. sp.)

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

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1994

Plate 1 A female Mahoenui weta displaying the threat posture

ABSTRACT

Basic information about the ecology of Mahoenui weta (*Deinacrida* nov. sp.) is provided from captive and field studies. Transmitters, betalights and capture-recapture were used to track movements and activity. Weta have a three year lifecycle with three main age groups present thoughout the year. Two colour morphs were present (brown and yellow); 15% of males and 27% of females were yellow morph. Mortality rate decreased with age; 80% died between instars 1 and 6, 40% died between instars 7 - 9. Mild overt agonistic behaviour was observed. Courtship behaviour was simple and females played a passive role. Mating took from 1 to 14 hours and often included multiple copulations. Weta were more active in summer than winter and adults were active for longer periods than juveniles. Activity patterns in captivity were similar to those in the field. Most weta remained within a small area (1 - 3 m^3) for much of their lives and often returned to rest in the same place on successive days. Large gorse (*Ulex europaeus*) bushes with little or no goat browsing were preferred whereas isolated bushes and small and heavily browsed gorse was less favoured. Weta are generalist feeders. Those reared on gorse and pasture plants had low mortality (1 died out of 9) and gained weight more steadily than weta reared on native vegetation (9 died out of 11). Mahoenui reserve provides suitable food and shelter and affords some protection against predators. However the possible destruction of the gorse habitat by fire or disease still poses a major threat to the weta population.

ACKNOWLEDGEMENTS

I wish to thank my supervisors Dr Murray Potter and Dr Ian Stringer for their input and assistance; Judy Redfearn for her invaluable typing skills; my fiance Cameron Redfearn for his assistance and enthusiasm in my field work; Dean Strange my co-worker at Mahoenui reserve; and all the others whose interest in my work was most supportive throughout the course of my research.

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CHAPTER ONE:

GENERAL INTRODUCTION

Mahoenui weta had been known to local people in the Mahoenui district for many years. It was only recognised as a giant weta of the genus *Deinacrida* in the mid 1960's after a school teacher at Mahoenui Primary sent a weta to Dr Charles Watt at the Entomology Division, D.S.I.R. (Watt 1963). At that time these weta were found in remnant forest patches of tawa (*Beilschmiedia tawa*) surrounded by farmland that had largely reverted to gorse (*Ulex europaeus*) shrubland. The weta numbers in these tawa remnants apparently declined because of grazing and trampling of the undergrowth by cattle, sheep and goats. This destruction may also have allowed predators increased access to the weta.

Mahoenui weta were located in mature pine trees and gorse during a survey in 1979 and many were found throughout 250 ha of gorse straddling the properties of N. Rauputu and J. Reeves in another survey in 1987. In 1990 the Department of Conservation purchased about 250 ha of this gorse shrubland to protect these weta. Gorse provides some protection for the weta against predators, and it is also eaten by them (Sherley and Hayes 1990).

All weta in New Zealand are nocturnal. Potential predators of the giant weta include possum (*Trichosurus vulpecula*), rat (*Rattus* sp), cat (*Felis catus*) (Sherley and Hayes 1993; Jowett 1989), hedgehog (*Erinaceus europaeus*) (Moller 1985) and Morepork (*Ninox novaeseelandiae*) (Lindsay and Ordish 1964). Predators are still a threat to the Mahoenui weta, especially when weta move about on the ground, when moving between bushes or feeding on ground foliage, and during oviposition.

The reserve is grazed by cattle (*Bos taurus*) during winter and by feral goats (*Capra hircus*) all year round. Goats also browse on the gorse and gorse bushes become cropped like a hedge to form a dense topiary around their bases up to approximately one meter high in areas where goats browse heavily. Research has recently been undertaken to determine if cattle and goats have an adverse or beneficial effect on the numbers of Mahoenui weta (Stronge 1993).

One other population of Mahoenui weta is known in addition to that at Mahoenui. This is at Otangiwai, 20 km east of Mahoenui. Few weta are present there and their conservation status is unknown (Jowett and Plant 1988). The Mahoenui population contains the majority of these weta and this is of concern because the reserve has a low habitat security and there is a high predation threat (Meads 1990). The Mahoenui weta in the reserve were described as threatened at the conservation of "threatened Weta" meeting in May 1990 (Anon. 1990). Fire breaks have been created in the reserve but there is still a risk that fire could destroy much of this area. The introduction of biological control of gorse in New Zealand will leave the gorse at Mahoenui vulnerable to attacks from control agents which could also destroy large areas of the suitable weta habitat. Gorse patches in much of the surrounding farmland are being sprayed and cleared and this is presumably reducing the amount of area suitable for Mahoenui weta to disperse into.

The potential threats to the Mahoenui weta make it important that a number of other populations are established to reduce the risk of extinction. Research on all aspects of the Mahoenui weta will aid weta translocation to new habitats.

Mahoenui weta have been translocated to three other sites. Sites at Cowan's Block in Northern Pureora and at Mangeokewa Scenic Reserve, 5 km from Te Kuiti are presently being monitored (Sherley and Hayes 1990). Recently a large number of weta were translocated to Mahorangi Island, Coromandel, following the clearance of a large block of gorse on Reeves' property near the Mahoenui reserve.

The aim of this thesis is to provide basic information about the ecology of the Mahoenui weta (*Deinacrida sp.*) that will be beneficial to the conservation of the species. This information should also benefit other *Deinacrida* species as there have been few detailed studies made of these weta (Richards 1973; Field 1980; Ramsay 1955).

I provide a detailed study of morphology, development and life cycle of Mahoenui weta (chapter 4). I give a preliminary description of the behaviour of Mahoenui weta both in the field and in captivity (chapter 5) and provide data on their nocturnal activity patterns (chapter 6). I describe Mahoenui weta habitat use and their movement within this habitat during the day and night (chapter 7) and provide knowledge of their diet (chapter 8). Where possible I relate my results to other weta studies, in particular those of other *Deinacrida* species (Richards 1973; Ramsay 1955; Field 1980) and other research on the Mahoenui weta (Sherley and Hayes 1993). Finally (chapter 9) I summarise the major findings of these studies, discuss the bearings my results have on the conservation of Mahoenui weta (chapter 10) and suggest topics for further research.

CHAPTER TWO

STUDY AREA

Mahoenui Reserve (240 ha; Lot 5 38 34, Long E 174 50) is located off Ngatarawa Road (which is along State Highway 3, 2 km north of Mahoenui). A 1.4 km track leads up through Mr Rauputu's property to the reserve entrance (Figure 2.1)

The Mahoenui reserve is bounded by the Mokau River along the northeastern boundary and sheep and cattle farms elsewhere. Most of the gorse has been cleared from these farms adjacent to the reserve. The reserve is covered predominantly in dense gorse (*Ulex europaeus*), although there are some native plants amongst it, such as Mahoe (*Melicytus ramiflorus*), manuka (*Leptospermum scoparium*) and divaricating Coprosma (*Coprosma areolata*). Areas of swamp occupy the valley floors. These are covered mainly in raupo (*Typha orientalis*) and surrounded by tree ferns (*Dicksonia fibrosa* and *Cyathea* species), manuka, kanuka (*Kunzea ericoides*) and *Pseudopanax* species. Throughout the reserve there are areas of more open gorse and pasture (Plate 2.1) and there are two main fire breaks of pasture through the reserve. Two remnant forest patches are included in the reserve boundaries. In these the predominant canopy tree is tawa (*Beilschmiedia tawa*) (Figure 2.2; Plate 2.2).

The reserve containes feral goats all year round and cattle during the winter months. Goats browse gorse especially in areas where they bed down overnight and where the gorse forms more open bushes amongst pasture. Browsing by the goats increases dramatically during winter when cattle heavily graze the pasture

(Stronge 1993). Gorse browsed regularly by goats acquires a dense hedge-like appearance (Plate 7.1). This browsed region rarely extends higher than 1 m (the height goats can reach when browsing). Above this bushes grow unimpeded.

My study sites were situated along the southeastern ridge adjacent to Mr Gaston's property and the Queen Elizabeth II Trust remnant of tawa forest, and on the southwestern face adjacent to Mr Rauputu's farm and pine plantation (Figure 2.2).

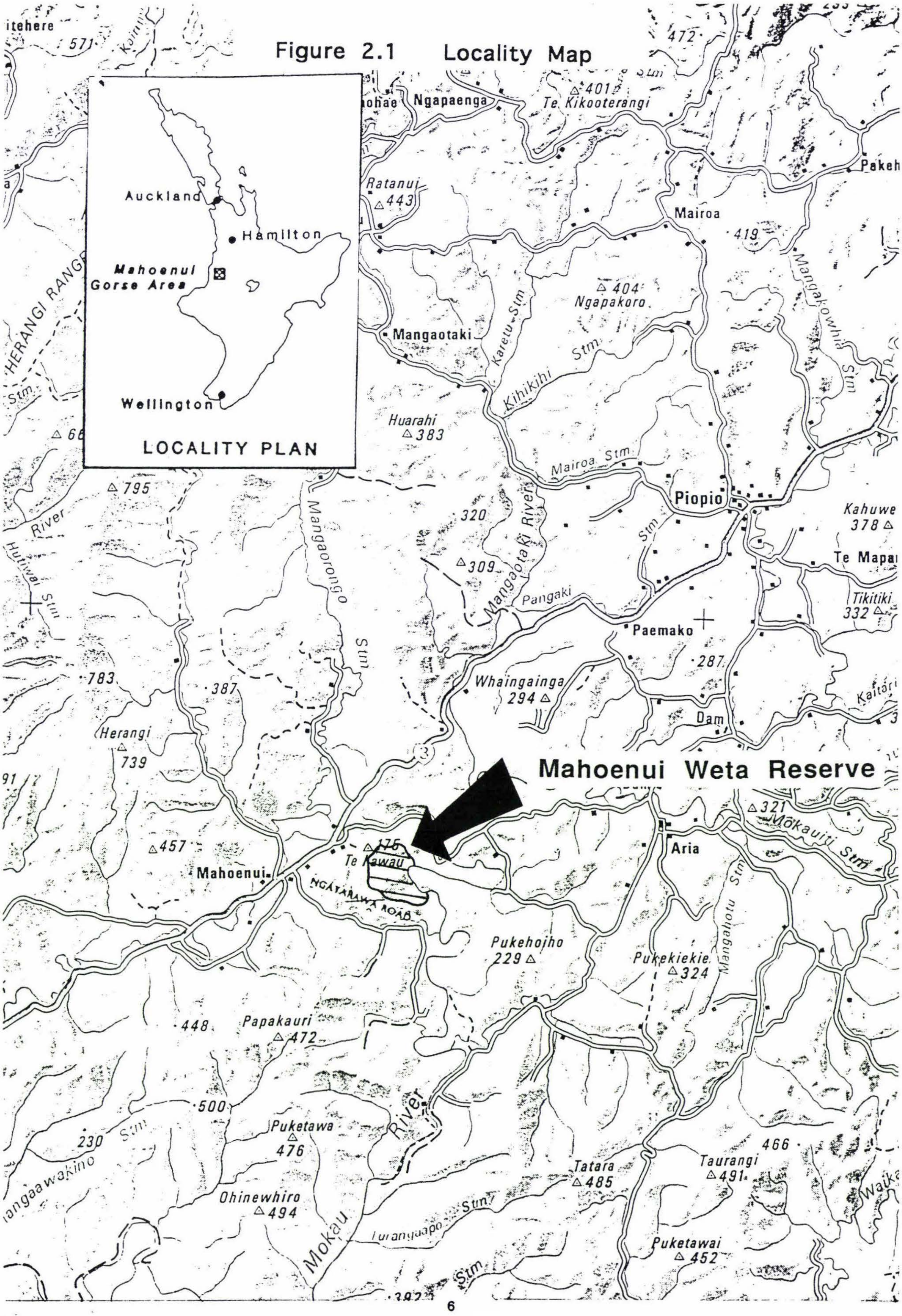


Figure 2.1 Locality Map

Figure 2.2 Mahoenui Weta Reserve

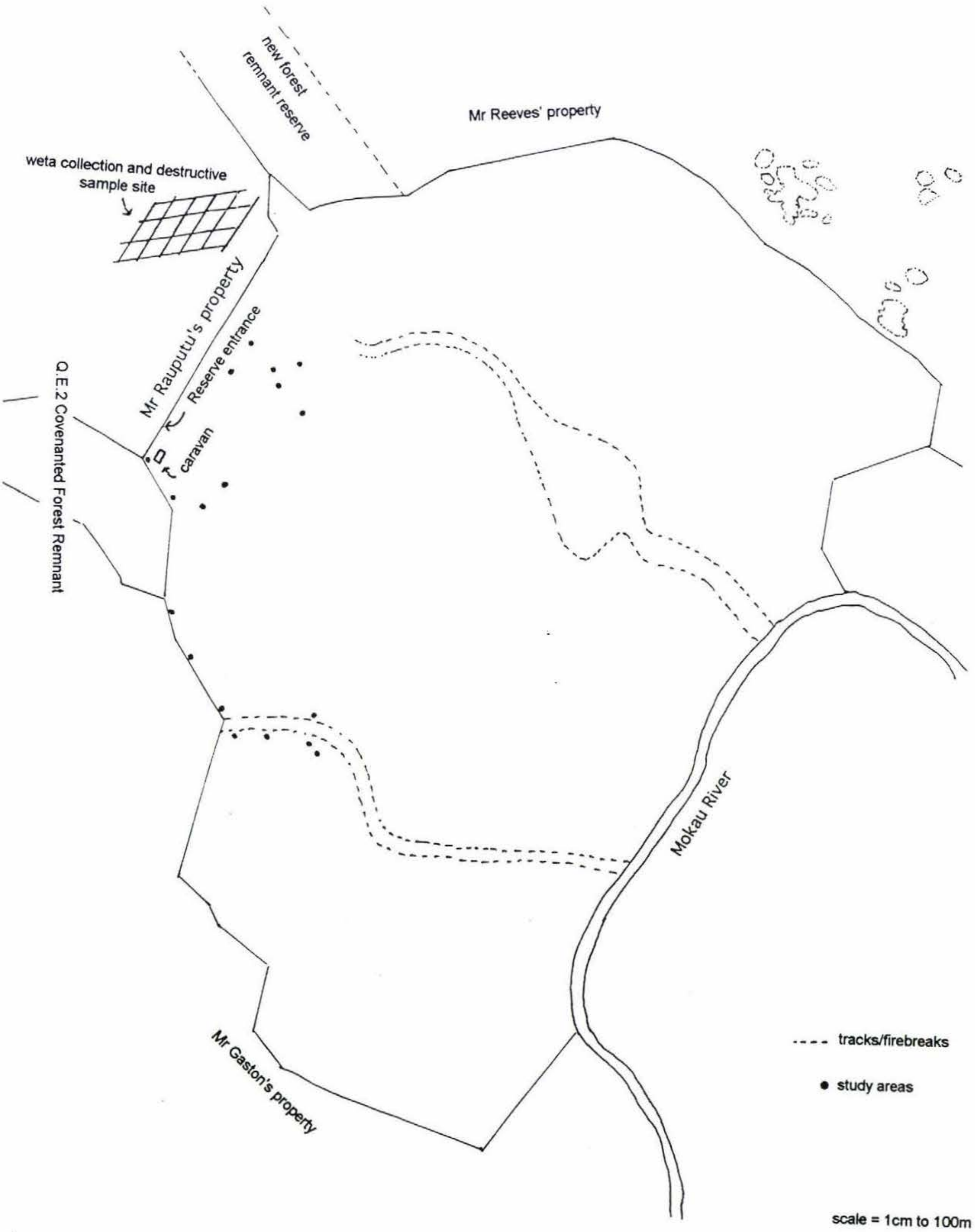


Plate 2.1 Mahoenui reserve showing areas of pasture on the periphery of gorse.

Plate 2.2 Example of Mahoenui reserve gorse habitat with a tawa forest remnant in the background.

CHAPTER THREE

GENERAL METHODS

3.1 Locating and measuring Mahoenui weta

Mahoenui weta were found during the day by searching gorse bushes by hand using leather gloves. At night weta were located on both gorse bushes and the ground using a torch.

All weta were measured with vernier calipers to determine their head width and pronotum length and, if female, their ovipositor length. They were weighed with a spring balance to the nearest 0.5 g. When required weta were labelled with an identification number using a silver paint marker pen (Pilot super color) (Plate 3.1).

3.2 Collection of Mahoenui weta for captive study

Mahoenui weta were collected from gorse in farmland belonging to Mr Ngati Rauputu that was adjacent to the reserve (Figure 2.1). Appendix 1 lists all weta collected.

3.3 Maintaining Mahoenui Weta

Maintaining 7th to 10th instar weta in captivity.

Larger weta were kept in a glass tank 1.0 m long x 0.4 m wide x 0.5 m high with a hardboard floor. The lid was made of thick plastic mesh (see figure 3.1).

Pieces of coiled eucalyptus bark were provided for refuges and to provide extra climbing material. A variety of plant foliage selected from those listed in Chapter 7 was provided for food. Foliage was kept fresh by pushing the stems through holes in the lids of plastic containers filled with water. In addition, a freshly killed cricket was provided each month. Drinking water was provided in small plastic container lids. A 600 ml. plastic container (12 cm diameter) filled with soil was placed in the cage to provide an oviposition site. The soil was kept moist but not water logged. Food and water were replaced twice a week. A typical layout of the weta cage is shown in Figure 3.2.

After the first four adults died, the cage was divided in half with a piece of hardboard (Figure 3.1b). Two male and two female weta were then put into each side of the cage. An identical cage with four weta in each half was placed in a constant temperature room set at 18^{O} C. The four weta on the left side of each tank were fed a mixture of gorse foliage (*Ulex europaeus*), dandelion (*Taraxacum officinale*), plantain (*Plantago* sp) and rye grass (*Lolium pereme*). The four weta on the right side of each tank were fed a variety of native plants. The remaining weta were kept in a cage measuring 0.6 m long x 0.5 m wide x 0.6 m high and were provided with a variety of plant foliage. The weta in this cage were used to restock the other two cages when any weta died, and were used in feeding experiments.

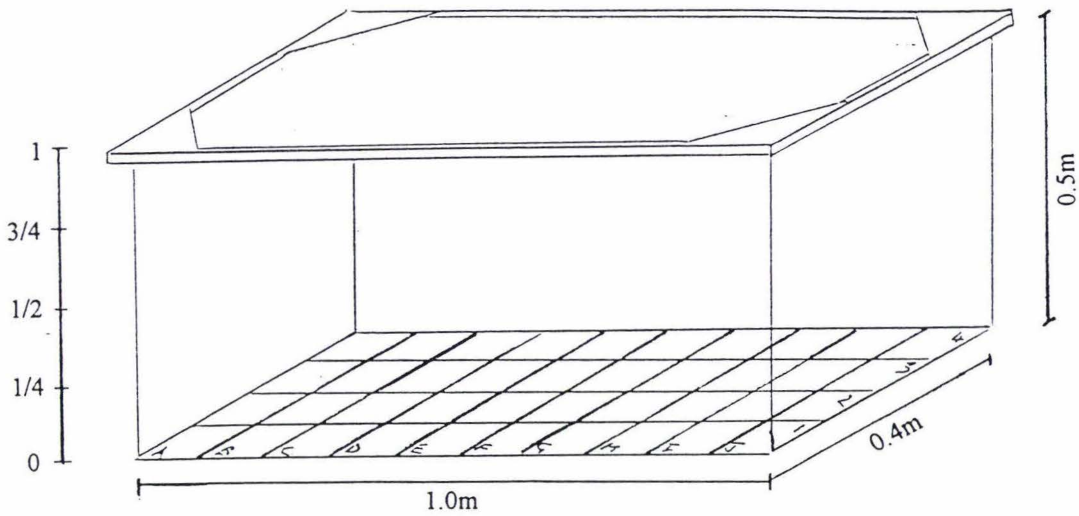


Figure 3.1 (a)

Diagram of the cage used to maintain 7th to 10th instars. The floor of the cage was marked with a reference grid for use when observing their behaviour.

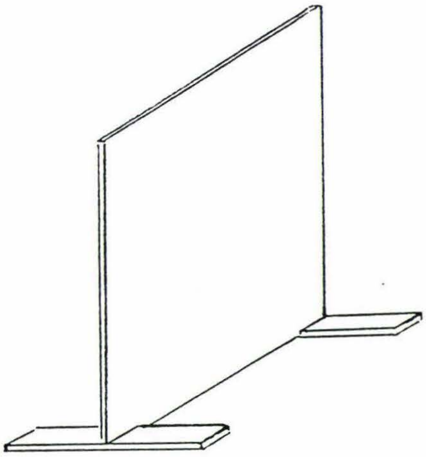
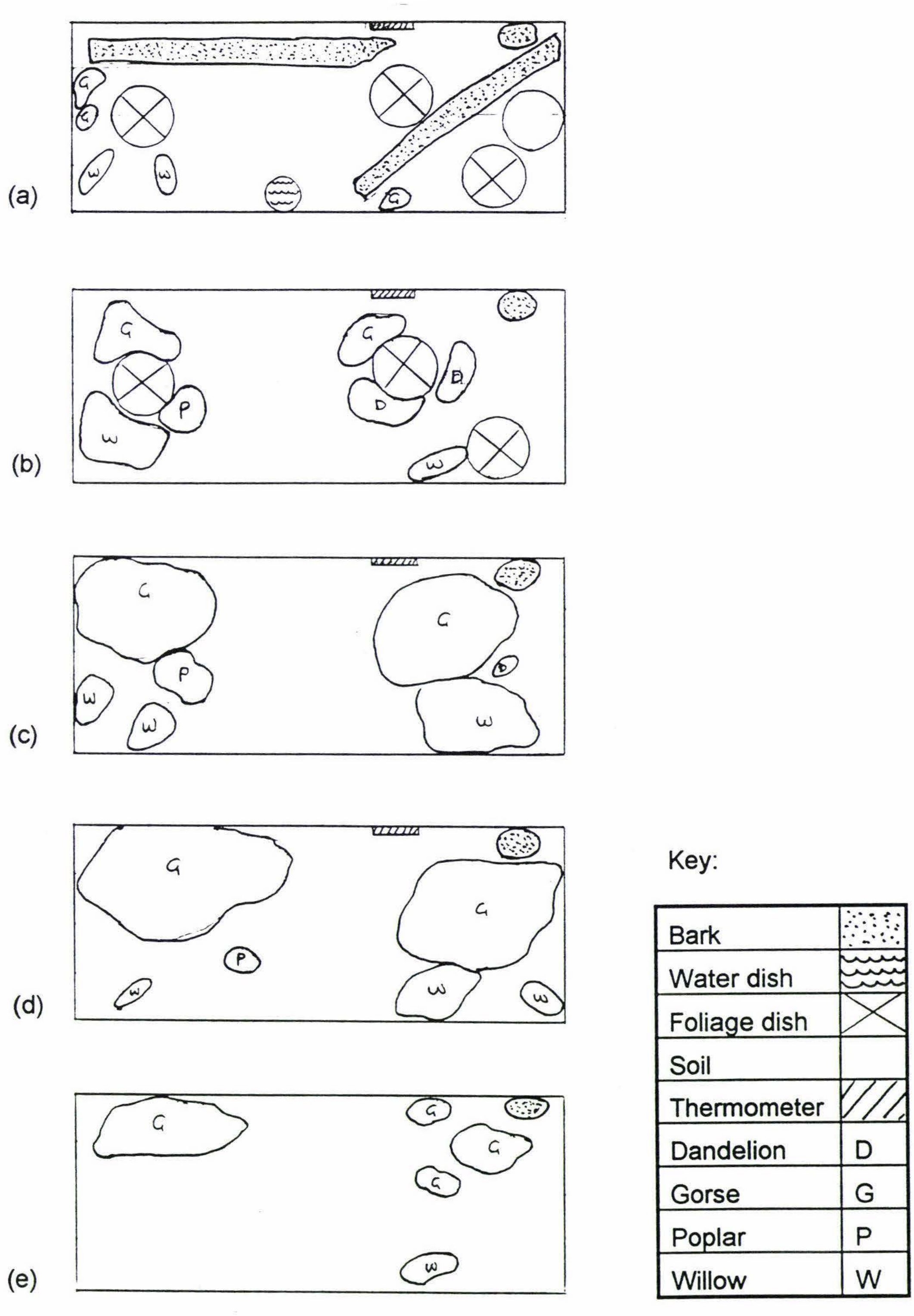


Figure 3.1 (b)

The divider used to separate weta in the cage.



Bark	⁙
Water dish	≋
Foliage dish	⊠
Soil	
Thermometer	▨
Dandelion	D
Gorse	G
Poplar	P
Willow	W

Figure 3.2

Diagramatic representation of the layout of the weta cages. (a) ground level, (b) quarter level, (c) half level, (d) three quarter level, (e) top of cage.

Maintaining 1st to 6th instar Nymphs in captivity

Smaller nymphs were housed in much the same way as described for older nymphs except for the following: Some of the younger nymphs were kept together in small cages, while others were kept in pairs or singly in 4 litre plastic ice cream containers. Plant foliage was kept fresh by pushing the stems into wet soil. This prevented nymphs from drowning in containers of water.

3.4 Nocturnal study of Mahoenui Weta

Captive weta

Captive weta were studied in their cages after the foliage and shelter were arranged in such a way that the weta could be observed easily.

Field weta

Intermittant observation of weta at night on the Mahoenui reserve was aided by attaching betalights to them (supplied by Saunders-Roe Development Limited). This enabled the weta to be located when they crawled into dense parts of gorse bushes. Betalights are small clear plastic capsules filled with a chemical that induces a relatively dim light which can be seen for some distance at night. Two button shaped betalights each weighing 0.5 g and two capsule shaped betalights each weighing 0.9 g were used. Individual weta so marked could be identified by the shape and colour (green or orange) of the betalight it was carrying (Plate 3.2) Only weta weighing 5 g or more were considered sufficiently large and strong enough to wear a betalight. Betalights were attached to weta with Selleys fish tank sealer. This was applied to the base of the betalight and then pushed onto the pronotum of the weta. The glue sets in 12 hrs but it was often sufficiently set after about 8 hrs for the weta to be released. While the glue was setting the weta were held in a small cage or container provided with gorse foliage or grass. Weta were usually released back onto the same gorse bushes they were collected from as early in the day as possible to let them settle before the evening. At the end of the study period betalights were easily removed from the weta by peeling the rubbery glue off the pronotum.

The Nocturnal Study of captive and field weta

Observations began just prior to dusk while the weta were usually in the same position that they rested in during the day. Observations were made every half or quarter hour and on most occasions the observations were continued throughout the night until the weta had settled down to rest again the following day.

Weta fitted with betalights were easily located but a light was still needed to observe their activity. A torch covered with red cellophane was used to aid these behavioural observations. Mahoenui weta have since been found to show little response to light above 618 um (Stringer and Field, pers comm) from an electrophysiological investigation.

Records taken at each observation:

Captive weta

The following data was recorded for each weta observed every quarter or half hour: the activity the weta was engaged in when located, the weta's position in the cage according to the grid reference marked on the floor of the cage, and the height of the weta in the cage (figure 3.1a), the object or type of foliage the weta was in, or on, and the room temperature.

Field weta

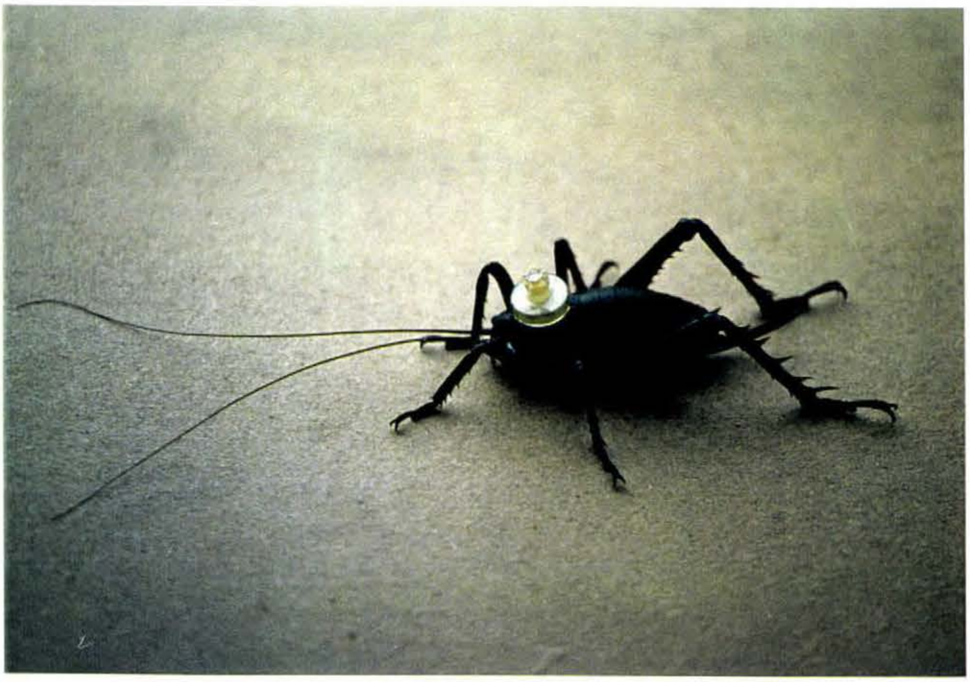
When weta were followed during the night the following data was recorded each quarter or half hour: What the weta was doing when located, the type of foliage the weta was in or on (eg. browsed or unbrowsed gorse; on grass), the time and the temperature. A numbered clothes peg was then placed as close to the weta as possible without disturbing it. The peg number and distance from the peg to the weta was noted so that adjustments could be made the following day when the weta movement was measured betwen pegs. The dimensions and brief description of all gorse bushes weta were found on during the study were recorded. This included bush height and width, maturity and percentage browsed by goats. The heights from the ground, the distance into the bush, and the distance to the next peg were measured for each peg. The distance from the first peg to the last was recorded as an estimate of the distance the weta moved between rest sites on adjacent days.

3.5 Statistical Analysis

Difference between two means was tested using the student t-distribution and differences between frequences were tested using the chi-square goodness of fit (Zar 1974).

Plate 3.1 Female Mahoenui weta (yellow morph) with an identification number painted on the pronotum

Plate 3.2 Female Mahoenui weta (brown morph) fitted with a button-shaped betalight.



CHAPTER FOUR

DEVELOPMENT, MORPHOLOGY AND LIFECYCLE OF MAHOENUI WETA

AIM

To provide a detailed description of the morphology, lifecycle and lifespan of Mahoenui weta.

INTRODUCTION

Several studies have involved investigation on the external morphology, lifecycles and lifespan of *Deinacrida* weta. Ramsay (1955) described the lifecycle of *D. rugosa* on Stephens Island, Richards (1973) described and compared aspects of development and morphology together with the lifecycles of *D. heteracantha* and *D. fallai*, and recently Sherley and Hayes (1993) made generalisations about the lifecycle of Mahoenui weta based on the estimation of instars present at Mahoenui reserve, and on information from captive rearing.

My aim was to make a detailed study of the external morphology and lifecycle of Mahoenui weta. Firstly I attempted to determine incubation time of the eggs, describe eclosion and investigate the percentage hatch in captivity. I also determined the weta colouration at eclosion, the proportion of the two colour morphs present as these weta developed and the sex ratio.

Secondly I investigated the number of instars and the size range of their head capsule widths, pronotum lengths, and female ovipositor lengths for each instar, together with their weight change during development. The intention was to establish a range of measurements that could be used to determine the instar of weta.

Thirdly each nymphal stadium was determined together with the longevity of adult weta. The instars present during the four seasons of the year were determined when they were either at the Mahoenui reserve or in captivity. An attempt was also made to determine the causes and rate of mortality of Mahoenui weta during different instars.

METHODS:

Collection and maintenance of captive weta:

Details on how weta were collected and maintained are given in Chapter 3, Sections 3.1 - 3.3.

Monitoring growth of captive Mahoenui weta:

Captive weta were weighed to the nearest 0.5 g each week on a laboratory balance. Whenever ecdysis occurred the weta were remeasured and marked with an identification number.

Maintenance of Mahoenui weta eggs:

Eggs were left undisturbed in soil where they were laid. This soil was kept moist but care was taken not to saturate it with water. The containers of eggs were then left in a cool shady place to prevent the soil drying out. Near the estimated time of eclosion the eggs and containers were placed inside 4 litre ice cream containers with mesh lids to prevent any emerging weta from escaping.

RESULTS

4.1 Mahoenui weta eggs:

4.1.1 Incubation:

Mahoenui eggs are brown in colour. They are oval and 7.0 mm in length by 2.5 mm at their widest part. The anterior pole is rounded and the posterior pole is slightly pointed and may be darker in colour (Plate 4.1).

Moist soil was essential for the development of eggs. Eggs left in dry soil quickly dessicated and shrivelled. Partly shrivelled eggs were able to take up moisture and become fully rounded again.

During incubation the eggs increased in size to 8 mm by 3 mm and the weight of the egg increased from 0.222 g soon after oviposition to 0.038 g for a fully developed egg close to eclosion. The choirion alone of hatched eggs weighed 0.015 g. The egg chorion became brittle prior to eclosion.

Table 4.1 - Egg weights for Mahoenui weta.

Egg type	Weight (grams)
Under developed	0.022
Mid developed	0.030
Fully developed	0.034 - 0.038
Chorion	0.015

Eggs laid between March and late April hatched approximately 10 months later in January and February the following year. Those laid in March and early

April 1992 hatched between 3rd January and 2nd February 1993. Eggs laid in late April 1992 hatched between 11th February and 18th February 1993 (Table 4.3).

4.1.2 Eclosion:

When near eclosion many eggs appeared on the surface of the soil. Here they remained from a few days to a few weeks until eclosion. Eclosion occurred only during the night. The choiron of hatched eggs were split in the region of the anterior pole and the split extended down one side of the chorion to about half way down the shell.

Eggs in a single batch did not hatch all at once but did so over a period of several days (Table 4.2).

Table 4.2 - Variability in hatching periods amongst Mahoenui weta eggs.

Batch	Number of days between first and last recorded hatch
D	9
C	7
E	8
G	14
F	5
Mean	8.6
Standard deviation	3.4

4.1.3 - Percentage hatch:

The percentage of eggs that hatched successfully was low compared with the total number of eggs laid. Only 58 weta hatched (Table 4.3) from 300 eggs laid, a success rate of about 20%. A search of the soil in each batch of eggs made in April 1993 well after eclosion had finished revealed that the number of hatched shells located in the soil was about twice the number of weta recorded as having hatched. This indicates that hatching success was higher, nearer 40% (Table 4.4).

Table 4.3 - The date of weta hatchings and the number of hatched weta collected the following day.

Date laid	Date hatched	Number of weta emerging from eggs
March to April 8th, 1992	3-1-93	9
	4-1-93	1
	5 to 12-1-93	11
	19-1-93	4
	20-1-93	3
	23-1-93	4
	24-1-93	3
	25-1-93	4
	27-1-93	6
	2-2-93	1
Late April 1992	11-2-93	3
	13-2-93	2
	14-2-93	1
	17-2-93	1
	18-2-93	1
Total Hatch		58

Table 4.4 - Mahoenui weta eggs remaining in the soil after the eclosion period for nymphs.

Batch	No of eggs in batch	No of hatched chorions	No of unhatched eggs	Recorded number hatched
D	38	15	3	21
H	?	17	10	1
F	39	29	9	9
E	?	21	67	5
C	38	8	6	9
Totals		90	95	45

4.2 Colouration:

Newly hatched Mahoenui weta were pale jade green in colour with some brown to black pigmentation at the edges of their body sclerites and on the tips of the legs (Plate 4.2). The amount of brown pigmentation increased at the 2nd instar where little green was visible. The colour darkened at each instar and after 3rd instar no green was visible at all.

Two colour morphs are present in the Mahoenui weta population. One colour morph is medium to dark brown with grey arthrodial membranes between its body sclerites and speckled gray on the ventral side of the abdomen. The other colour morph is predominantly yellow overlaid with brown specked patches. The brown patches increase in relative area at each moult so that these weta often become browner overall dorsally in later instars. The arthrodial membranes between the tergites always remain yellow and there is also always speckled yellow present on the ventral side of the abdomen.

There was a significantly higher proportion of yellow female morphs than yellow males collected at Mahoenui reserve . chi square: p $(x^2>8.3) = 0.005$. 27% of all female weta were the yellow morph and 73% were brown (total 195 individuals). 15% of all male weta were the yellow morph and 85% were brown morph (total 190 individuals). In total of 385 weta recorded 21% were yelow and 79% brown.

4.3 Sex ratio:

The sex ratio of Mahoenui weta was not significantly different from 1:1 p $(x^2<0.01) = 001$ with 197 males and 195 females being observed between November 1991 and February 1993.

4.4.1 Number of instars and size range of instars:

Mahoenui weta passed through nine nymphal instars and reached adult at 10th instar when reared in captivity from egg.

Dimensions of head capsule width and pronotum length from 1st to 10th instar, for male and female Mahoenui weta and female ovipositor length from 4th instar to adult from nymphs reared from eggs or after collection are given in Table 4.5. The sex of 1st to 3rd instars was difficult to determine so male and female 1st to 3rd instar were grouped together.

Table 4.5 The range of measurements for female and male Mahoenui weta, instars 1-10, for measure of pronotum length, head capsule width and female ovipositor length, instars 4-10. Instars 1 to 3 have combined data for male and female.

	INSTAR	1	2	3	4	5	6	7	8	9	10
Female	Pronotum (mm)	1.6-1.8	2.1-2.4	2.5-3.0	3.1-3.6	3.9-4.6	4.8-6.0	6.0-7.4	7.1-8.6	8.4-10.0	9.2-13.5
	Head (mm)	1.9-2.1	2.4-2.6	2.9-3.2	3.4-3.7	4.2-4.6	5.0-5.7	5.5-6.9	6.8-7.8	7.7-9.4	9.0-12.0
	Ovipositor (mm)	-	-	-	0.5-0.7	1.6-2.2	2.3-3.5	4.1-6.6	8.0-12.5	17.0-21.7	18.3-25.6
Male	Pronotum (mm)	1.6-1.8	2.1-2.4	2.5-3.0	3.4-3.7	4.0-4.6	4.9-5.6	5.6-7.7	6.8-8.9	8.1-9.8	9.4-11.4
	Head (mm)	1.9-2.1	2.4-2.6	2.9-3.2	3.4-3.7	4.0-4.6	5.0-5.5	5.8-7.4	6.4-8.2	7.4-9.4	9.0-10.1

Table 4.6 The average pronotum length, head capsule width, and female ovipositor length calculated from (a) Mahoenui weta raised from captive eggs , and (b) combined both weta raised from eggs and weta collected at Mahoenui and raised to adults. Instars 1 to 3 have combined data for male and female weta.

	INSTAR	1	2	3	4	5	6	7	8	9	10
Female (a)	Pronotum (mm)	1.7	2.2	2.7	3.4	4.3	5.4	6.7	8.2	9.5	-
	Head (mm)	2.0	2.5	3.0	3.5	4.4	5.3	6.4	7.7	8.8	-
	Ovipositor (mm)	-	-	-	0.6	2.0	2.8	5.5	11.2	20.7	-
Male (a)	Pronotum (mm)	1.7	2.2	2.7	3.4	4.3	5.3	6.3	7.4	8.5	-
	Head (mm)	2.0	2.5	3.0	3.5	4.3	5.2	6.0	7.4	8.1	-
Female (b)	Pronotum (mm)	1.7	2.2	2.7	3.4	4.3	5.4	6.7	7.9	9.2	10.8
	Head (mm)	2.0	2.5	3.0	3.5	4.4	5.3	6.3	7.4	8.5	10.1
	Ovipositor (mm)	-	-	-	0.6	1.9	2.8	5.4	10.1	19.1	21.2
Male (b)	Pronotum (mm)	1.7	2.2	2.7	3.4	4.3	5.3	6.6	8.0	9.1	10.2
	Head (mm)	2.0	2.5	3.0	3.5	4.3	5.2	6.4	7.4	8.5	9.7

The average pronotum length and head capsule width were calculated for male and female weta for each instar 1 to 10, and the average length of the female ovipositor for each instar 4 to 10 (Table 4.6). Two groups of weta were calculated, Group A - weta raised from eggs in captivity, and, Group B - combined weta raised from eggs and weta collected from Mahoenui and raised to adults.

Amongst weta from Group A there was no difference in the average pronotum length and head capsule width between the sexes of instars 4 and 5. Instar 6 females had slightly longer pronotums and wider head capsules than males. By instars 7 to 9 the differences in these measurements between females and males were quite marked but not significant.

There was no difference between the average measurements for pronotum length and head capsule width between the sexes for instars 1 to 9 in weta from Group B. Adult females had larger average measurements for pronotum length and head capsule width than adult males.

4.4.2 Growth rates:

Pronotum length, head capsule width and female ovipositor length showed an exponential increase in length between instar 1 to 10 with the exception of the ovipositor between instars 9 and 10 (Figure 4.1).

The pronotum length increase was the same as the head capsule but the ovipositor increased in length faster than both these. The ovipositor growth rate between instars 9 and 10 was at about the same rate as the head capsule and pronotum (Figure 4.2).

4.4.3 Weight change:

The mass of each weta constantly changed during each instar (Figure 4.3). Weta showed a decrease in weight prior to ecdysis and an increase in weight after ecdysis. Between moults weta increased to a peak weight which fluctuated depending on how long the weta remained in the particular instar.

Male and female instars 1 to 6 had similar mean maximum weights and their masses had similar ranges. Female instars 7 to 10 had increasingly heavier maximum weights and larger ranges than males (Table 4.7). The maximum weights and dimensions increased exponentially from instar 1 to instar 10 for both males and females (Figure 4.4).

4.5 Instar estimation:

A range of measurements for pronotum length, head capsule width and ovipositor length, best fitted to each instar, was estimated from the results of captive reared weta (Table 4.8). Weta of unknown instar could be measured and a good estimate of the instar number of the weta could be made (Figure 4.5, 4.6) The peaks in the frequency graphs for Mahoenui weta measured at the Mahoenui reserve should coincide with the mean estimated measurements for pronotum, head capsule and ovipositor length for each instar.

Figure 4.1

Average head capsule widths, pronotum lengths and ovipositor lengths of (a) male and (b) female Mahoenui weta collected and reared in captivity.

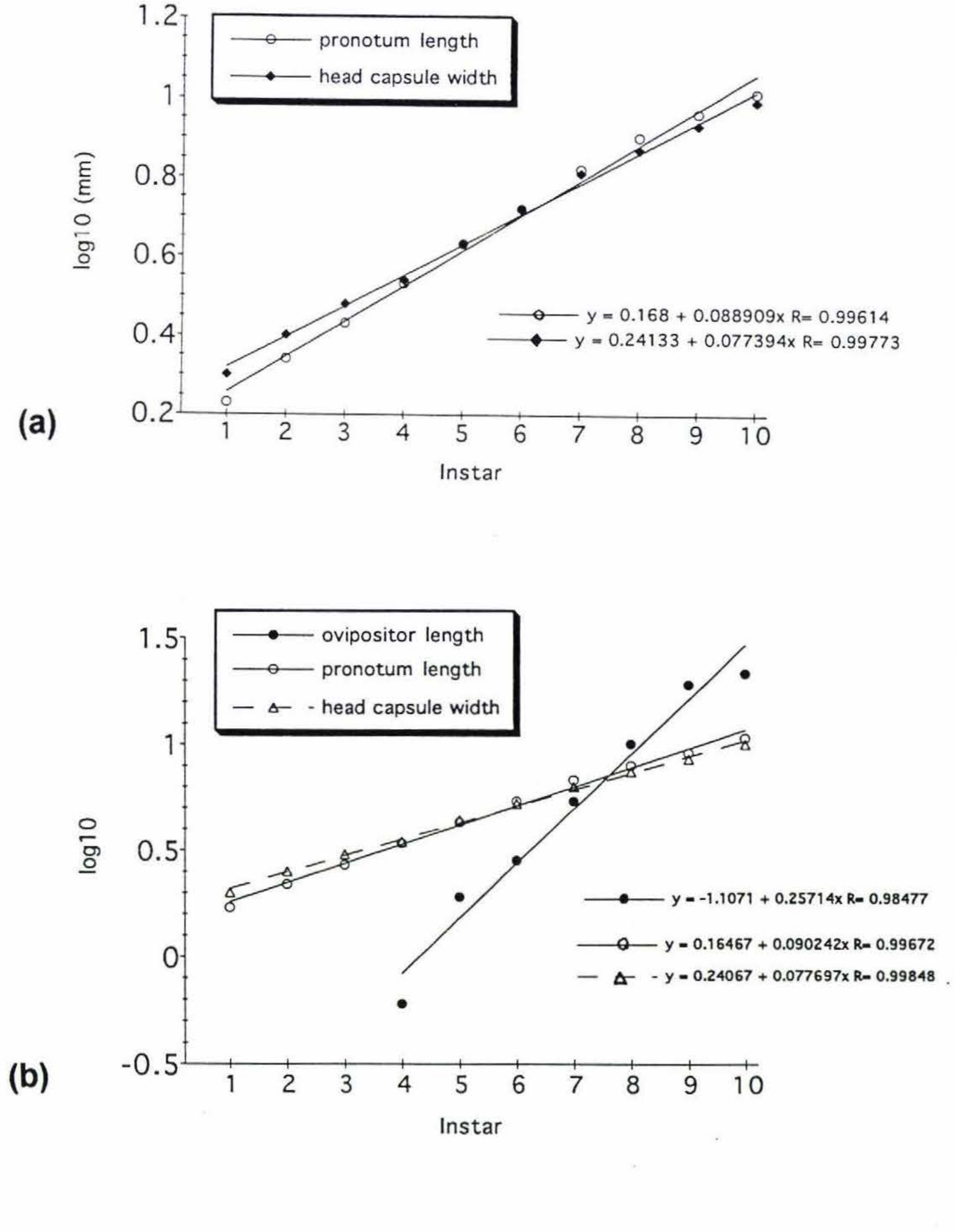
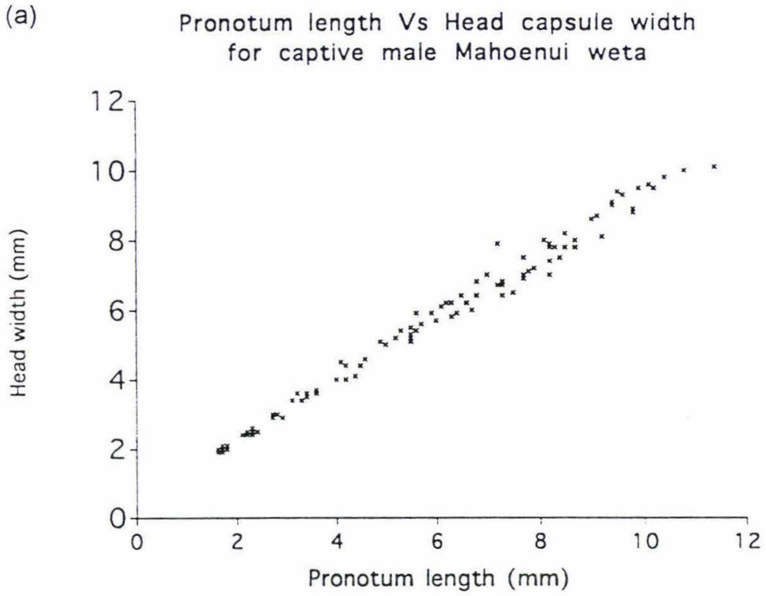
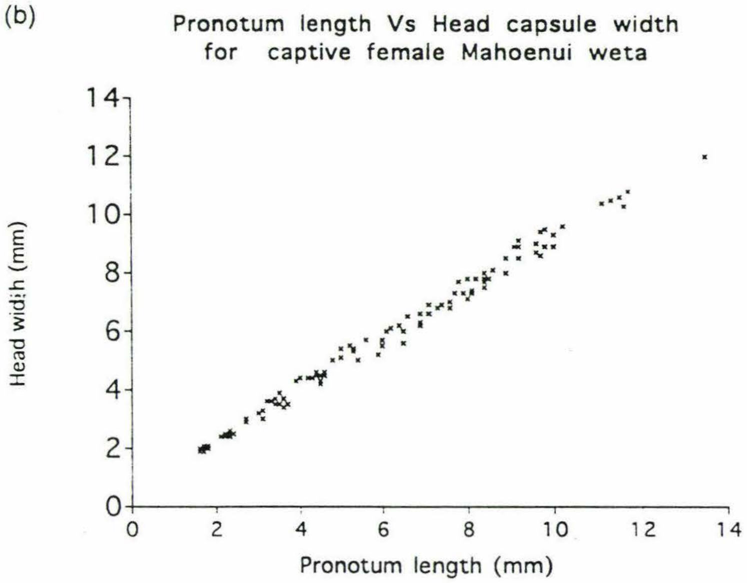


Figure 4.2 (a-c)

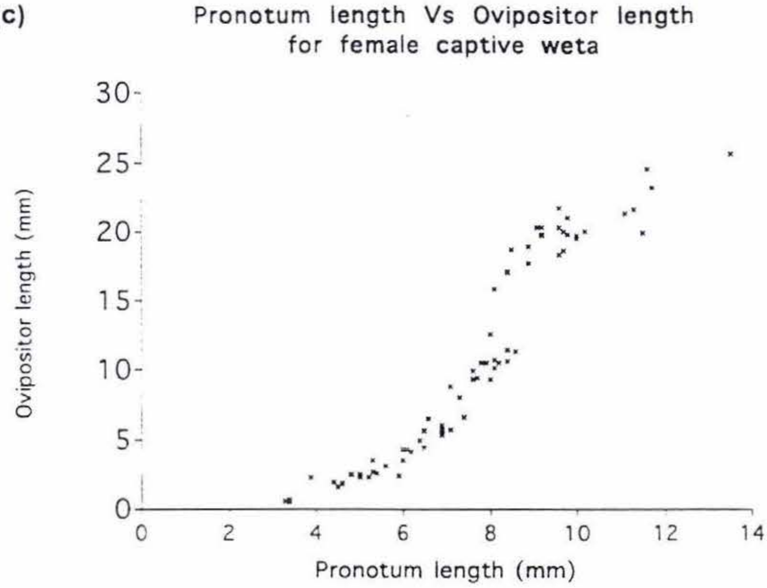
(a)



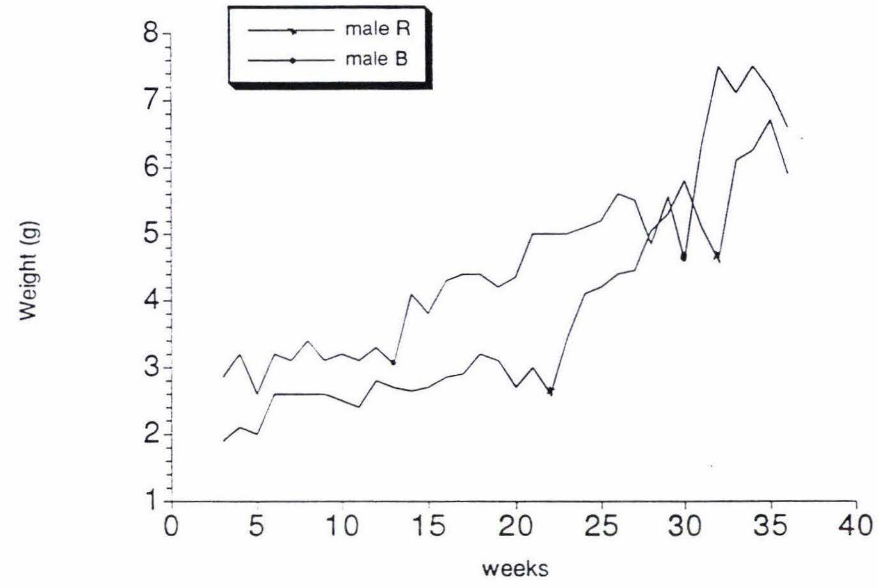
(b)



(c)



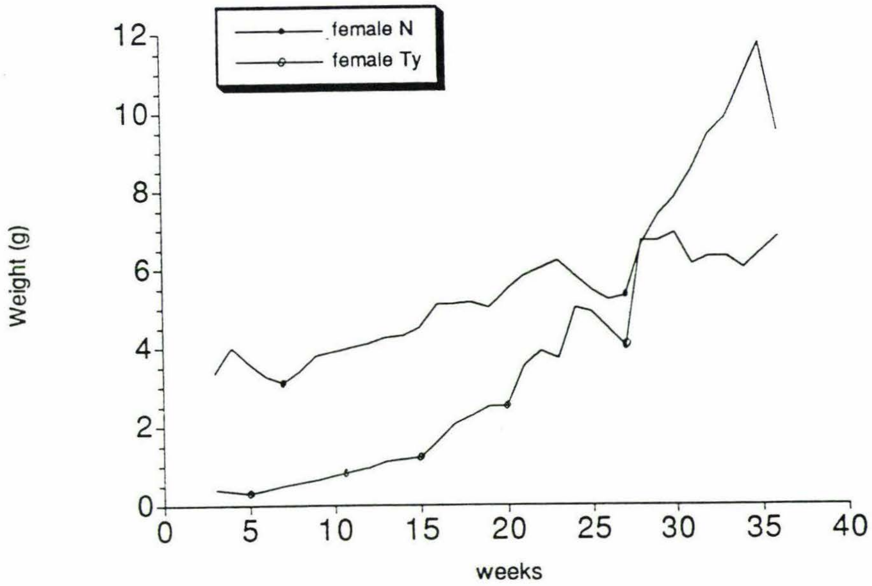
Pronotum length Vs Ovipositor length for female captive weta



Weight change for two male Mahoenui weta

Figure 4.3 (a)

Examples of change in mass of two male Mahoenui weta between instars 8 and 10. Ecdysis is indicated by marks.



Weight change for two female Mahoenui weta

Figure 4.3 (b)

Examples of change in mass of two Female Mahoenui weta between instars 4 and 10. Ecdysis is indicated by marks.

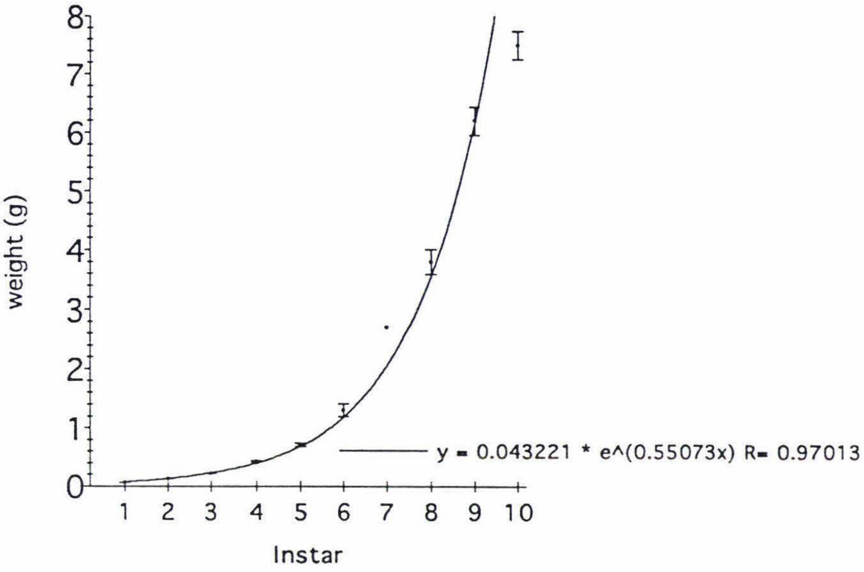
Table 4.7 The mean maximum weight oof male and female Mahoenui weta between 1st and 10th instars. Data for male and female are combir together for instars 1st to 4th.

	MALE				FEMALE			
Instar	Mean peak weight	S.E.	N	Total weight range	Mean peak weight	S.E.	N	Total weight range
1	0.06	4x10-4	5	0.03-0.06	0.06	4x10-4	5	0.03-0.06
2	0.13	3x10-3	4	0.07-0.13	0.13	3x10-3	4	0.07-0.13
3	0.22	0.01	4	0.12-0.25	0.22	0.01	4	0.12-0.25
4	0.43	9x10-3	5	0.19-0.46	0.43	9x10-3	5	0.19-0.46
5	0.71	0.03	3	0.55-0.77	0.70	0.03	6	0.53-0.80
6	1.3	0.11	3	0.85-1.45	1.3	0.12	5	0.68-1.6
7	2.7	-	1	1.1-2.7	2.9	0.40	2	1.5-3.3
8	3.8	0.21	9	1.7-4.9	4.2	0.26	8	2.2-5.0
9	6.2	0.24	11	3.1-7.9	7.5	0.40	13	3.9-9.1
10	7.5	0.24	10	5.8-9.2	13.7	1.10	11	7.0-21.0

Table 4.8 Range of measurements for pronotum length, head capsule width and female ovipositor length, that best fit each instar from 1-10.

FEMALE	1	2	3	4	5	6	7	8	9	10
Pronotum length mm	1.5-1.9	2.0-2.4	2.5-3.0	3.1-3.7	3.9-4.7	4.8-6.0	6.1-7.4	7.5-8.8	8.9-10.3	10.4+
Head capsule length mm	1.8-2.2	2.3-2.7	2.8-3.1	3.2-3.8	3.9-4.7	4.8-5.7	5.8-6.8	6.9-8.0	9.1-9.5	9.5+
Ovipositor length mm	-	-	-	0.5-1.0	1.5-2.2	2.3-3.6	4.0-7.0	7.1-14.0	15.0-22.0	18.0-27.0
MALE										
Pronotum length mm	1.5-1.9	2.0-2.4	2.5-3.0	3.1-3.7	3.9-4.7	4.8-5.9	6.0-7.2	7.3-8.5	8.6-9.8	9.9+
Head capsule length mm	1.8-2.2	2.3-2.7	2.8-3.1	3.2-3.8	3.9-4.7	4.8-5.6	5.7-6.7	6.8-7.8	7.9-9.1	9.2+

(a) Mean peak weight of male Mahoenui weta



(b) Mean peak weight of female Mahoenui weta

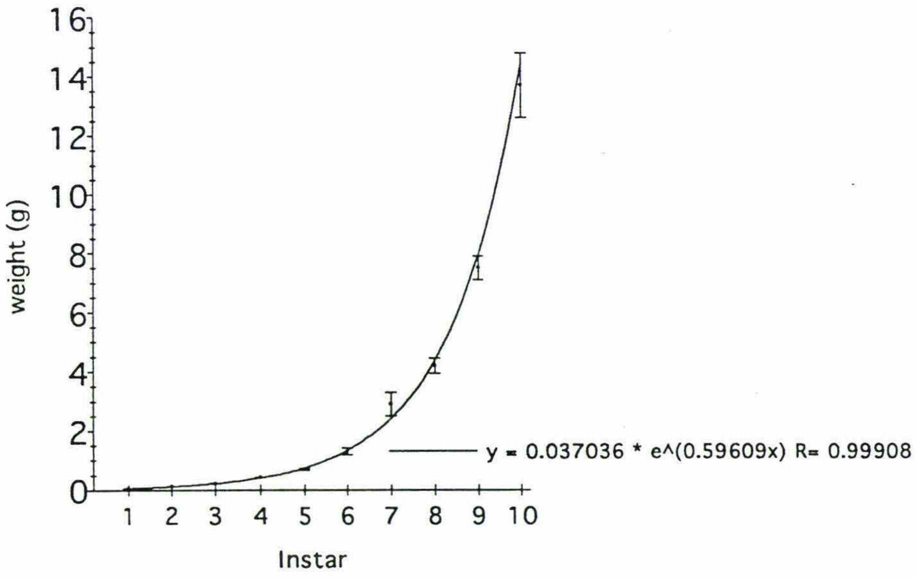


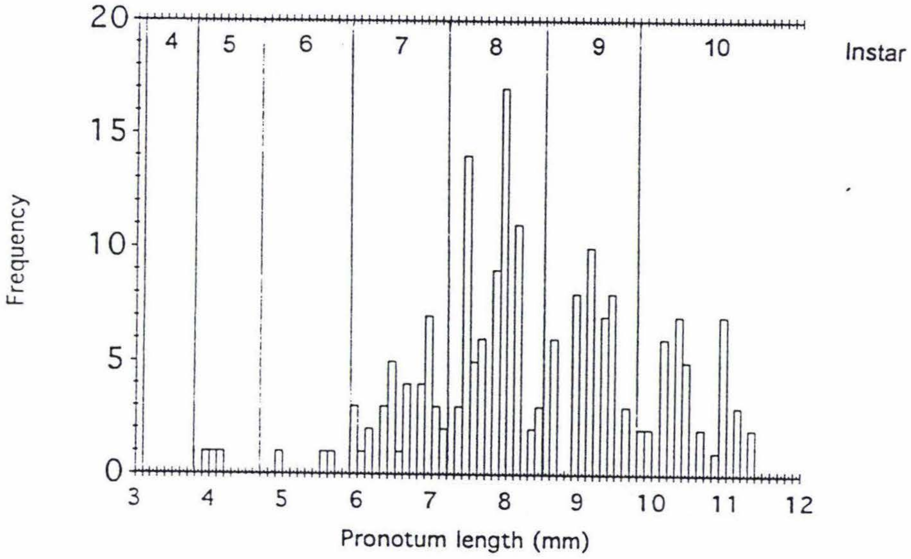
Figure 4.4

Average maximum weights for (a) male and (b) female Mahoenui weta. Bars give standard error.

Figure 4.5

Distributions of (a) pronotum length and (b) head capsule width of male Mahoenui weta recorded at Mahoenui reserve. The suggested instars are shown across the top axis of the graphs.

(a) Pronotum lengths for 194 Male Mahoenui weta



(b) Head capsule width for 194 male Mahoenui weta

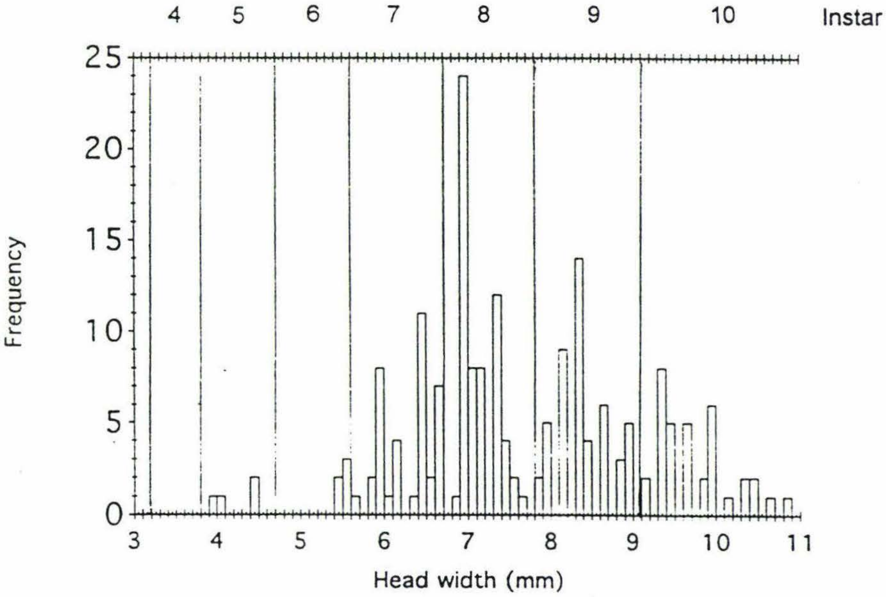
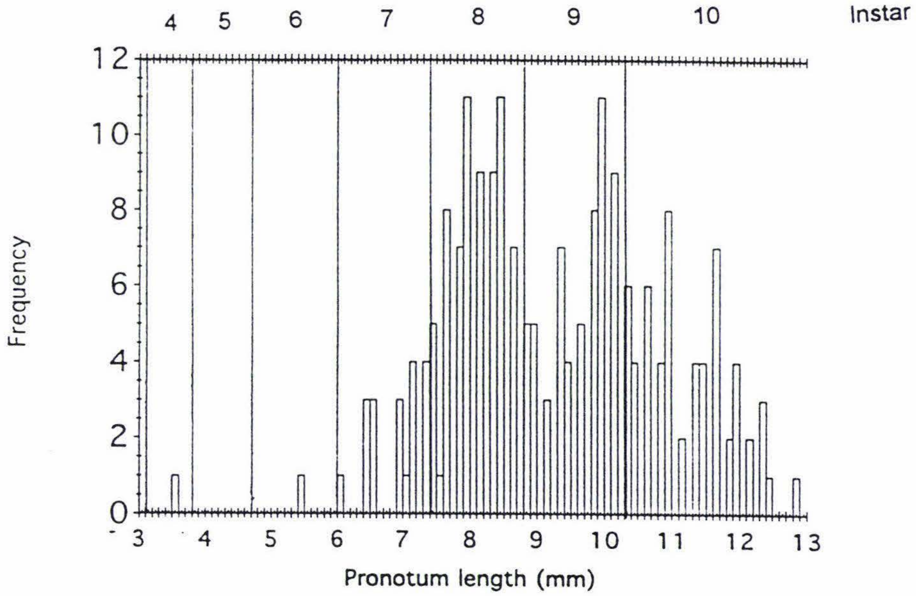


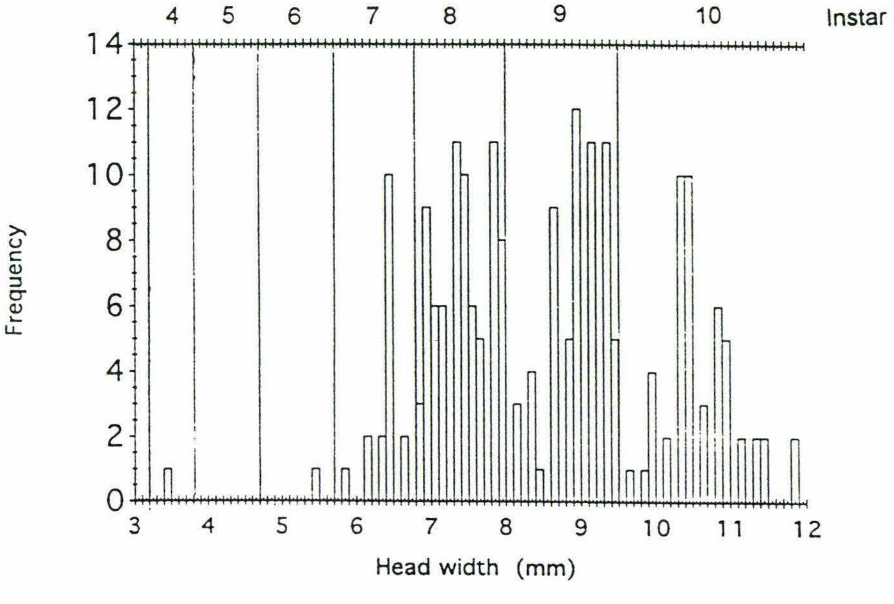
Figure 4.6

Distributions of (a) pronotum length, (b) head capsule width and (c) ovipositor length of female Mahoenui weta recorded at Mahoenui reserve. The suggested instars are shown across the top axis of the graphs.

(a) Pronotum length for 205 female Mahoenui weta



(b) Head capsule width for 205 female Mahoenui weta



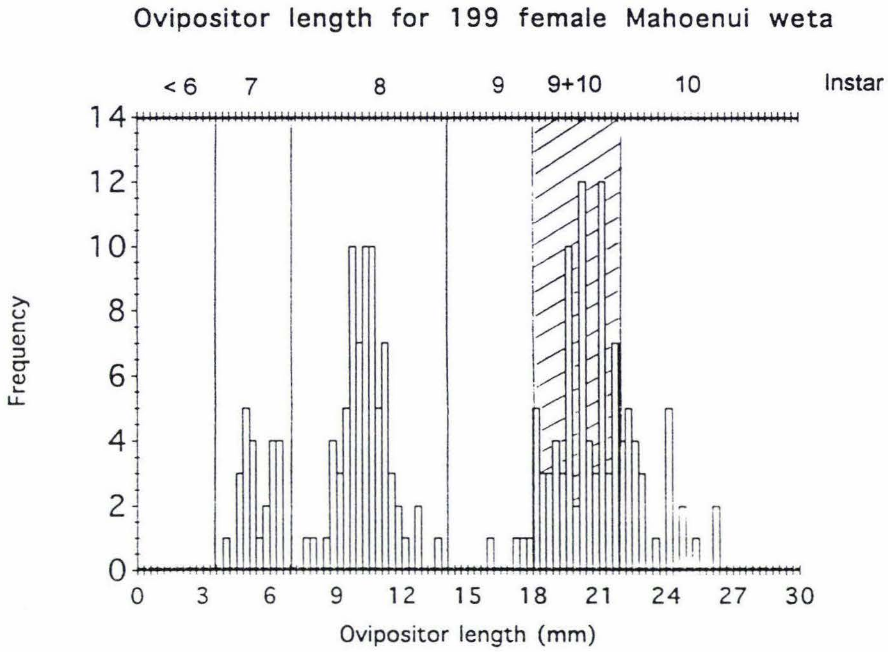

Ovipositor length for 199 female Mahoenui weta
< 6
7
8
9
9+10
10
Instar
Frequency
0
2
4
6
8
10
12
14
0
3
6
9
12
15
18
21
24
27
30
Ovipositor length (mm)

Figure 4.6 (c)

4.6.1 Duration of stadia

Approximate durations of stadia for individual captive Mahoenui weta are given in Table 4.9. Stadia 8 and 9 showed a large variation whereas there was less variation in stadia 5 to 7. However this may be due to the small sample size of these latter stadia.

Instars 1 to 3 were each observed to have stadia of one month. The stadia of 4 to 7 ranged from 1 to 4 months and averaged less than two months except for instar 5 which averaged 2.3 months. The duration of stadium 9 averaged 3.4 months. This was never less than two months, but it ranged up to 5 months (Table 4.10).

4.6.2 Longevity of adults:

Adults showed a large variation in longevity. Males lived between 44 to 331 days whereas females lived between 92 to 356 days (Appendix 2). The average lifespan for all adults was 169 days (standard error 20 days) and for males it was 149 days (standard error 27 days) with females being 189 days (standard error 31 days). The difference between lifespans of males and females was not significant (t = 0.9780, p.0.05).

Table 4.9 The duration of instars 4-9 for male and female Mahoenui weta held in captivity

	Range (Days)		Mean (Days)			
Instar	Male	Female	Male	N	Female	N
4		25			25	1
5		28-42			35	2
6	33	25-34	33	1	30	2
7	36	36-38	36	1	37	2
8	42-185	44-70	113	5	58	3
9	52-162	60-151	89	10	106	6

Table 4.10 Duration the nearest month of instars 1 to 9.

Months in Nymphal Instar...............

Instar	1	2	3	4	5	6	Average	Range	N
1	5						1	1	5
2	5						1	1	5
3	8						1	1	8
4	7	3	1				1.5	1-3	11
5	5	2	2	3			2.3	1-4	12
6	5	2	-	1			1.6	1-4	8
7	3	2	1				1.7	1-3	6
8	2	2	1	1	-	2	3.1	1-6	8
9	-	4	-	2	3		3.4	2-5	9

4.6.3 Overwintering:

Mahoenui weta spent an increased period of time in each instar during the cooler part of the year (Table 4.11). The time of moulting was only known for these 12 captive reared weta. None of these weta moulted in June and July and only one moulted in August. The majority moulted again in September. This suggests that June to September was the main overwintering period for captive weta. Four weta showed increased duration of this stadia in March and April and three remained in the overwinter phase until October and November. The average overwinter period of a single stadium was 4.5 months (SE = 0.31).

The overwinter period recorded for weta at Mahoenui reserve was based on weta relocations of marked individuals (Table 4.12). Thus weta found for the first time later in the season may not have moulted for some time previously and this data from them may reduce the estimated overwintering period. None of the relocated weta had moulted by August and September but most that were relocated in early October had also not moulted. The main overwintering period appeared to be between July and October. Four weta did not moult from April/May to October and four others did not mould until November/December. The average overwintering period was estimated at 4.8 months (SE = 0.41).

Table 4.11 "Over winter" period recorded for Mahoenui weta in captivity

[Note: M = moult]

	March	April	May	June	July	August	September	October	November	No of mths
1				+	+	+	M			33
2			+	+	+	+	M			4
3				+	+	+	M			3
4			+	+	+	+	M			4
5			+	+	+	+	M			4
6				+	+	+	+	+	M	5
7	+	+	+	+	+	+	M			6
8				+	+	+	+	+	M	5
9	+	+	+	+	+	+	M			6
10	+	+	+	+	+	+	M			6
11				+	+	+	+	M		4
12		+	+	+	+	M				4
TOTAL	3	4	7	12	12	11	3	2		x = 4.5 S.E. + 0.31

Table 4.12 Durations of Mahoenui weta studied at the reserve over winter. Exact moult dates are unknown. Each sighting of a marked weta i recorded as a "+" until it moulted.

	April	May	June	July	August	September	October	November	December	No of mths
1	+	+	+	+	+	+	+			7
2					+	+	+	+		4
3					+	+	+			3
4				+	+	+	+			4
5			+	+	+	+				4
6			+	+	+	+	+			5
7			+	+	+	+	+	+	M	6
8				+	+	+	+	+		5
9					+	+	+			3
10		+	+	+	+	+	+	+		7
11		+	+	+	+	+	+			6
12		+	+	+	+	+	+			6
13					+	+	+			3
TOTAL	1	4	7	9	13	13	12	4		x 4.8 S.E. = 0.41

4.7.1 Instars present during four seasons:
Autumn, winter, spring & summer.

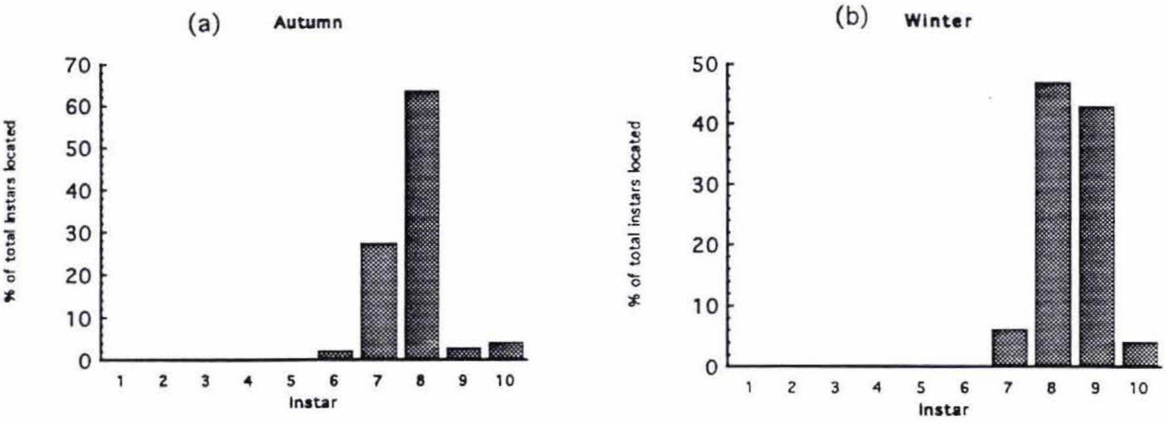
Weta observed at Mahoenui reserve were segregated into autumn, winter, spring and summer captives. They were then allocated as to instar in accordance with the size ranges given in Table 4.8 (Appendix 3a). They were converted to percentages (Appendix 3b) to compensate for uneven sample sizes for being different seasons. The results were similar for male and female weta.

In autumn instars number 8 (64%) and 7 (27%) predominated but a small percentage of 6th, 9th and 10th instar weta were found. Instars 8 and 9 predominated in winter. These represented 47% and 43% respectively of the weta found. A small percentage of 7th and 10th instar weta were also located. The predominant instars during spring were 9 (57%) and 8 (27%) with a small percentage of 4th, 5th and 7th instars. 10% of the weta were adults in spring whereas most weta (60%) were adults in summer, 21% were 9th instar and 10.3% were 7th instar. A small percentage of 5th, 6th and 8th instar weta were located (Figure 4.7).

No instars 1 to 3 were located at the reserve and only small numbers of instars 4 to 6 were found. This was most likely due to their small size. 7th instar weta were located in moderate numbers while instars 8 to 10 were more readily located.

Amongst captive weta 4th and 8th instar weta were the predominart instars (19% for each instar) in autumn and instars 2 to 10 were present in lower numbers (Appendix 4b, Figure 4.8). The predominant instars during winter were instars 8 (27.5%) and 9 (29.4%), and a small peak in instar 6 weta (14%). Instars 4 to 10 were all present in lower numbers at this time. During spring the predominant instars were 9 (28.1%) and 10th instar adults (25%). The instars 4 to 10 were all present in lesser numbers. Adults were predominant (42.9%) along with 1st instar weta (36.7%) during summer.

Maximum numbers for each instar during the four seasons at Mahoenui reserve coincided with the maximums of the captive weta between instars 6 to 10 (Figure 4.9).



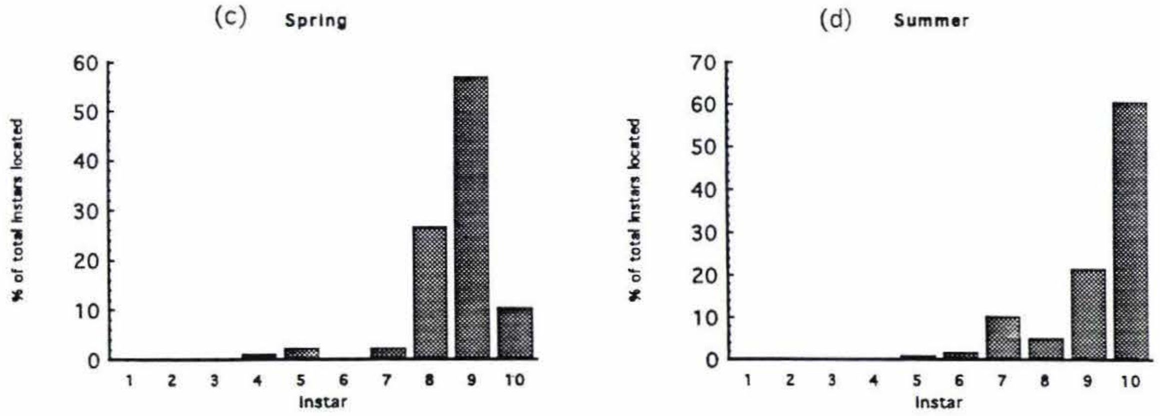


Figure 4.7

Percentages of each instar caught at Mahoenui reserve during (a) Autumn, (b) Winter, (c) Spring, (d) Summer.

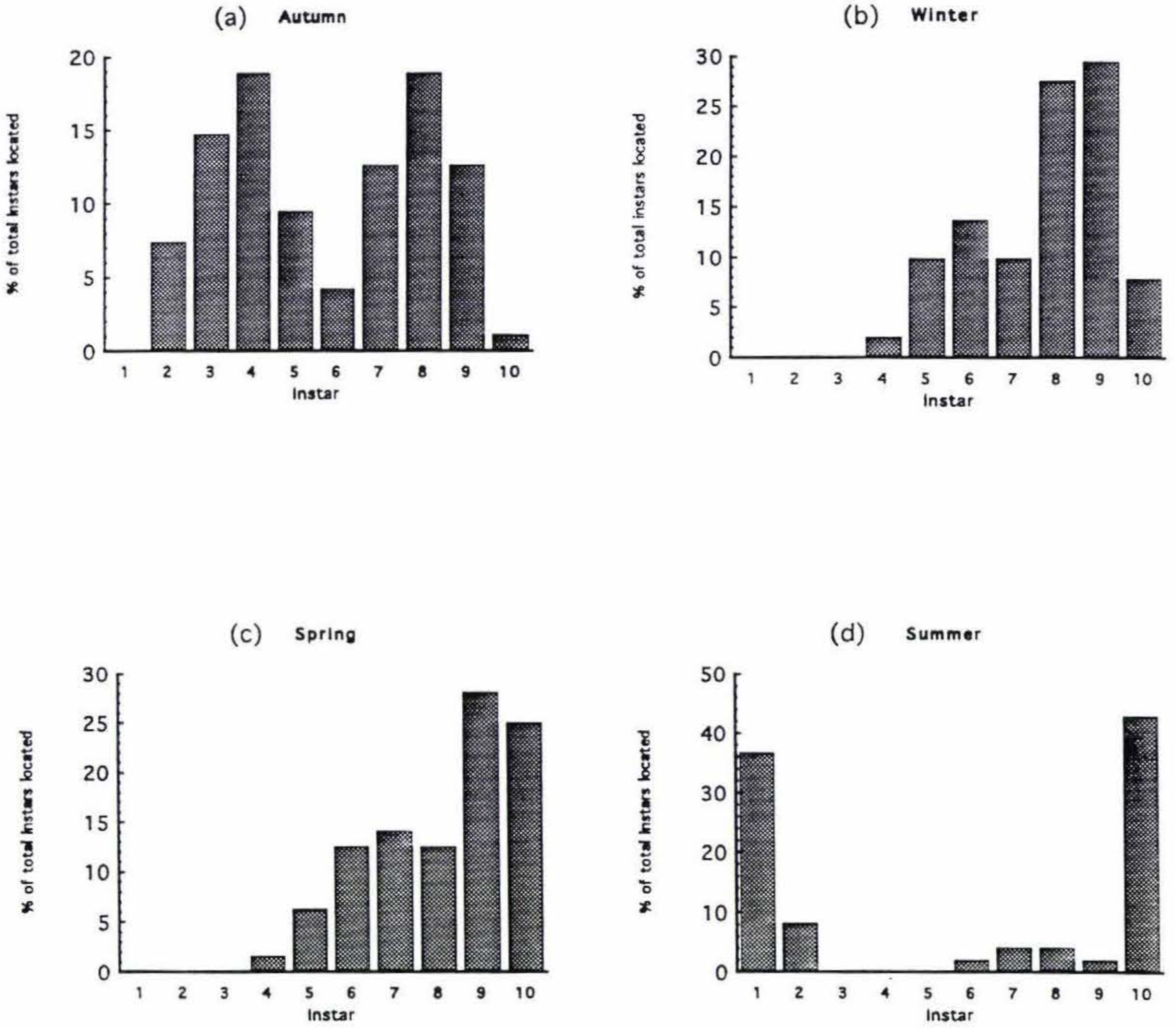
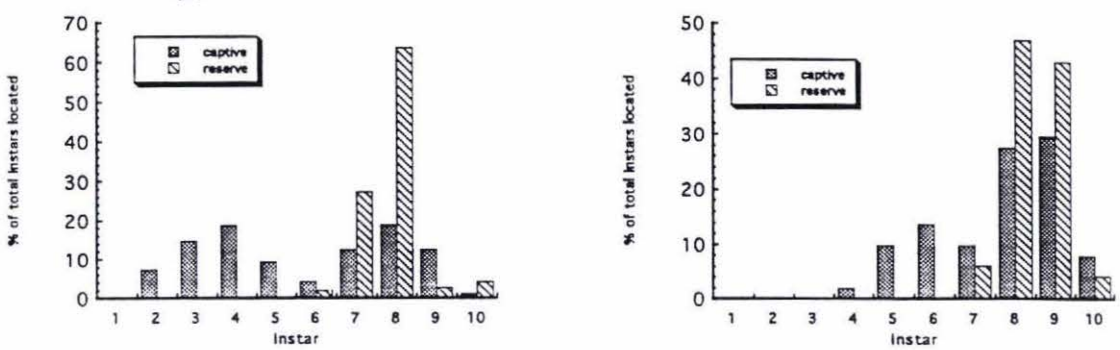


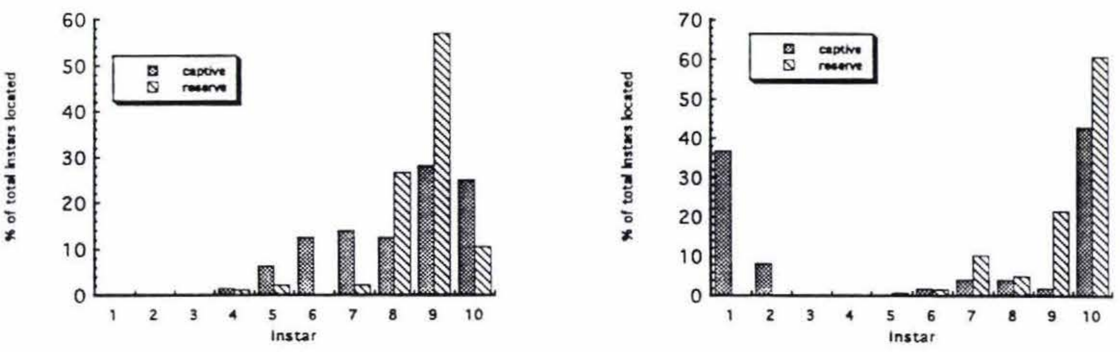
Figure 4.8

Percentages of each instar for captive Mahoenui weta during (a) Autumn, (b) Winter, (c) Spring, (d) Summer.



(a) Autumn

(b) Winter



(c) Spring

(d) Summer

Figure 4.9

Comparison between the percentages of each instar for Mahoenui weta caught at Mahoenui reserve and those in captivityduring (a) Autumn, (b) Winter, (c) Spring, (d) Summer.

4.7.2 Lifecycle of Mahoenui weta:

The growth rates through the instars of Mahoenui weta reared in captivity from eggs and from others reared from 4th or 5th instar when collected at Mahoenui are given between February 1992 and January 1994 in Figure 4.10. Male JB was collected from Mahoenui reserve in October 1992 and reared in captivity until it died as an adult in November 1993. Female JS was collected from Mahoenui reserve in October 1992 and reared in captivity until it died at 9th instar, in August 1993. Female Ty was hatched in captivity from eggs incubated at a constant temperature until eclosion in September 1992. Female Ty reached 9th instar before overwintering and died as an adult in January 1994. Females E and J were hatched from eggs held under natural (variable) conditions. Female E hatched in early January 1993, reached 8th instar in August 1993, and overwintered as 8th instar until November 1993. It was still a 9th instar on 12th January 1994. Female J hatched in late February 1993 and reached 4th instar in May, 1993. It then overwintered as instar 4 until September 1993. It was still at instar 7 on 12th January 1994.

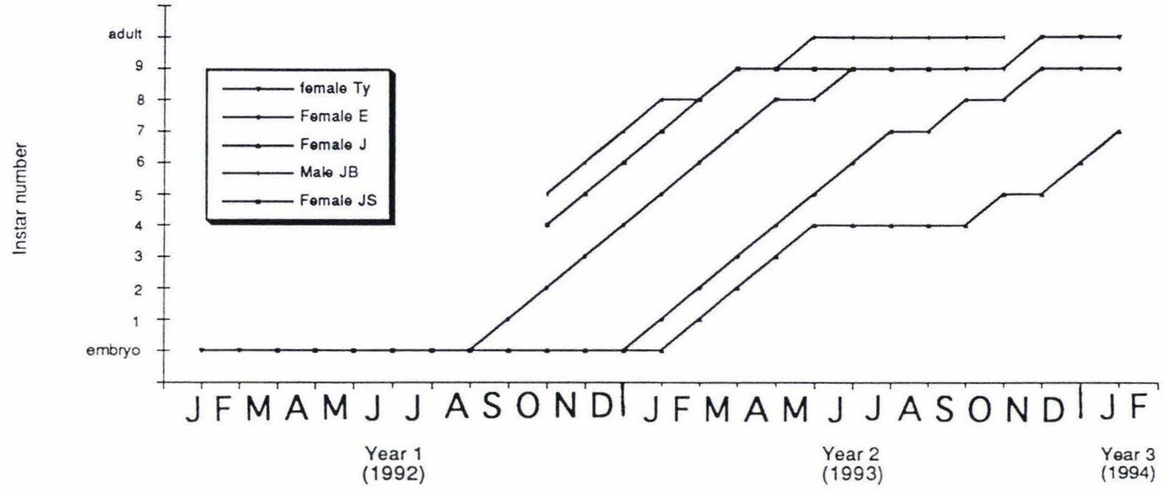


figure 4.10

Lifecycles of five Mahoenui weta reared in captivity. From eggs, Ty, E, and J, or collected from Mahoenui reserve as nymphs, and then reared in captivity, JB and JS.

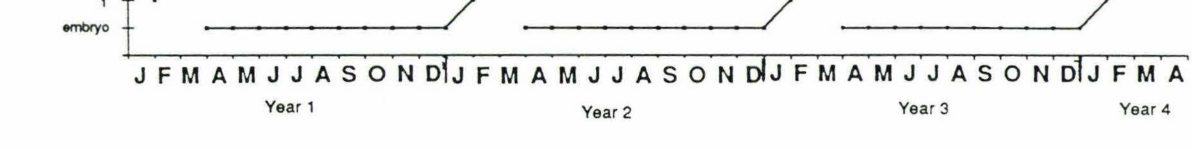


figure 4.11

Generalised lifecycle for Mahoenui weta hatched in january/febuary from eggs layed in march the previous year. Each line in the graph represents one generation of Mahoenui weta.

4.7.3 Lifespan of Mahoenui weta:

The shortest total lifespan I recorded for Mahoenui weta was 25 months (female Ty). The egg incubation time was eight months at a constant temperature of 18°C. Female Ty took then 14 months from eclosion to reach adult and lived for a further 3 months.

The lifespans of other weta reared in captivity from eggs are to date; 11 months from eclosion to instar 7 for two females and one male, and 12 months from eclosion to instar 8 and 9 for two males and 1 female. From the generalised lifecycle (Figure 4.11) the lifespan for Mahoenui weta was estimated to be 3 years, 1 month, if assuming adult weta live for 3 months.

4.8 Mortality of Mahoenui weta:

Known causes of death observed for Mahoenui weta in captivity were severe damage to appendanges during ecdysis, failure to complete ecdysis, cannibalism during ecdysis, fungal attacks to the weta exoskeleton, and old age. Accidental deaths included nymphs instar 1 to 3 drowning in water dishes and escape which resulted in death by dessication or starvation. Known causes of death observed at the Mahoenui reserve were failure to complete ecdysis and old age. No predation was observed there

CAUSES OF DEATH	Age class most likely affected			
	Eggs	Instars 1-6	Instars 7-9	Adults
Adverse environmental conditions	soil too dry or wet			
Misadventure		drowning and escape	escape	
Damage to appendages or failure to complete ecdysis		yes	yes	
Cannibalism during ecdysis		(captive)	(captive)	
Fungi	yes	?	yes	yes
Old age				yes
Predation	?	(reserve)	(reserve)	(reserve)

Table 4.13 Observed causes of mortality for Mahoenui weta in captivity or at Mahoenui reserve.

Mortality was high for nymphs of instar 1 to 6 in captivity. Only 14 weta remain to January 14th, 1994, from 58 weta hatched in January and February 1992. These 14 weta are 11-12 months old and presently range from 7th to 9th instar. Weta of 7th to 10th instar have a lower mortality rate than younger nymphs. 25 out of 41 weta (60%) collected at 7th to 9th instar from Mahoenui died as adults from old age. Two weta died during 7th instar, six died during 8th instar, five died during 9th instar, and three died during the final moult. Two of the latter failed to moult successfully and one died because of wounds caused during ecdysal cannibalism.

Plate 4.1 Mahoenui weta eggs one month after oviposition

Plate 4.2 Two day old Mahoenui weta nymph

DISCUSSION:

Richards (1973) suggested that some eggs of *Deinacrida heteracantha* had a winter diapause. Eggs of *D. heteracantha* and *D. fallai* laid between September and December have an average incubation period of 4.2 months whereas *D. heteracantha* eggs laid on 14th April hatch after 7.5 to 8.5 months. The incubation time for Mahoenui weta eggs laid between February and March was 10 months although one batch of Mahoenui weta eggs laid in February 1992 were kept at $18^{O}C$ and hatched after about 7.5 months in September. This suggests that the rate of development of the Mahoenui weta embryo is temperature dependant and supports Richards' (1973) suggestion of a winter diapause for some *D. heteracantha* eggs. Ramsay (1955) recorded the weight increase of developing *D. rugosa* embryos. There was a relatively small and slow increase in size and weight during winter (15.3 - 17.9 mg from February to August) and this suggested that the eggs were in diapause in winter and they developed relatively quickly with the onset of the warmer spring temperatures (17.9 - 35 mg from August to November). The incubation period for *D. rugosa* was 9 - 10 months (Ramsay 1955) much the same as for Mahoenui weta eggs, and the eggs were laid in April and May.

There appears to be an overwintering period where the growth of the embryo is slowed but not stopped completely for eggs of *D. rugosa* (Ramsay 1955), *D. heteracantha* (Richards 1973), and the Mahoenui weta, whose eggs are laid during late summer and autumn. *D. rugosa* and the Mahoenui weta are found at lower latitudes than *D. heteracantha* and *D. fallai* and they have the longest incubation which also suggests that a cooler climate affects the rate of development for *Deinacrida* embryos.

The rate of mortality was very high in Mahoenui weta as was described for *D. heteracantha* and *D. fallai* by Richards (1973), where the mortality rate was 97.6% and 99% in the two species, and by Ramsay (1955) who, after 11 months had 11 *D. rugosa* remaining (then at 7 - 9th instar) from 68 weta that hatched. Mortality decreased in later instars but was still high, about 60% for nymphs over 5th instar. The mortality rate for adults was very low.

Mahoenui weta eggs laid on the same day hatched over a period of several days. This could be advantageous to the dispersal of weta nymphs since cannibalism was the main cause of mortality amongst captive reared weta nymphs. Mahoenui weta raised individually rather than in groups had a much higher survival rate. At the Mahoenui reserve cannibalism would be less likely to occur due to the low densities of weta there.

There was an uneven proportion of the two colour morphs present in the Mahoenui population. One in every 4.8 weta were the yellow morph, and there was a higher proportion of yellow morph females than males. Sherley and Hayes (1993) also found more female yellow morphs (39%) than male yellow morphs (23%) in the Mahoenui population. They suggested that the distribution of the two colour morphs may have been correlated with sex.

The proportion of male to female weta was equal in the Mahoenui population, as was observed by Sherley and Hayes (1993). In Richards (1973) study of *Deinacrida heteracantha* and *D. fallai* there was a bias towards male weta of 1:4, however her weta species were raised in captivity which may have had some influence on the sex ratio and may not reflect the sex ratio of the natural populations.

Both male and female Mahoenui weta reared in captivity passed through nine nymphal instars to become adult at the 10th instar. There was no variation in the number of instars between individual weta. *D. fallai* (Richards 1973) and *D. rugosa* (Ramsay 1955) are also reported to pass through nine instars prior to becoming adult. *D. heteracantha* has an extra instar (Richards 1973).

The measurements of pronotum length, head width and ovipositor length within each instar varied between individual Mahoenui weta. This variation was small in younger nymphs (1st to 6th instar) and broader in older nymphs and in adults. The range of measurements of pronotum length and head width overlapped for instars 7 to 10. The range of measurements of female ovipositor length overlapped in instars 9 and 10. The average measurements for pronotum length and head capsule width indicated that male and female weta showed no sexual dimorphism in relation to size until instars 6 to 10. During these instars females became increasingly larger at each instar and were most obviously larger than males when adult. The range of measurements for Mahoenui prothorax and head width supplied by Barrettt in Sherley and Hayes (1993) suggested females were consistently larger after instar 4. My results do not correlate with this and since females were easily identified from instar 3 a mixup of sexes could be eliminated as a possible cause of error. Richards (1973) observed a difference in size between sexes from instar 6 where female *D. heteracantha* and *D. fallai* were larger which supports my results for the Mahoenui weta.

The weta collected at the Mahoenui reserve at 6th to 8th instar and reared to adult in captivity showed no obvious size difference between the sexes until they were adult. These appeared to be smaller adults than adults from Mahoenui reserve or adults reared from eggs in captivity. These small weta were raised in identical conditions to those raised from eggs so the differences must have been due to the change in climate or diet when brought into captivity.

A large decrease in the weight of a weta nymph most often indicated that it was going to moult within one to two weeks. In the adult female a sharp drop in weight indicated ovipositon (Richards 1973). Females had increasingly larger maximum weights than males from instar 7 to 10, although the differences in weight between the sexes were not significant until instar 9 and adults. Similar results were reputed for *D. heteracantha* and *D. fallai* by Richards (1973).

My results show that weta instar number can be established reasonably well from the range of measurements for pronotum length, head capsule width and ovipositor length. My results did not fully agree with Sherley and Hayes' (1993) allocation of instar size. Instars 9 and 10 showed the most overlap of measurements, but an adult could often be differentiated from a 9th instar weta by the darker and more shiny appearance of the exoskeleton, and from the more pointed tips of claspers in the male, and ovipositor, if female. Moller (1985) also noted that the ovipositors of adult *Hemideina crassicruris* were much more pointed than the immature females, although the adult females could be distinguished by a separate mode in ovipositor length of > 19 mm.

The duration of time Mahoenui weta were in each instar varied considerably. Instars 1 to 8 could extend over 3 to 4 weeks, or spend up to 7 months in one instar. Weta never spent much less than 2 months in instar 9, and spent up to 7 months at this instar. In Ramsay's (1955) study of *D. rugosa* the length of each stadium was also very variable and after eleven months the instar numbers of 11 weta (raised from eggs) ranged from instar 5 to instar 9. There was a large variation in adult longevity, 6 to 50 weeks. There was no difference in the average longevity between male and female adults. Richards (1973) observed males to generally outlive females in *D. heteracantha* and *D. fallai.* The average longevity of these two species and the Mahoenui weta was 5 to 6 months for weta in captivity.

The Mahoenui weta had an overwintering period where the growth rate of the weta ceased. This 'overwintering' was likely to be a low temperature induced quiescence, since the length of overwintering period varied between individuals and several different nymphal instars have the ability to overwinter (Corbert 1978). The overwintering period for Mahoenui weta extended from March to November but was generally from June to October. Richards (1973) observed overwintering in *D. heteracantha* from May to September. In *D. fallai* overwintering was far less pronounced but did occur in some weta for varying periods between June and October. Ramsay (1955) did not make any reference to an overwinter period for *D. rugosa* nymphs.

Various instars of Mahoenui weta were prominent in each season. There seemed to be 2 to 3 main generations of weta present even though some weta of most instars were found throughout the year. During autumn the two generations consisted mainly of 4th instar weta in the younger generation and 8th instar weta in the older generation. In winter the younger generation were predominantly 6th instar and the older were 8th and 9th instar weta. During spring the younger generation were still 6th instar with some 7th instar, and the older generation were predominantly 9th instar. In summer the younger generation were mostly 7th instar and the older generation were now adults. There was a new third generation of predominantly 1st instar nymphs. The captive weta appeared to be slightly older than the reserve weta since a higher proportion of captive weta reached the adult stage during spring than the Mahoenui reserve weta. Ramsay (1955) found that laboratory specimens of *D. rugosa* grew faster than they would have in the field, probably due to warmer temperatures in the laboratory.

The average lifespan for Mahoenui weta took about 37 months from egg to death. Eggs were laid from February to April and incubated for approximately 10 months to hatch the following January to February. Weta reached about instar 5 by May to June of the second year where they overwintered from June to October. The weta reach instar 7 by the end of summer and instar 9 by May to June of the third year where they overwintered a second time. The weta became adults in November to December. Maturation, copulation and ovipositon occurred during the summer of the fourth year. The adults lived on average 5 to 6 months in captivity but due to their virtual absence at Mahoenui from April they were assumed to live for a shorter period of about 3 to 4 months at the reserve.

The Mahoenui weta showed seasonality, however their lifecycle was not tied rigidly to the seasons in the sense that there was no true diapause so a large amount of variation occurred between the lifecycles of individuals. Three main generations appeared to dominate the Mahoenui weta population. This included eggs. It was possible for weta that hatched earlier in the season to reach instar 8 to 9 by winter of the second year and become adults the following summer, thus the weta overwintered for only one year and their lifecycle reduced to around 2 years from egg to death.

The Mahoenui weta lifecycle closely resembles the lifecycle of *D. rugosa* described by Ramsay (1955). Both species had an estimated three year lifecycle where eggs were laid in summer and autumn and the embryos took around 10 months to develop. The newly hatched nymphs passed through 6 instars on average in the second year and became adult towards the end of the third year. Each summer three generations exist in these two weta populations, one will be at the egg or 1st instar, another will be half grown nymphs, and the last mature weta.

The lifecycle of *Deinacrida heteracantha* (Richards 1973) was similar to the Mahoenui weta but was less tied to the season. Some weta that hatched in spring passed through only one overwintering period and became adult after about 14 months, but others that hatched in autumn could pass through two overwinter periods and take up to 21 months before becoming adult. In general *D. heteracantha* and *D. fallai* (Richards 1973) populations consist of many overlapping generations and a shorter development time for eggs and nymphs than *D. rugosa* and Mahoenui weta.

The lifecycles deduced for Mahoenui weta by Sherley and Hayes (1993) determined the Mahoenui lifespan to be 22 to 24 months from egg to death where weta developed into adults by February of the third year. Most of the results obtained from Sherley and Hayes (1993) fit closely to my results except their study did not determine the long periods of overwintering that I observed for individually marked weta. Sherley and Hayes concluded weta of instar 5 were most abundant in winter and instar 6 - 8 were most abundant in summer but failed to determine that these weta only reached instars 8 - 9 by winter and did not mature into adults until early the following summer, thus allowing for copulation and oviposition to begin earlier in the season than they deduced.

CHAPTER FIVE

BEHAVIOUR OF MAHOENUI WETA IN CAPTIVITY AND AT MAHOENUI RESERVE

AIM:

To provide a preliminary description of the behaviour of Mahoenui weta (*Deinacrida sp*) both in the field and in captivity.

INTRODUCTION:

It is important that the behaviour of Mahoenui weta is understood before options are considered for conserving this species. Knowledge of the behaviour of this weta will provide a better understanding of where they fit in their ecological community, which species they are reliant on, and which species are a threat to the weta. When considering translocations of weta to new sites it could be advantageous to find environments that suit the weta's behaviour rather than trying to find an exact habitat match. This could increase the number of options available. Seasonal changes in climate may affect weta behaviour and this may need to be taken into account if weta are being translocated into a new climatic zone. Knowledge of how to rear Mahoenui weta in captivity will be important if captive rearing techniques are needed to boost existing populations (Jowett and Plant 1988). Captive rearing also provides an easier way to study their behaviour since the same weta are always available for observation. It is important, however, to know if the behaviour of captive weta is representative of the behaviour of weta in their natural habitat.

There have been very few detailed studies published on the behaviour of *Deinacrida* weta. Richards' (1973) comparative study of *D. heteracantha* and *D. fallai* describes in detail many behavioural aspects of these two species. Field (1980) published his observations on the biology of *D. connectens*, an alpine weta. Barrett (1990) published a book on captive rearing of weta and in it he described some of the behaviour he observed in the Mahoenui weta. In Field and Sandlant's (1983) paper 'Aggression and Mating Behaviour in the Stenopelmatidae' they mentioned that in *Deinacrida* little is known of the degree of intraspecific aggression and male-male rivalry but from the information they had obtained there seemed to be a lack of the overt agonistic behaviour that has been reported from *Hemideina* weta.

The aim of this chapter is to provide a preliminary description of the behaviour of the Mahoenui weta (*Deinacrida sp*) both in the field and in captivity. I will describe cannibalism, ecdysis, regeneration of appendages, defence, aggression, courtship, copulation and oviposition. Where possible, comparisons are made between weta of different sexes or ages and between captive and field weta. This study increases our understanding of the overall patterns of behaviour of the Mahoenui weta throughout their life cycle and enables comparisons to be made between the behaviour of Mahoenui weta and that of other *Deinacrida* weta, *D. rugosa* (Ramsay 1955), *D. fallai* and *D. heteracantha* (Richards 1973), *D. connectens* (Field 1980).

Methods:

Refer to General Methods (Chapter 3).

RESULTS

5.1 CANNIBALISM:

No cannibalism or evidence of cannibalism was observed in Mahoenui weta in Mahoenui reserve. In captivity cannibalism was commonly observed in 1st to 5th instar weta, and less commonly in 6th instar. Weta were usually cannibalised during ecdysis or soon after when they were still soft and unable to escape. Usually the whole weta was eaten except when legs and small pieces were dropped while being consumed. Adults were never seen to attack each other.

In older nymphs I only observed one case of cannibalism on a female of 8th instar during ecdysis. The female's right palp, right midleg and half of her right foreleg were eaten, and there was damage to her right side from the head down to the base of her abdomen. The female died a day later. The weta had been in a cage with five other adult female and one adult male weta.

5.2 ECDYSIS:

Two Mahoenui weta in captivity were observed throughout the entire duration of ecdysis and several other Mahoenui weta in captivity and at Mahoenui reserve were observed at various stages of ecdysis. Of the two females observed throughout ecdysis, one took 2 hours 30 minutes to moult from 8th to 9th instar and took an additional 3 hours to consume the exuviae. The other weta took 45 minutes to moult from 3rd to 4th instar and took 1 hour to consume the exuviae. Both the weta moulted as described below.

The weta emerged from their day resting place early in the evening, usually just after dusk. One weta in captivity was observed to drink just prior to ecdysis. The weta nymphs then hung head downwards from a leaf or a branch, with their hind tarsi hooked firmly on. They then began to arch and contract their abdomen. The abdomen and cerci were partially withdrawn from the old cuticle and the pressure exerted split the cuticle down the ecdysial line which extends from the fastigium on the head to the metanotum. The thorax and anterior part of the abdomen were then protruding and the weta then freed themselves with the help of gravity. The head was freed first followed by the legs and finally the antennae.

Once the weta were free from the exuviae they hung still for up to 30 minutes and then turned around 180° to an upright position and then consumed the exuviae. After this the weta remained sitting at the ecdysis site for the remainder of the night. Before dawn the weta often moved a short distance into the foliage where they remained at least until the following evening.

The exuviae of the Mahoenui weta is pale brown. The newly emerged weta are milky-pink, but the colour soon darkens to brown. Within 24 hours the wetas' exoskeleton were almost fully hardened.

Of the many weta that were observed to have moulted in captivity (75 moults from 33 weta) and at the reserve (10 moults from 10 weta), only two were found not to have moulted successfully. In both cases the weta had become entrapped in their old exuviae. One was a captive 8th instar female while the other was a female from the reserve that was found half-out of its exuviae. Three weta in captivity had damaged legs after completing ecdysis. The cause of this was not observed although it probably occurred as the new soft legs were pulled free from the exuviae. One of these weta had such severely damaged legs that it died a few days later.

Two weta in captivity were observed to begin ecdysial behaviour by hanging head downwards and contracting their abdomen. After several minutes the weta stopped this behaviour and sat inactive for the remainder of the night. Both these weta died a few days after this behaviour was observed, without proceeding through ecdysis.

Captive weta kept isolated and given known quantities of food (Chapter 8: feeding experiments), were observed to refrain from feeding prior to, and after, ecdysis (Table 5.1). The shortest period observed for a weta to refrain from feeding prior to ecdysis was 4 days by an 8th instar male. The longest period observed was approximately 14 days by a 9th instar female. Of the six weta that moulted during the feeding experiment and from which data could be collected, five began feeding on the third night and the first faecal pellet was found after the fifth night. The sixth weta had not eaten after the third night and since the experiment had completed by this time, it was not known when this weta began feeding again. During the period when weta were not feeding prior to ecdysis, they remained relatively inactive, often not emerging from their resting sites at all during the night.

TABLE 5.1:

The number of days weta were observed to refrain from feeding prior to ecdysis, the number of days between ecdysis and when weta resumed eating, and the number of days between ecdysis and when weta excreted their first faecial pallet.

Sex	**Instar No.**	**Date of moult**	**No. of days observed not feeding prior to moult**	**No. of days between moult and first observed feeding**	**No. of days between moult and first faecial pellet**
Female B	9	2/1/92	14	-	-
Male AA	8	18-24/8/92	14-20	-	-
Male X	8	8-10/8/92	7-9	-	-
Female AC	9	26/9/92	4 known	-	-
Male AF	8	-20/9/92	-	3	5
Female AG	9	23/9/92	-	3	5
Female AI	8	28/9/92	6 known	3	-
Male G	8	22/9/92	-	3	5
Male Q	9	28/9/92	4	4 (at least)	-
Female W	9	24/9/92	-	3	5

5.3 DAMAGE AND REGENERATION OF APPENDAGES:

5.7% of the weta recorded at Mahoenui reserve were found with damaged or missing appendanges or damaged tergal plates (from 405 individuals) (Table 5.2). 48% of these had damage to legs (most often tibia and/or tarsi were missing), 35% had portions of antennae missing, 26% had damage to tergites on the abdomen or prothorax, and 23% of females had damaged or slightly bent ovipositors. Damaged appendanges were more common in females (57%) than in males (43%).

In captive weta damage was caused when nymphs were attacked during ecdysis. If not fatal, this usually involved loss of legs or portions of legs. Damage during ecdysis was observed, and antennae were commonly broken.

There was little opportunity to observe regeneration of limbs in captivity. One male Mahoenui weta of 8th instar, collected from farmland adjacent to the reserve, had only one regenerated segment on the right midleg. In the next two moults leading to adulthood the limb regenerated four new segments. The segments were reduced in size and had no form or structure to them compared with segments normally present on a leg. Each regenerated segment tapered to a very small terminal segment, and the leg gained no functional use (Plate 5.2).

Several weta that were observed to moult had broken antennae. Some antennae were broken off about half way along their length. After ecdysis they had regenerated almost to normal length. A female weta observed in the field during ecdysis had one antennae broken off at the base where it joined the head. After ecdysis 4-5 new segments of the antennae had regenerated.

TABLE 5.2

Damage to appendages recorded for 23 weta from the Mahoenui Reserve.

	Damage to legs	**Damage to ovipositor**	**Damage to antennae**	**Damage to tergites**	**Total No of damaged individuals**
Male	5	-	3	2	10
Female	6	3	5	4	13
Total:	11	3	8	6	23

5.4 DEFENCE:

Mahoenui weta exhibited very little aggression towards one another and so little defence behaviour was observed from the weta in the field and in captivity. During a night study one female at the reserve was seen with its legs raised in the threat position described below. No sound was produced by stridulation although this could have been carried out in the 15 minutes prior to observation. The female remained still with its legs raised for 30 minutes. Its legs were then slowly lowered and the female remained stationary for a short period before continuing its movement through the bush. No other weta or potential threats other than the observer were seen nearby, so the cause of this female's defence behaviour was unknown. Defence behaviour was observed while handling and measuring the weta. Defence behaviours are described below and summarised in Table 5.3.

1. Threat posture: A weta will raise its hind legs vertically and forward over its head. This was observed in males and females from 2nd instar to adults (Plate 5.1).

2. Tick sound: This is an abdomino-abdominal stridulation (Field 1980). The tick sound could be produced by weta from about 5th instar but was most prominently heard in weta from 6-7th instar to adults. This tick sound was often made in conjunction with the threat posture. There was no visible movement by the weta while producing this sound.

3. Abdomino-femoral stridulation: This is a harsh grating sound produced when the hind legs are quickly drawn down across the abdomen. The sound is produced from ridges on the femor and abdominal tergites being

rubbed together. This stridulation was observed in all weta from about 3-4th instar, although instars 3 and 4 produce only a faint sound.

4. Kick: A weta will kick with its hind legs in a more aggressive manner. This differs from the abdomino-femoral stridulation in that the legs are raised only partially and is often not associated with sound production. Kicking of the hind legs is most often observed in young nymphs or in older weta if highly provoked.

5. Jumping/Running: When collecting weta at the reserve and in captivity, the weta may escape by running further into dense foliage or under objects in their cages. Jumping was also a common means of escape for weta of instars 1-7. These young nymphs are quite agile and can jump readily to avoid capture.

6. Freeze: Remaining immobile was observed by weta of 1-4th instar and usually only by weta disturbed during the day while they were resting.

7. Biting: When provoked, eg: during measurement, a weta may bite. This appears to be the last resort for defence and is almost a counter-attack. For example, when handling a weta in such a way that it cannot kick or escape the weta will often bite and cling to the skin and fingers of the handler. The weta's legs and jaws have to be prised off to put the weta back down. Biting is usually observed in nymphs of 7-9th instar and by adults. Adult males appear to bite more commonly than adult females.

8. Vomiting and Reflex Bleeding: When handling a weta it would often discharge liquid from its mouth. This liquid was brown in colour and had the smell of plant extracts. Similar liquid was often seen as drops formed

from the membranes between plates on the abdomen and thorax and in the leg joints. Reflex bleeding (Matsuda 1982) was observed in adults and 7th to 9th instar nymphs. Instars 1-6 were not handled and so no observations of reflex bleeding were made in these instars. A few nymphs from 1-6th instar were observed to discharge green-brown liquid from the mouth when confined in small dishes during measurement. Adults showed reflex bleeding but not as often as in 7-9th instar nymphs.

As noted, defence behaviour varied between different instars and between individuals. Young instars 1-5 were either unable to produce stridulatory sounds (instars 1 and 2), or the sound was too faint to be heard by many potential predators or intruders. Due to their small size, biting was relatively ineffective against larger intruders. These young instar nymphs would most often run or jump from an intruder or display the threat posture or kick at the intruder. Occassionally the young nymphs would remain immobile.

TABLE 5.3

BEHAVIOURS ASSOCIATED WITH DEFENCE AND ESCAPE IN THE VARIOUS INSTARS OF MAHOENUI WETA.

Defence Behaviour	Instars for which the behaviour is most common
Threat Posture	2-10
Femoro-abdominal stridulation	4-10
Kick	1-4
Jump	1-6
Run	1-10
Freeze	1-4
Bite	7-10
Reflex bleeding	7-9
Abdomino-abominal stridulation (Tick sound)	7-10

The instars 6-10 were larger and their cuticle was harder. They could produce sound effectively and the spines on their legs were strong and could potentially induce greater injury to an intruder than the spines of younger nymphs. When disturbed, instars 6-10 would either run or display the kick response. The threat posture was usually followed by femoro-abdominal stridulation and abdomino-abdominal stridulation. If a weta was restrained it would bite and undergo reflex bleeding, and if it escaped it would run to cover.

There was little difference in defence behaviour between sexes for instars 1-9. However adult males were generally more aggressive in defence that adult females which become quite placid as they mature.

5.5 AGGRESSION

Mahoenui weta rarely showed any intraspecific aggression, and in general Mahoenui weta tolerated each other in close proximity. Often one weta would climb across another, while out foraging, and no apparent response was observed to such close contact. During the day the weta in captivity would often take refuge huddled together under bark or in corners of their cage. At the reserve this was observed less often due to the low density of Mahoenui weta there, but often weta were found together either touching or in very close proximity. In January 1992, four males and one female were found in close contact in a gorse branch.

No aggressive interactions were ever observed between females or by males towards a female, or females towards males. Some mild antagonistic encounters were observed between adult males in the presence of reproductively receptive females. These encounters consisted of chasing, leg grabbing, homosexual courtship, and interference with courtship behaviour of other males.

The male/male interactions observed in captivity are listed in Table 5.4. Male 1 and Male 2 were kept with Female C and Female D. Male 1 was observed to mate four times while in the cage with these three other weta, twice with each female. Male 2 was not observed to mate while in this cage, although he had previously mated with Female D while separated from Female C and Male 1. Male 1 was observed climbing onto Male 2 and observed on another occasion chasing Male 2. Male 2 was never observed to initiate any interactions with Male 1 and fled from encounters with Male 1.

The second pair of males, Male 3 and Male 4 were initially in a cage with two females, Female A and Female B. No male rivalry interactions were observed when the two females were present. Male 4 was observed mating with each female once, and Male 3 mated three times with Female A and twice with Female B.

Female B died and the two males were left with one female, Female A. With one female present male/male interactions were observed between Male 3 and Male 4. Male 4 was observed to grab Male 3 by the back leg and then run away. Later in the night Male 4 engaged in homosexual courtship with Male 3 by climbing onto Male 3 and trying to connect with his claspers. Male 3, during a study on 2/2/93 was observed to half climb onto Male 4 and on the same night was observed to interfere in courtship between Male 4 and Female A. With only the one female present Male 4 was observed to mate with Female A twice and Male 3 was observed to mate with her once.

Table 5.4 Male/male interactions observed in captivity for two pairs of male Mahoenui weta.

All Weta present	Date	Time	Male/male interactions
Male 1, Male 2, Female C, Female D	27-1-92	22.30	Male 1 climbed onto Male 2
As above	14-2-92	04.15	Male 1 chased Male 2
Male 4, Male3, Female A	26-1-93	22.45	Male 4 grabbed Male 3 by back leg and then ran away
As above	26-1-93	04.20	Male 4 on top of Male 3 with abdomen under Male 3 and attempting copulation
As above	26-1-93	05.15	Male 4 and Male 3 on ground facing each other
As above	2-2-93	21.45	Male 4 clmbing onto Female A, and Male 3 trying to climb on Female A
As above	2-2-93	22.00	Male 3 half climbed onto Male 4
As above	2-2-93	00.30	Male 4 and Female A in contact, Male 3 attempted to climb onto them.

Table 5.5 The total number of matings observed for four males during their adult life span and the number of times each male mated one of two females, when together with the two females and other male of each group.

	Male Weta	No. of matings with each female in the presence of the second male		Total number of matings observed for the males entire adult lifespan
		Female D	Female C	
Group 1	Male 1	2	2	4
	Male 2	0	0	1
		Female A	Female B	
Group 2	Male 3	3	2	6
	Male 4	1	1	7

Table 5.6 A comparison of the size and weight of four adult male Mahoenui weta.

Male Weta	Prothorax length (mm)	Head width (mm)	Peak weight (g)	Average weight throughout adult life
2	9.4	9.1	6.5	-
1	10.2	9.5	7.0	-
3	9.5	9.4	6.7	6.3
4	10.2	9.6	7.5	6.9

5.6 COURTSHIP AND COPULATION:

Courtship behaviour of the Mahoenui weta was observed both at the reserve and in captivity. Copulation was only observed in captive weta.

During courtship male Mahoenui weta would follow a female continuously, either touching or holding her from behind with his legs. When the female was stationary the male would sit, usually behind her, with his forelegs holding the female's hind legs. The male would then palpate the female with his antennae and palps while he climbed onto her back. This continuous pursuit, palpating and holding of the female occurs throughout their nightly active period.

Mating usually commenced just prior to dawn and continued throughout the day, although one mating was observed during the night and others commenced at various times during the day (Table 5.7).

Once the male had climbed onto the female and was palpating her, he would then move down beside the female. Both the male and female had their antennae directed back alongside their bodies. The male then backed under the female and applied his abdomen to the subgenital plate of the female. Once the genitalia were hooked together the male turned his head vertically away from the female. The male produced and inserted a spermatophore into the subgenital plate of the female. The male then released the female's subgenital plate and the spermatophore ampulla was forced out. Once out of the female the spermatophore ampulla usually stuck to the base of the female's ovipositor and then eventually fell off.

The spermatophores were a translucent white colour and soon darkened to pale brown as they dried. Females were never observed to eat the spermatophore ampullae, however a male Mahoenui weta was seen to eat two ampullae that had fallen from the female's ovipositor onto the floor of the cage after a night time mating. This was the only time spermatophore ampullae were observed to be eaten by a Mahoenui weta.

The number of copulations at each mating varied. Only one mating was observed during the night and this lasted for 1 hour 30 minutes during which three spermatophores were produced. Twenty-two matings were recorded during the day. For some of these the total number of spermatophores produced and the duration of the mating was recorded. Table 5.7 lists the 23 matings observed for the captive Mahoenui weta. Any number from 1 to 10 spermatophores were produced and mating periods varied from about 1 hour 10 minutes to over 13 hours 30 minutes. The average number of spermatophores produced during one mating period was 4.5 (S.E=0.90; n=12) and the average duration of a mating was 6 hours 4 minutes (S.E=1 hour 8 minutes; n=12).

TABLE 5.7

Weta matings observed in captivity from January 1992 - April 1993

Wetas mating	Date	Time (hr) when mating was observed	Length of time mating	No. of Spermatophores produced	Approximate time to produce each spermatophore	Other weta present in cage with mating pair
Male 2 - Female D	13-1-92	- 2200	-	-	-	None
Male 1 - Female D	25-1-92	0930-1040	1 hr 10 min	1	1 hr 10 min	Male 2 - Female C
Male 1 - Female C	28-1-92	- 1130	-	-	-	Male 2 - Female D
Male 1 - Female D	14-2-92	1720-2010	2 hrs 50 min +	-	-	Male 2 - Female C
Male 1 - Female C	18-2-92	1415-2200	7 hrs 45 min +	-	-	Male 2 - Female D
Male F - Female S	15-12-92	1300	-	2 +	-	None
Male R - Female A	3-12-92	1200	-	-	-	Male B - Female N
Male B - Female N	9-12-82	0830 - 1700	8 hrs 30 min +	-	-	Male R - Female A
Male R - Female A	13-12-92	1930	-	-	-	Male B - Female N
Male R - Female N	14-12-92	0845 - 1640	5 hrs 25 min +	2	2 hrs 43 min	Male B - Female A
Male AA - Female W	18-12-92	1030 - 1700	6 hrs 30 min +	-	-	-
Male B - Female A	22-12-92	0800 - 2130	13hrs 30 min +	7	1 hr 56 min	Male R - Female N
Male R - Female A	23-12-92	0850	-	6	-	Male B - Female N
Male AA - Female S	4-1-93	1000 - 1237	2hrs 37 min +	2	1 hr 19 min	-
Male R - Female N	9-1-93	0900	-	-	-	Male B - Female A

Male X - Female S	17-1-93	0930 - 1835	9 hrs 5 min +	10	55 min	Female AG
Male R - Female A	26-1-93	1315 - 1730	4 hrs 15 min +	7	43 min +	Male B
Male X - Female S (N)	26-1-93	2245 - 0015	1hr 30 min	3	30 min	Female AG
Male B - Female A *	27-1-93	0900 - 2000	11 hrs	9	1 hr 17 min	Male R
Male B - Female A	2-2-93	0830	-	-	-	Male R
Male X - Female S	19-2-93	1130	-	3	-	Female AG
Male B - Female AI	6-4-93	1900 - 2000	1 hr +	2	30 min +	Female AK
Male B - Female AK	7-4-93	0955	-	1 +	-	Female AI

NB:

[N] NIGHT TIME MATING

[*] BREAK IN MATING AFTER TWO SPERMATOPHORE PRODUCED. THE WETA THEN MOVED ACROSS TO THE OPPOSITE SIDE OF THE CAGE AND CONTINUED MATING. SEVEN MORE SPERMATOPHORES WERE PRODUCED DURING THIS TIME.

5.7 OVIPOSITION

Oviposition was not observed in the field studies at Mahoenui reserve. Oviposition in captive female Mahoenui weta began in summer, 2-3 weeks after their first copulation had been observed (Table 5.8). The initial oviposition period ranged from late December to March, although most weta began oviposition in February (Table 5.3).

Once a weta started ovipositing it continued thoughout the rest of its life. Most mature female weta died in captivity from mid January to mid to late May. Two females lived much longer. One died early in September 1993 after becoming adult on 30-11-92 and another was still alive in mid September 1993 after becoming adult on 8-12-92. These weta were not observed to oviposite from May 1993, although it had occurred at least once since then because eggs were collected from their cages.

Oviposition was observed most often from early morning up to mid afternoon, and on one occasion during the night. When ovipositing the Mahoenui weta can spend up to several hours on the soil.

When weta were observed immediately before ovipositing they selected a spot by palpating the soil and often pushed their head down into the soil and dug out a hollow before ovipositing in and around this hollow. When they had selected a spot they raised themselves up on their legs and brought their ovipositor down at right angles to their body. The ovipositor was then thrust into the soil as the body was lowered. The ovipositor remained in the soil for 1 to 5 minutes and eggs were released. It was then withdrawn and reinserted into the soil nearby.

TABLE 5.8:

Observed period of oviposition and the dates of first and last copulations for female Mahoenui giant weta in captivity. [1]

Weta	Observed Oviposition Period	First Copulation observed	Last copulation observed	Date weta deceased
Female C	early February - May	10-1-92	18-2-92	11-5-92
Female D	early February - May	13-1-92	14-2-92	19-5-92
Female N	early January	9-12-92	9-1-93	12-1-92
Female A	early January - mid Feb	13-12-92	2-2-93	16-2-93
Female AG	early Feb - late March	(not observed)	8-3-93	30-3-93
Female S	late December - late May	15-12-92	19-2-93	25-5-93
Female AI	late March - May	8-3-92	6-4-93	2-9-93
Female AK	late March - May	(not observed)	7-4-93	still living at 17-9-93

[1] THE DATA IN THIS TABLE ARE BASED ON OBSERVATIONS AND SO IT PROBABLY DOES NOT INCLUDE ALL COPULATIONS OR OVIPOSITION TIMES. THE TABLE SHOULD GIVE A REASONABLE IDEA OF THE TIME BETWEEN FIRST COPULATION AND START OF OVIPOSITION, AND OF THE DURATION OF THE FEMALES' LIVES OVER WHICH THEY OVIPOSITED.

Table 5.9 shows details of eight observations of a captive Mahoenui female laying eggs. This is a typical procedure of oviposition for all the captive weta. Oviposition in this female occurred over a 6 hour period during the day. The female weta would lay for a short time before moving a few centimetres (1-3 cm) and then reinsert her ovipositor to lay again. The weta seemed to be laying her eggs either singly or in small clusters based on the number of times it shifted on the soil.

The eggs were layed in a vertical position. The eggs found in the captive weta's soil were layed either singly, in small groups, and once in three larger groups of up to 30 eggs. Mahoenui weta eggs were found from a few millimeters deep to up to 30 mm deep. The depth that the eggs were layed in the soil was generally about the length of the female's ovipositor, 20-26 mm for Mahoenui weta, although sometimes the eggs were closer to the surface.

Although the Mahoenui weta in captivity initially had only a small area in which to lay their eggs (5 cm radius) they tended to only move from 1-3 cm each time they reinserted their ovipositor (Figure 5.1).

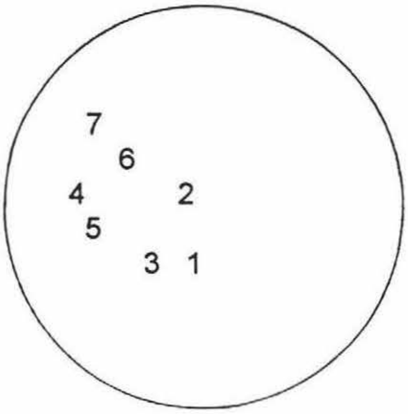
Table 5.9

EIGHT OBSERVATIONS OF A FEMALE MAHOENUI WETA DURING OVIPOSITION ON 8TH APRIL, 1992. THE FEMALE RE-INSERTED HER OVIPOSITER AT LEAST SEVEN TIMES DURING EGG LAYING. THE FEMALE NEVER MOVED FAR BETWEEN EACH SHIFT (FIGURE 5.1)

Time	Observation of Oviposition
7.40	Start oviposition - inserted ovipositor
9.40	Re-inserted ovipositor
9.55	Re-inserted ovipositor
10.38	Re-inserted ovipositor
12.00	Re-inserted ovipositor
12.50	Re-inserted ovipositor
13.20	Re-inserted ovipositor
13.50	Has finished oviposition - sitting on soil

Figure 5.1:

SITES OF OVIPOSITION, FOR A FEMALE CAPTIVE MAHOENUI WETA, ON SOIL PROVIDED IN A PLASTIC POTTLE OF 6CM RADIUS.



DISCUSSION

The observations of cannibalism in the Mahoenui weta were consistent with reports of nymphal cannabilism for other species of weta. In *Deinacrida fallai* and *D. heteracantha* Richards (1973) noted ecdysial cannibalism and also noted what she termed sexual cannibalism between adult males and females either during mating or when one sex had to choose between two of the opposite sex. This sexual cannibalism was not observed in the Mahoenui captive weta. Barrett (1990) noted that cannibalism occurred predominantly in instars 1-5 of *Deinacrida* and *Hemideina* weta. He suggested that nymphal cannibalism may be a strong incentive for dispersal. Cannabalism in the Mahoenui weta appeared only to be ecdysial and its function was probably dietary, where one individual would eat another immobile or defenceless individual as they did with dead insects such as crickets. Cannibalism of weta was never observed at Mahoenui reserve. Ramsay (1955) suggested that cannibalism occurred only under unnatural conditions (captivity) where the weta were overcrowded or unable to escape.

The moulting process described here for the Mahoenui weta seems to be similar to that described in other species of *Deinacrida* and *Hemideina*, although not all weta species would consume the exuviae at the completion of ecdysis. *D. fallai* ate the exuviae whilst *D. heteracantha* did not (Richards 1973). Barrett (1990) observed various species of *Hemiandrus, Deinacrida, Hemideina* and Rhaphidophoridae weta to consume their shed exuviae.

A small number of weta failed to complete ecdysis successfully. This may have been due to a lack of suitable food or adverse environmental conditions (Barrett 1990).

How long a weta refrained from feeding prior to ecdysis was variable. Weight loss occurred 1-2 weeks prior to ecdysis (chapter 4), indicating that weta refrained from feeding during this period. In contrast the length of time a weta would refrain from feeding after ecdysis was consistently either three or four days (Table 5.1). Barrett (1990) observed a 2-3 delay in feeding after ecdysis in *Hemideina* weta from 6th instar to adult but found that 1st to 5th instar nymphs often recommenced feeding within 24 hours.

In Moller's study of *Hemideina crassicruris* (Moller 1985) a higher percentage of damaged individuals was recorded (42% of females and 17% of males) compared with the Mahoenui *Deinacrida* weta (3.2% of females and 2.5% of males). This was probably due to the more aggressive nature of the *Hemideina* weta. A higher proportion of females were damaged and the most common form of mutilation was damaged or broken tarsi and tibia. Damage to tarsi and tibia was also the most common damage seen in the Mahoenui weta at the reserve. The proportion of damage in female Mahoenui weta was slightly more than for males, but not significant as that recorded for *Hemideina crassicruris*.

Total regeneration of appendages is relatively rare in the Orthoptera but partial regeneration has been observed for many of the Stenopelmatidae (Ramsay 1964) and I have observed it for Mahoenui weta. Ramsay (1964) and Richards (1973) recorded an acceleration of growth in the damaged appendages so that at each moult a portion of the appendages may be regenerated. Tibia and tarsi have been observed to almost fully regenerate on a femur. Young nymphs have a better chance of regenerating appendages simply because they undergo more moults than older nymphs, however it is rare for a regenerated appendage to ever reach normal length by adulthood. Regenerated limbs were often stunted and deformed in some way, even if the damage had occurred on a very young nymph. Antennae on the other hand seemed able to almost fully regenerate even after a single moult.

This is because accelarated growth in damaged antennae is higher than in other appendages such as legs (Ramsay 1964). The antennae are major sensory structures and their total regeneration is likely to be more advantageous to the weta's survival than if a damaged leg was fully regenerated.

The Mahoenui weta had several mechanisms that could be used for defence against potential threats. These varied in use, depending on age and also between individual weta. There did not appear to be major differences between the sexes, although the intensity of the behaviour did vary, ie: adult males often defended more aggressively than adult females. Watt (1963) also noted that the male Mahoenui weta in his care was more readily "annoyed" than the females which were usually quite docile. Juveniles appeared to react more aggressively although this could be a reflection of the more agile movements of young nymphs rather than increased aggressiveness. The defence behaviour of the Mahoenui weta is very similar to those described for other *Deinacrida* species (Richards 1973, Field 1980, Ramsay 1955) and for many *Hemideina* species (Barrettt 1990) although sound produced during stridulation varies with the weta species (Barrett 1990, Richards 1973).

Another behaviour displayed by nymphs from 1st to 5th instar which was more protective than defensive, consisted of nymphs burrowing into the soil provided at the base of the foliage. This behaviour was also observed in young *Deinacrida fallai* and *D. heteracantha* nymphs (Richards 1973), and by *D. rugosa* nymphs (Ramsay 1955) which burrowed into the soft earth covering the floor of their cage (Richards 1973).

Mild aggression has been reported by most authors during studies of *Deinacrida* species. Mild sexual aggression was observed between males of *D. heteracantha* and *D. fallai*, which included males entwining themselves around each other, males mounting other males or males interfering with the copulation of another male and female (Richards 1973). The most agonistic response by *Deinacrida* weta to tactile contact by other members of its species was observed in *D. connectens* (Field 1980) where the weta showed a graded response from a mild repulsion of leg pushing to full "leg kicking", sound production and leg thrusting at the intruder. This agonistic behaviour appeared to be used to maintain individual space between the species members. There was some mild aggression observed for the captive Mahoenui weta in my care. The behaviour observed between Male 1 and Male 2 suggested that Male 2 was subordinate to Male 1. Male 1 was larger than Male 2 (Table 5.4). Male 2 fled from all encounters with Male 1, was never observed to initiate any interactions with Male 1, and did not successfully mate with either female in the presence of Male 1. The other pair of males studied, Male 3 and Male 4, showed no evidence of a dominant/subordinate relationship when they were in a cage together with the two females present. Both males mated successfully with each female. Male 3, the smaller and lighter weta mated more often with each female than Male 4. When the population of two males and two females was reduced to the two males and only one female, male/male interactions were observed between Male 3 and Male 4. This might suggest that the males were now competing for the female and/or trying to establish a heirarchical order. The homosexual behaviour of Male 4 and Male 3 may have had something to do with establishing a dominant/subordinate relationship between each other, although the reason for homosexual behaviour in weta is not understood. Rocha (1991) found that homosexual behaviour in cockroaches was performed by dominant males towards subordinates. In studies of crickets (Alexander 1961), homosexual courtship had been observed between males when isolated from females and in encounters where one male approached another from behind, or both males displayed little or no aggressive behaviour upon contact and failed to retreat. A courted male either reacted aggressively, moved placidly away, or became temporarily immobile much as a responsive female would (Alexander 1961).

Homosexual behaviour was often observed in *Hemideina* weta (Field and Sandlant 1983), usually when a male intruder to a gallery attempted to mate with the occupant male. This behaviour seemed to mark a transition point when the interaction was either terminated, or escalated to more intense aggression. There does not appear to be any evidence for homosexual behaviour in any of the other *Deinacrida* species studied (Field 1980, Richards 1973), although a *D. heteracantha* male was observed climbing onto the back of another male (Richards 1973). This may have been an attempted courting.

The behaviour involved in the courtship between Mahoenui weta appears to be a simple procedure. A male will become attracted to a female, probably due to the release of pheromones by the receptive female (Barrett 1990). Females appeared to play an entirely passive role in the courtship behaviour. There was never any stridulation involved by any weta or any aggressive behaviour toward either the female or the male involved in courtship.

Richards (1973) noted four different copulation positions in *Deinacrida fallai* and *D. heteracantha*. The position usually adopted in these two weta species was the one described for the Mahoenui weta. This was the only position observed in the Mahoenui weta during this study.

The long bouts of mating by Mahoenui weta are typical of other *Deinacrida* species studied (Richards 1973), and are much unlike the short mating periods of the *Hemideina* weta which varies from a few minutes to rarely more than an hour depending on the species (Barrett 1990, Moller 1985, Field and Sandlant 1983). Field and Sandlant (1983) suggested that the long bouts of mating in *Deinacrida* are to ensure that other males have reduced access to females since *Deinacrida* weta do not show any female guarding behaviour towards other males like the *Hemideina* weta. The Mahoenui weta are monogamous and in a low density population (Sherley and Hayes 1993) the number of receptive females located throughout a male's lifetime would be limited and it may be more beneficial for a male to put a greater sexual investment, in terms of the number of copulations, into each mating with a female.

In the captive Mahoenui weta the period of oviposition ranged from January to May. Sherley and Hayes (1993) suggested that Mahoenui weta oviposited during April/May. Barrett (1990) also stated that the Mahoenui weta in his care layed during April/May. The adult weta at Mahoenui reserve were largely present from December to March and in March and April very few adults were located which suggested most weta had completed oviposition by March. It is possible that the period of oviposition could vary from year to year if variations in seasons affect the maturation and longevity of the weta.

Oviposition in Mahoenui weta was very similar to that described for *Deinacrida faillai* and *D. heteracantha* (Richards 1973) except that in these two species and *Hemideina* species described by Barrett 1990 and Moller 1985, oviposition only occurred at night.

D. fallai and *D. heteracantha* both lay on average about 27 eggs during oviposition (Richards 1973). A rough estimation of the number of eggs layed for Mahoenui weta was about 30 eggs, similar to these two species.

The Mahoenui weta tended to oviposite in a small area less than 10 cm radius. Richards (1973) also observed *D. fallai* and *D. heteracantha* to reinsert their ovipositor into soil no further than 1-2 cm at each shift. The eggs were layed singly or in clusters in all *Deinacrida* weta observed including the Mahoenui weta (Richards 1973, Ramsay 1955).

The behaviour of Mahoenui weta fits closely to that observed for *D. fallai*, *D. heteracantha* (Richards 1973) and *D. rugosa* (Ramsay 1955). *D. connectens* (Field 1980) appear to be less tolerant towards other members of their species and maintain individual distance. Together these studies of *Deinacrida* weta behaviour should broaden the knowledge of this genus and its relationships with the other genuses in the Orthoptera.

CHAPTER SIX

MAHOENUI WETA ACTIVITY TIME BUDGETS

AIM:

To observe the nocturnal behaviour patterns of Mahoenui weta in captivity and at Mahoenui reserve.

INTRODUCTION:

Virtually nothing is published on the nocturnal behaviour patterns of weta perhaps because it has been difficult to carry out extensive observational studies of weta behaviour in the field. Observers have not been able to locate and follow individual weta for an entire night without losing sight of them. Most weta are arboreal, living in forest canopy and scrub, or are found in alpine tussock habitat and many only exist on isolated islands so are collected and studied in captivity (Richards 1973, Field 1980). The little knowledge of weta activity in the field has been based on a few observations of individual sightings of different weta (Sherley and Hayes 1973; Field 1980; Moller 1985; Richards 1973). These observations can be used to discuss aspects of behaviour as is set out in Chapter five of this thesis, but cannot be easily used to create a picture of the overall activity patterns of weta.

The aim of this chapter was to observe the nocturnal behaviour patterns of Mahoenui weta and to determine detailed activity time budgets for this species. This was made possible by using a new method - to follow and relocate weta at night. This method involved using Betalights (Chapter 3). These allowed me to follow individual Mahoenui weta in the Mahoenui reserve and observe the weta activity throughout an entire night. From these observations and from observations of captive weta activity levels I hoped to learn the period of the night that weta were active, what activities the weta engaged in throughout this active period, and what proportion of the night the weta spent in each activity. I also wished to determine whether activity levels varied with the season, the age and sex of the weta, and between captive and field Mahoenui weta.

METHODS

Refer to General Methods (Chapter Three).

The seasons were divided into winter (June to November) and summer (December to March). No weta of appropriate size for nocturnal study were available in autumn. Spring observations were included in winter results because, in Spring, most weta were still nymphs and were still relatively inactive during the nocturnal studies.

Figures 6.7 to 6.15 show the night period divided into a percentage from 5-100% rather than into hours after dark so that the results can be compared between night periods of differing hourly lengths, for example, summer night lengths ranged from about 8 to 9 hours, and winter night lengths ranged from about 10 to 13 hours.

RESULTS

6.1. Noctural Activity:

The following seven behaviour patterns were observed for Mahoenui weta.

1. Not active. Immobile except for the antennae being moved about.
2. Moving. This included walking or climbing but was precluded if contact occurred with another weta.
3. Eating. A weta eating foliage, insect material or drinking water.

4. Preening. A weta cleaning any part of itself.

5. Moulting. Moulting included all phases of ecdysis and consuming the exuviae.

6. Contact. The activity was classified as contact if two weta were touching. This usually involved courtship behaviour. It excluded copulation.

7. Mating. This was limited to actual copulation and the interval between copulation when the two weta remained in the copulatory position.

6.2 Activity levels:

The mean overall active period of Mahoenui weta ranged from 7% to 50% of the night and individual weta remained relatively inactive for 50-95% of the night (Figures 6.1 to 6.6)

There was a significant decrease in activity during the winter months compared with the summer months for weta studied at the Mahoenui reserve (student $t = 2.740$, $n = 27$, $P<0.05$) (Figure 6.1) and in captivity (student $t = 3.374$, $n = 22$, $P<0.05$) (Figure 6.2). Nymphs in captivity were generally more active in summer although the difference was not significant (student $t = 1.553$, $n = 14$, $P>0.05$) (Figure 6.3). The time spent moving, feeding and preening increased during summer at the reserve. Contact, copulation and moulting were only observed in summer (Figures 6.1, 6.2, 6.3). Although activity was generally increased in summer, the proportion of time weta spent preening and moving remained similar in summer and winter (Table 6.1). Captive weta spent 66% of their active period feeding during winter but only 35% during summer. Contact and copulation occupied 38% of their active period. Captive nymphs also showed a decrease in the proportion of time eating from 70% in winter to 47% in summer and moulting occupied 27% of the total activity period. In the Mahoenui reserve the proportion of time weta spent feeding remained constant in winter (57%) and summer (55%).

Weta at the Mahoenui reserve tended to be less active than weta in captivity, however the difference is not significant (student t = 1.883, n = 29, P>0.05) (Figure 6.4) in summer or winter (Figure 6.5). Preening, making contact with other weta and copulation were significantly increased in captive weta during the summer; (Contact, student t = 2.815, n = 29, P<0.05, Preening, student t = 2.143, n = 29, P<0.05) and feeding activity is decreased compared with the Mahoenui reserve weta. Copulating weta were not observed in the reserve. Weta in the Mahoenui reserve spent a higher proportion of time moving than in captivity (Table 6.1).

Captive adult female weta showed a lower total activity period than adult male weta but this is not significantly different (student t = 1.767, n = 14, P>0.05) (Figure 6.6), and adult males spent a larger proportion of their active period preening (13%) than the adult female weta (7%) (Table 6.1).

During summer, movement was constant throughout the night for captive weta and in the Mahoenui reserve weta there were two peaks of increased activity after 35% of the night and from 75-85% of the night. At the reserve feeding was observed continuously at a low level throughout the night. Captive weta fed throughout the night too, but had a break in feeding activity at the start of the night (0-35% of the night) and after 65% of the night. Preening occurred throughout the night. Moulting was observed in captive weta from dusk until 40% of the night. Contact was observed during the first 15% of the night period for reserve weta and in captive weta contact and copulation was ongoing and showed two peak activity periods from 15-25% and 70-80% of the night. Weta were active from dusk until dawn with two peak active periods from 15-35% and 55-80% of the night period in the Mahoenui reserve weta (Figure 6.8, 6.9).

During winter the interpretation of trends in the individual activities is restricted by the small amount of activity occurring throughout the night . At the reserve there seems to be a peak in activity at about 45% of the night period. No activity was observed after 65% of the night period had passed (Figure 6.10). In the winter, captive weta were observed during the first 75% of the night. Feeding peaked at 20% of the night and a second feeding period occurred from 90-100% of the night. Preening and moving were not observed after 60% of the night period. The overall activity peaked at 20% of the night period after which activity declined. Very little activity was observed from 65-85% of the night. A second period of activity which involved feeding only, occurred in the last 15% of the night period (Figure 6.9).

In captive male adults during summer, moving, eating, contact and copulation were ongoing with two peak activity periods. Preening occurred between the peaks of these activities (Figure 6.11).

In captive female adults during summer contact and mating followed the bimodal trend in peak activity but moving and feeding peaked from 0-15%, 50-60% and 95-100% of the night period. These peaks coincided with the non-active period for contact and copulation (Figure 6.12).

Captive nymphs during summer varied from the adults in showing only one major peak activity period from 10-35% of the night period after which activity decreases. Feeding was ongoing throughout the night and peaked again at a lower level from 60-65% of the night period (Figure 6.13). There is no obvious variation between the activity period of captive male and female nymphs during winter (Figures 6.14 and 6.15).

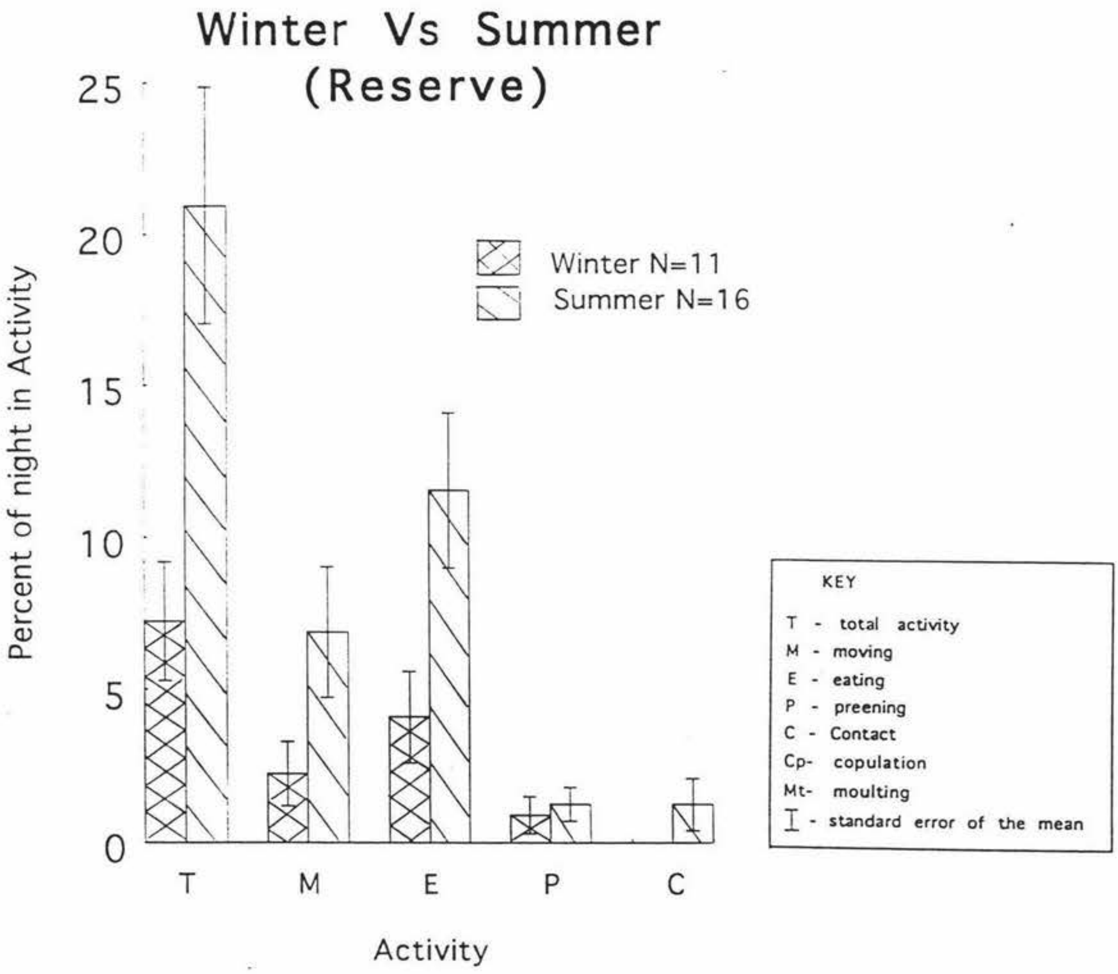


Figure 6.1

Activity levels of Mahoenui weta during the night at Mahoenui reserve during summer and winter.

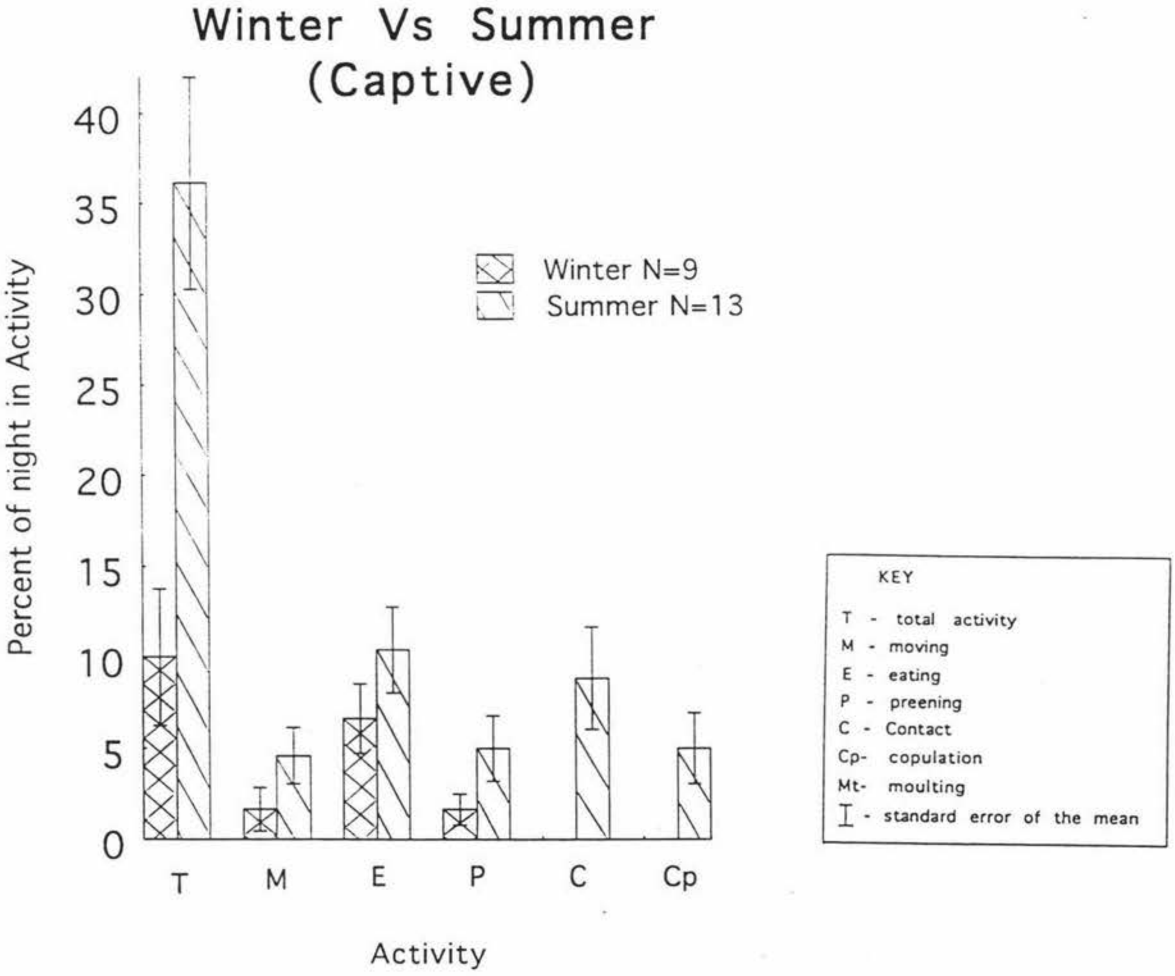


Figure 6.2

Activity levels of Mahoenui weta during the night in captivity during summer and winter.

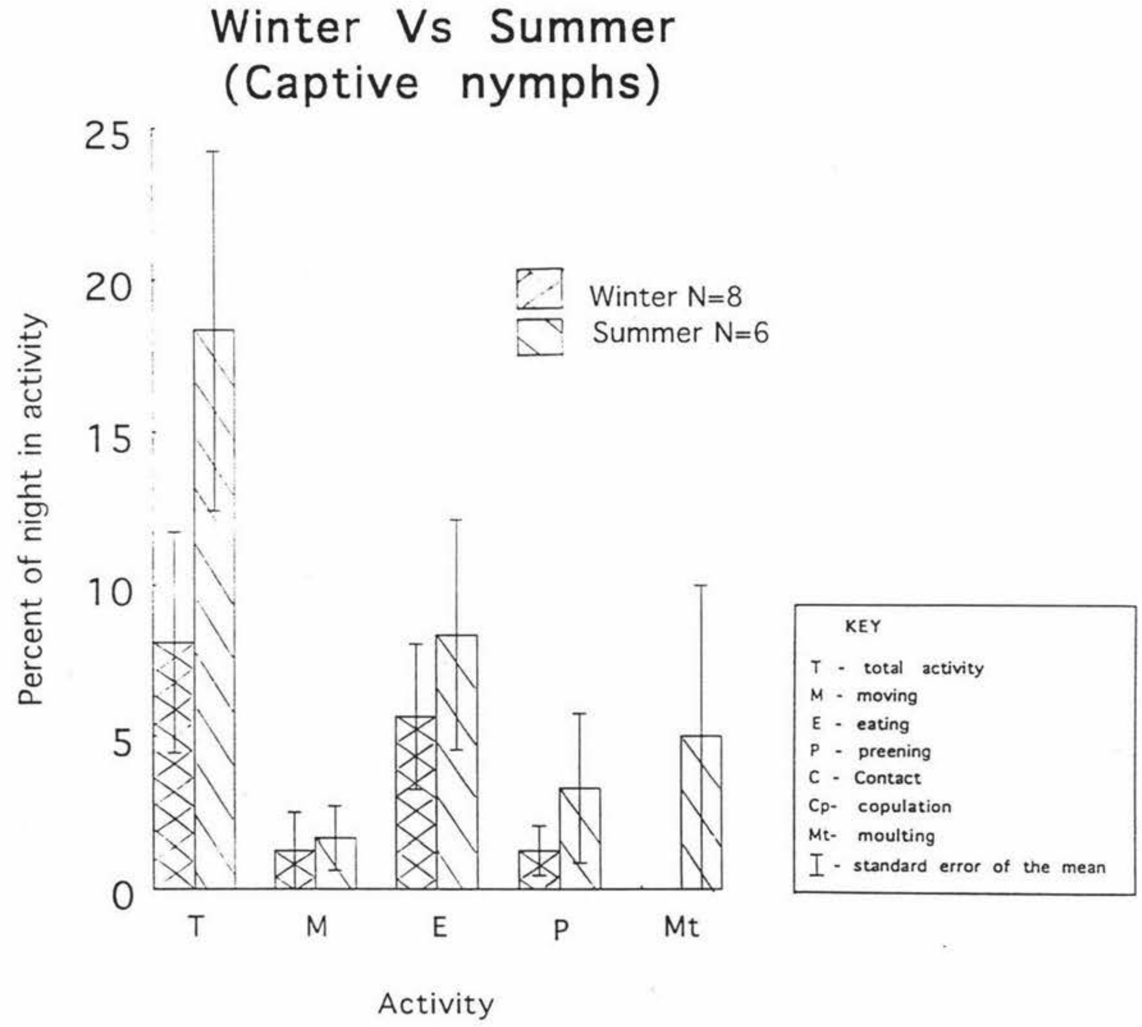


Figure 6.3

Activity levels of Mahoenui weta nymphs during the night in captivity during summer and winter.

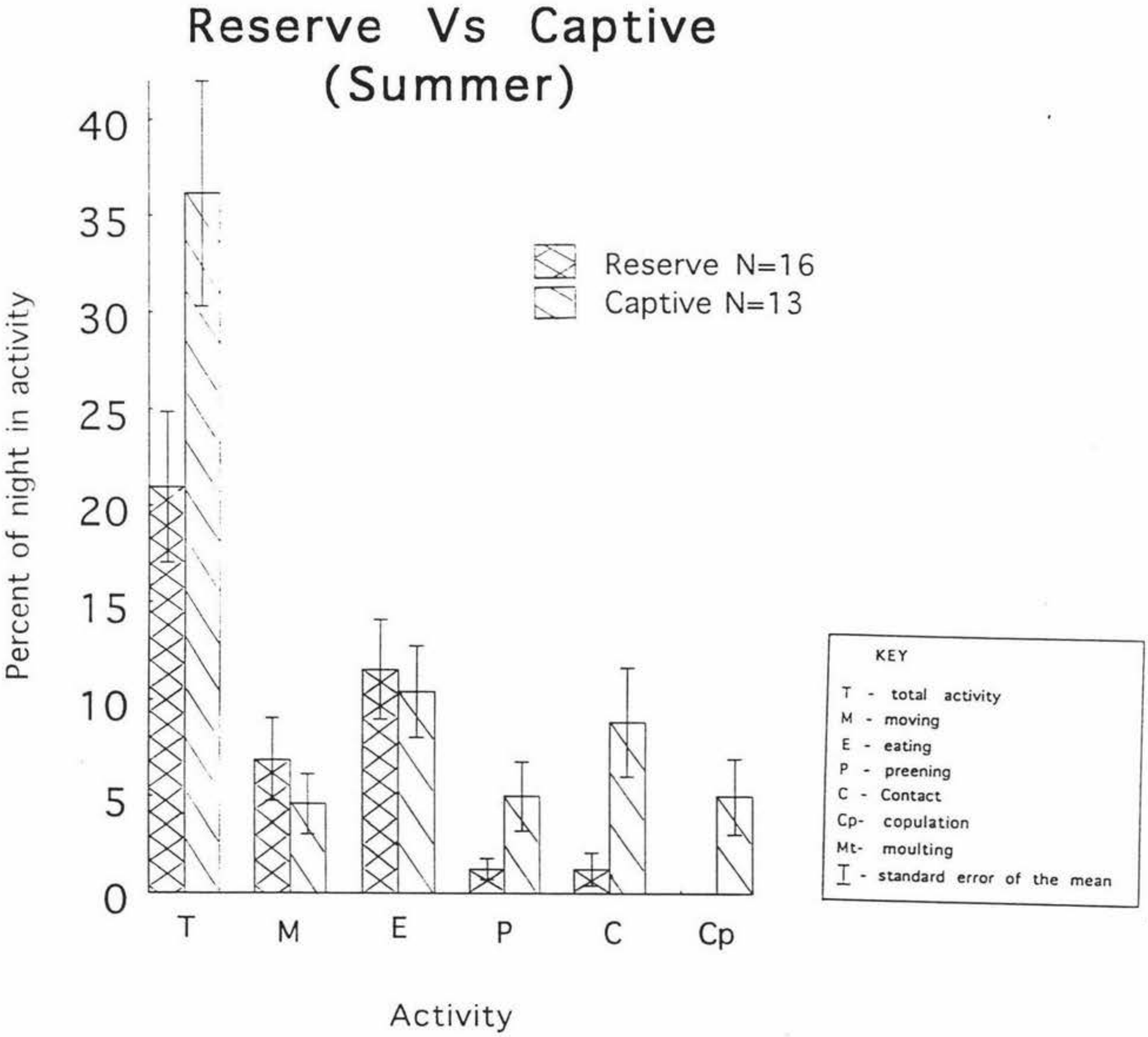


Figure 6.4

Activity levels of Mahoenui weta during the night at Mahoenui reserve and in captivity during summer.

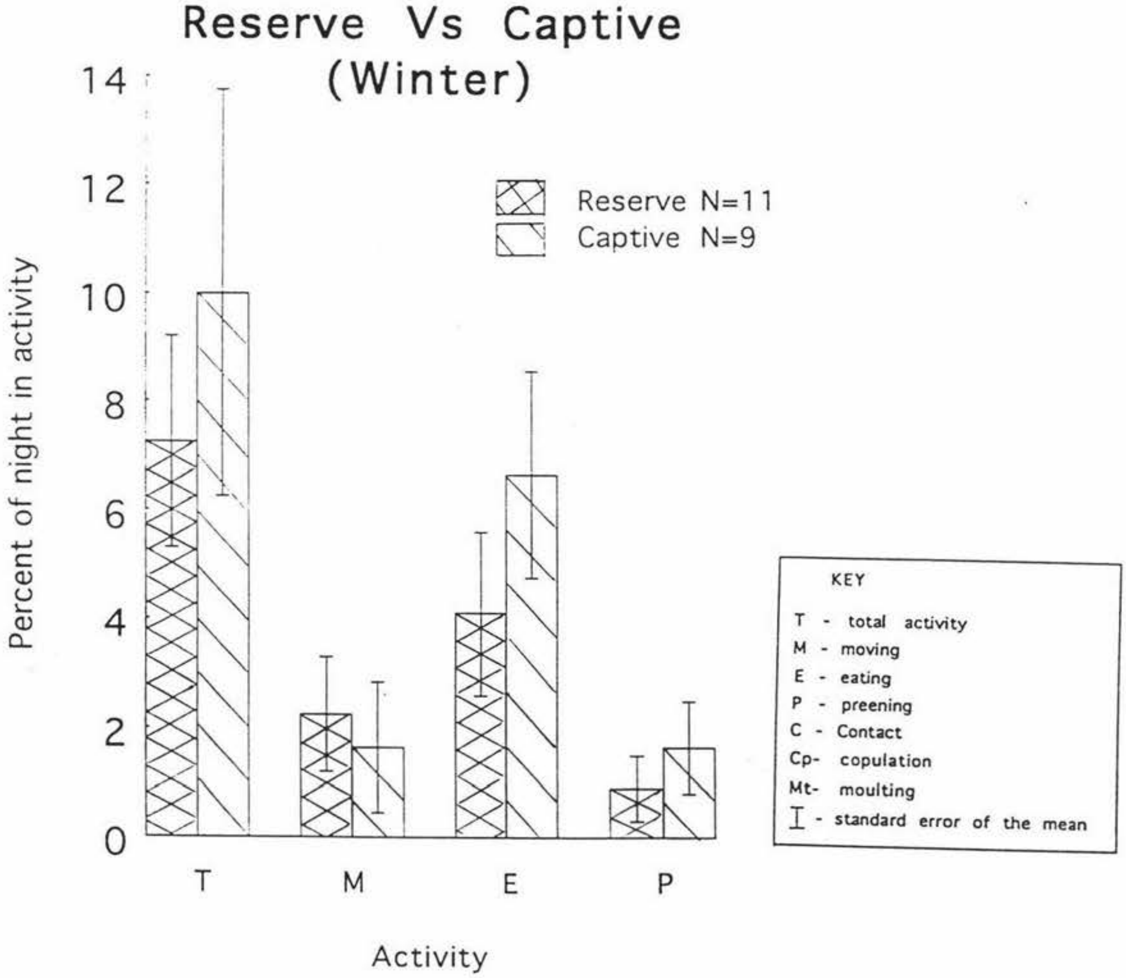


Figure 6.5

Activity levels of Mahoenui weta during the night at Mahoenui reserve and in captivity during winter.

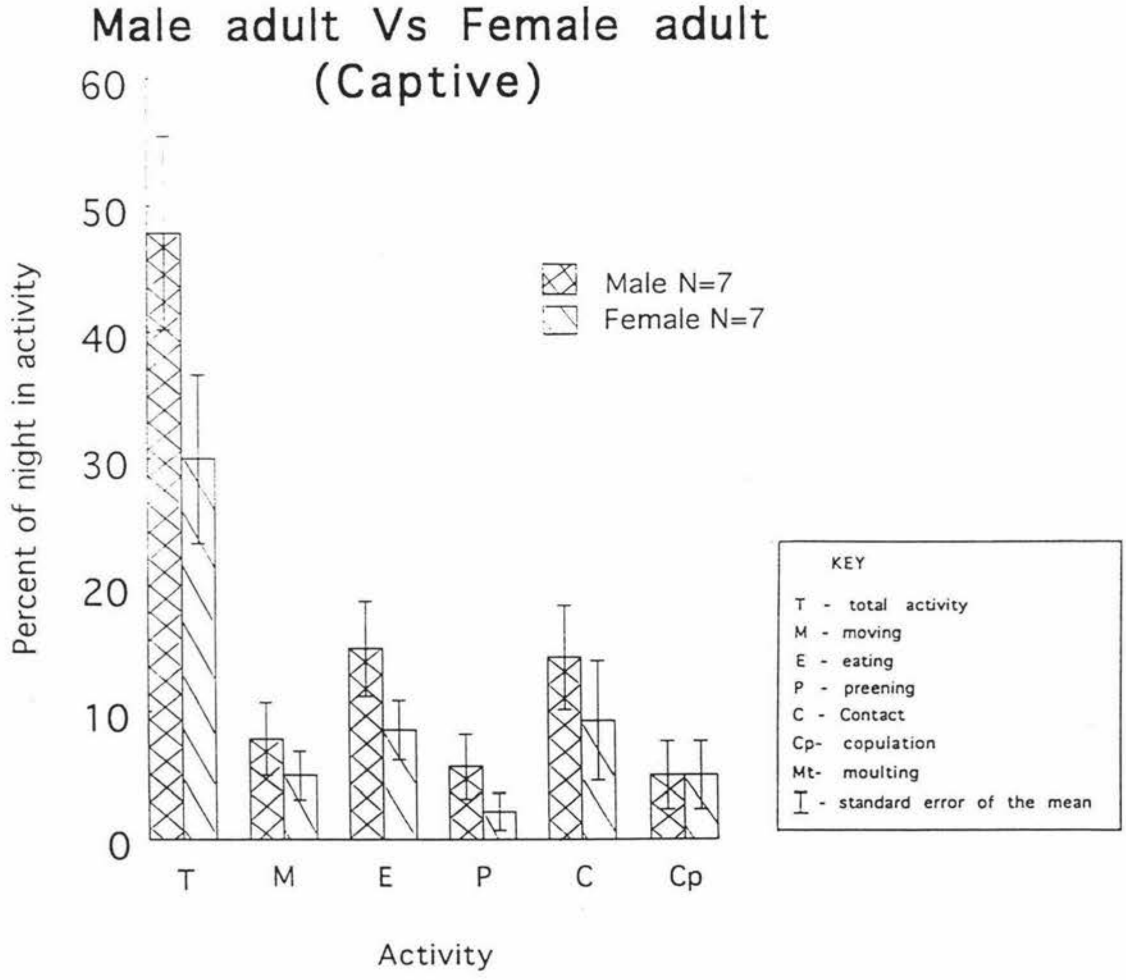


Figure 6.6

Activity levels of adult male and female Mahoenui weta in captivity during the night.

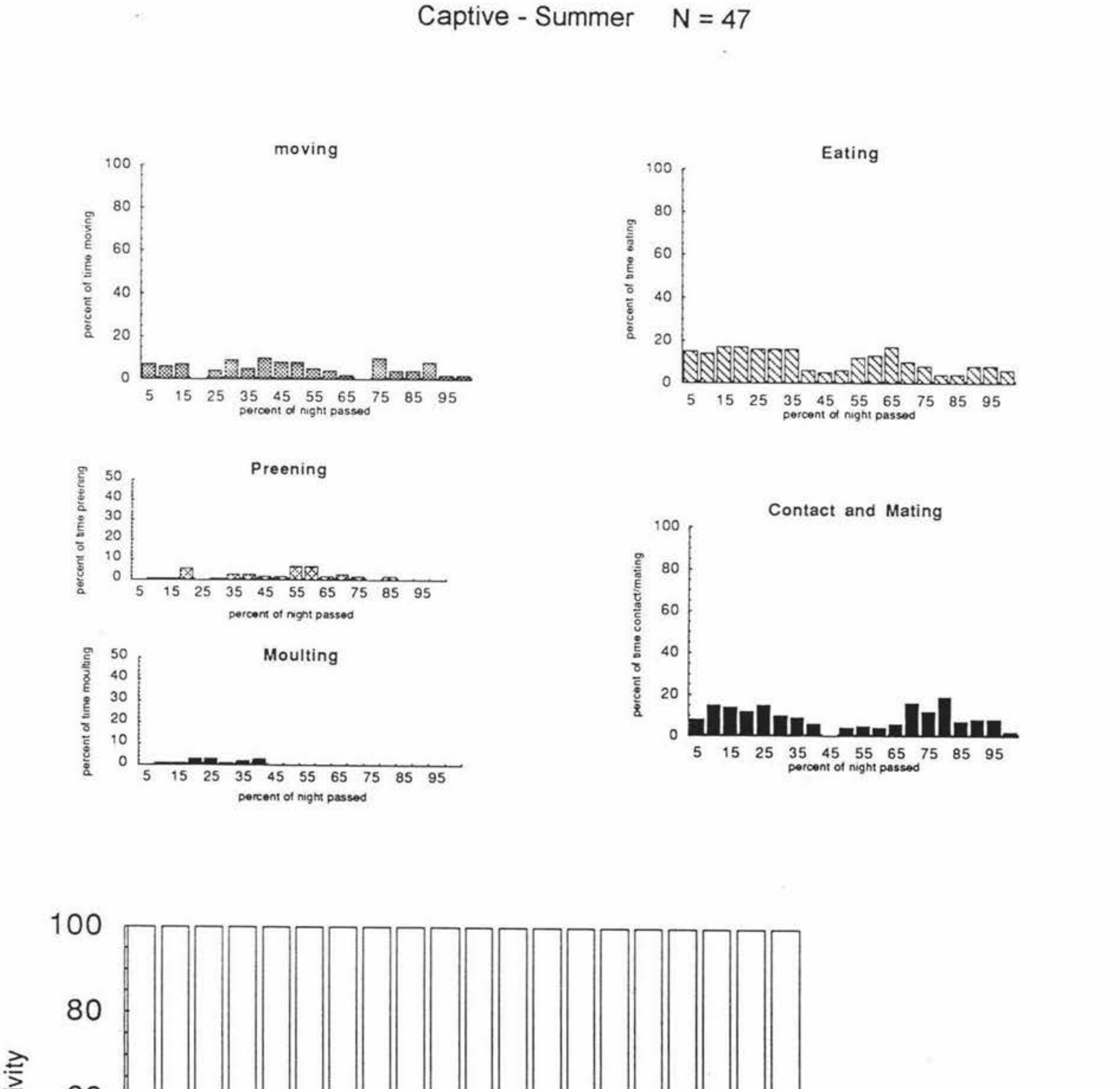


Figure 6.7 Averaged activity levels at 5% intervals during the night of 47 Mahoenui weta in captivity during summer. Each activity was graphed individually and then combined into one graph.

Reserve - Summer N = 27

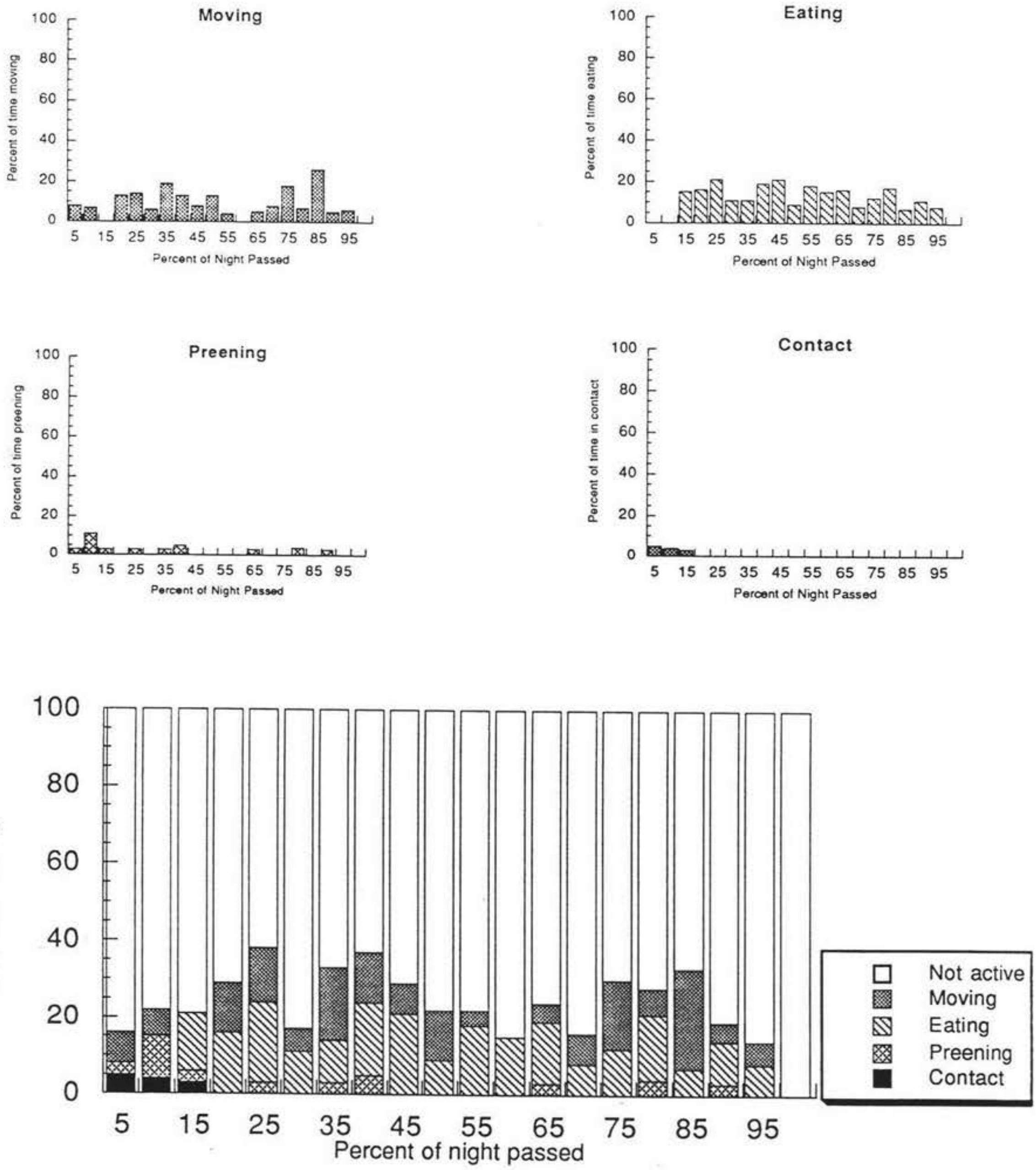


Figure 6.8 Averaged activity levels at 5% intervals during the night of 27 Mahoenui weta at Mahoenui reserve during summer. Each activity was graphed individually and then combined into one graph.

Captive - Winter N = 30

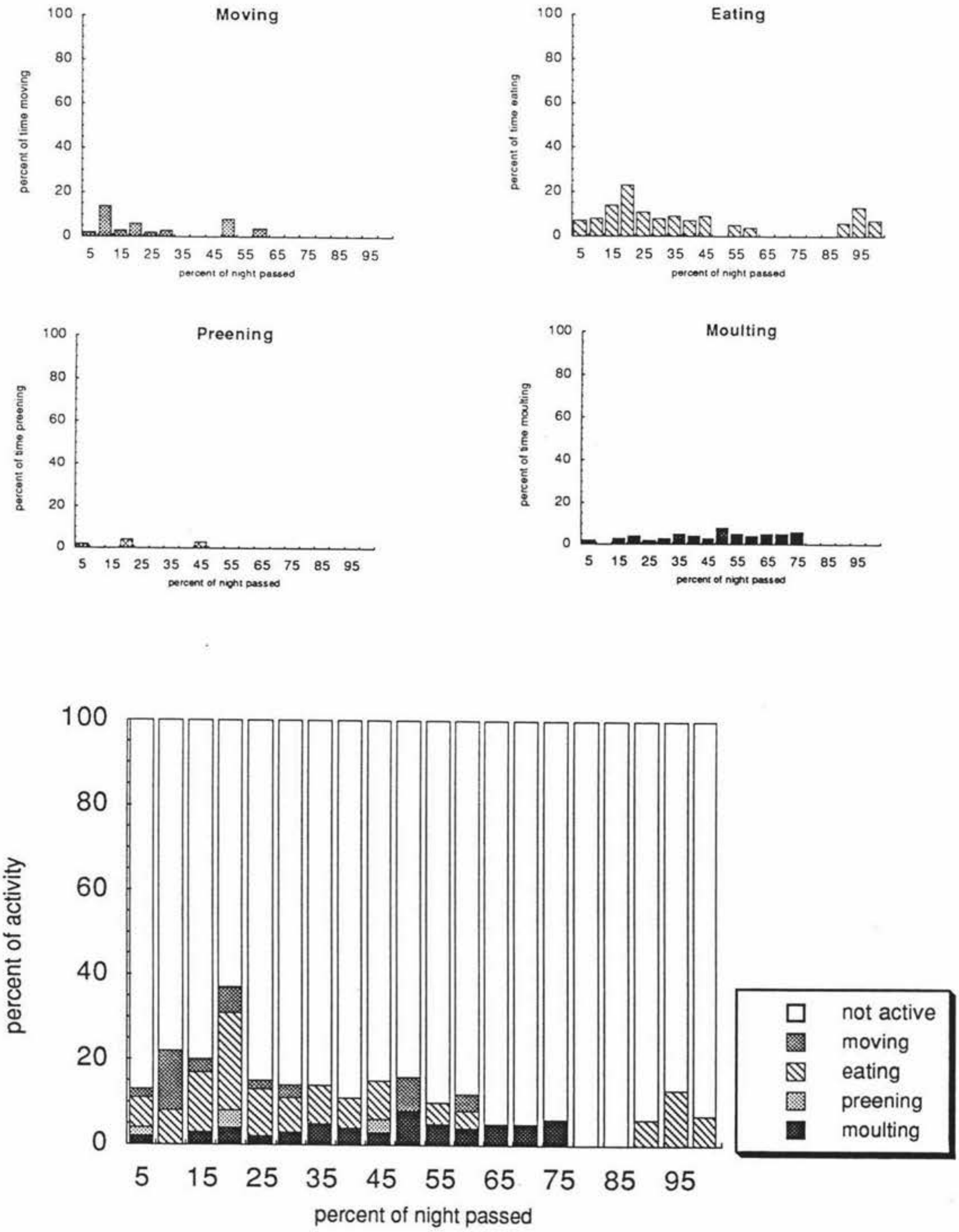


Figure 6.9 Averaged activity levels at 5% intervals during the night of 30 Mahoenui weta in captivity during winter.Each activity was graphed individually and then combined into one graph.

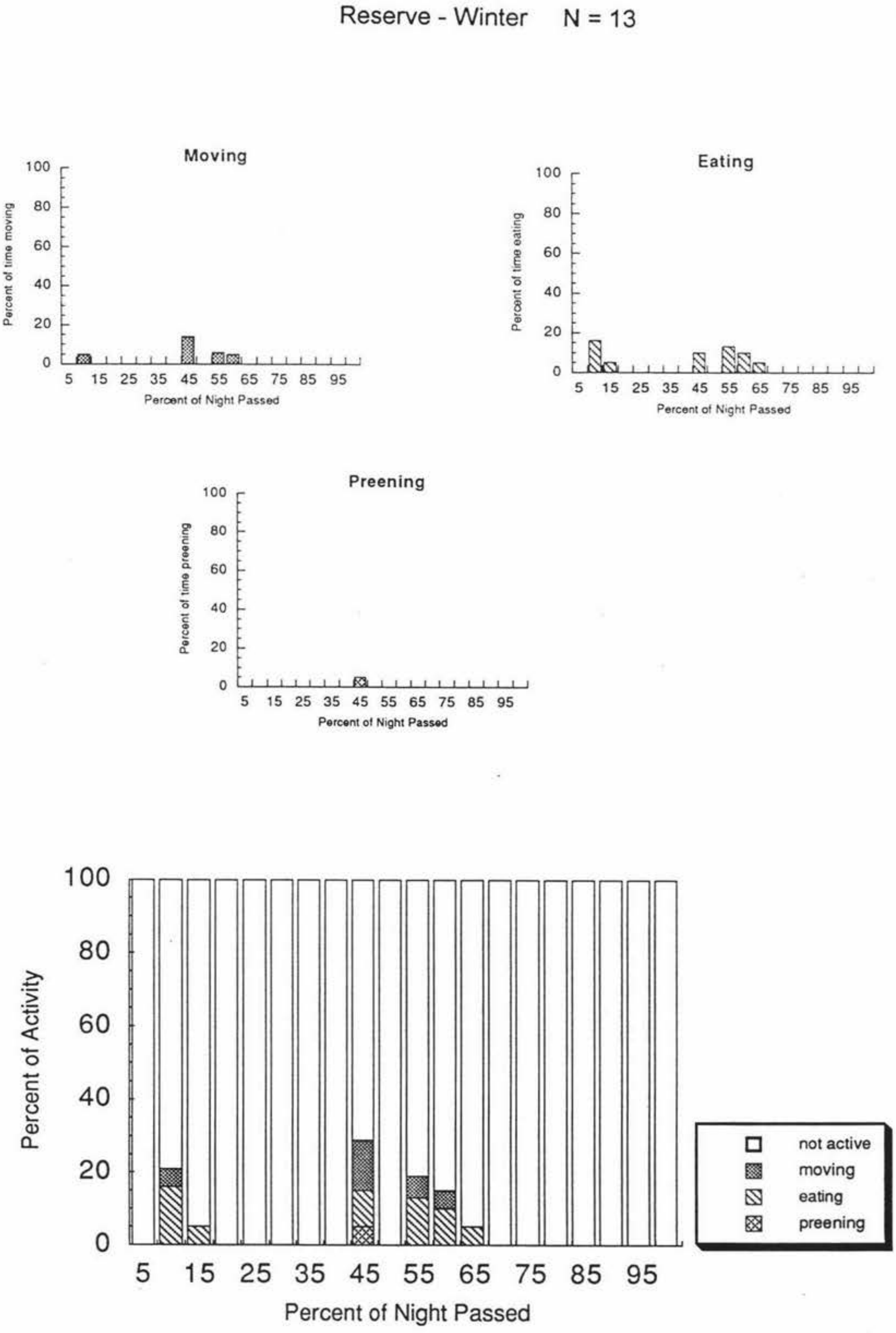
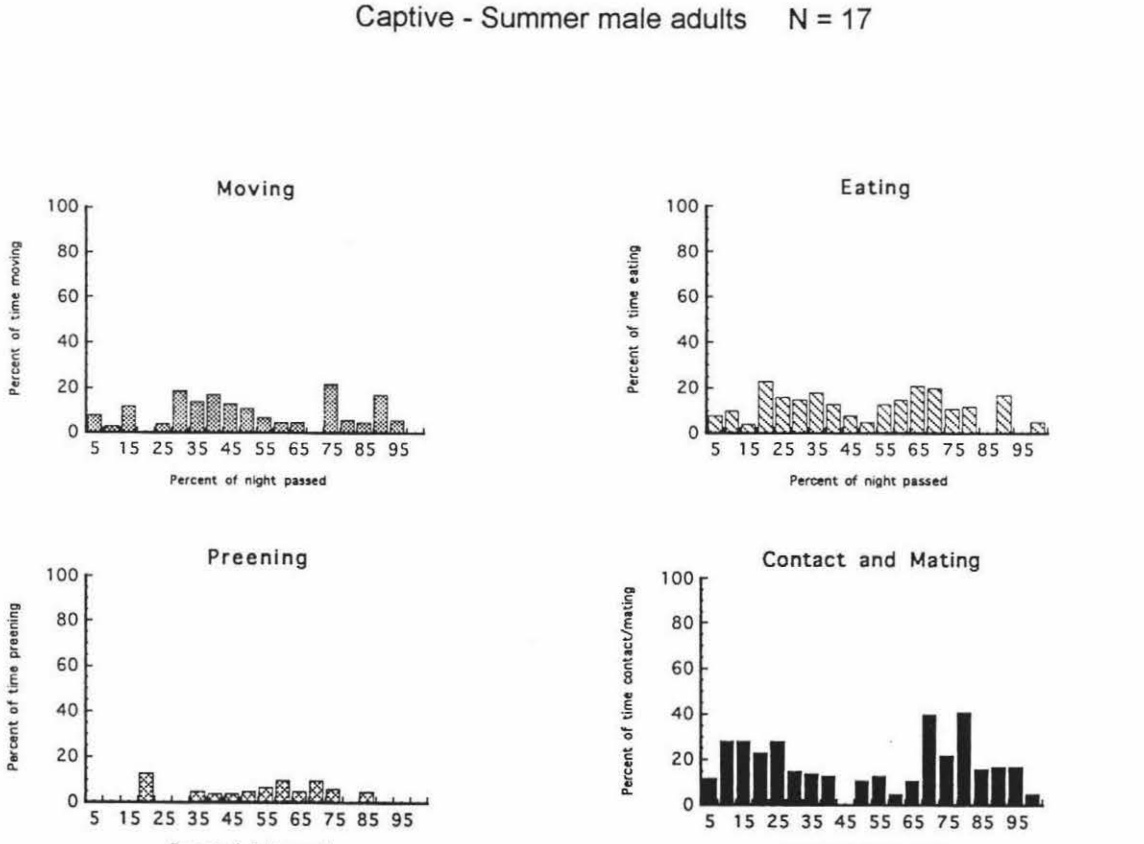


Figure 6.10 Averaged activity levels at 5% intervals during the night of 13 Mahoenui weta at Mahoenui reserve during winter. Each activity was graphed individually and then combined into one graph.



Captive - Summer male adults N = 17

Figure 6.11 Averaged activity levels at 5% intervals during the night of 17 adult male Mahoenui weta in captivity during summer. Each activitywas graphed individually and then combined into one graph.

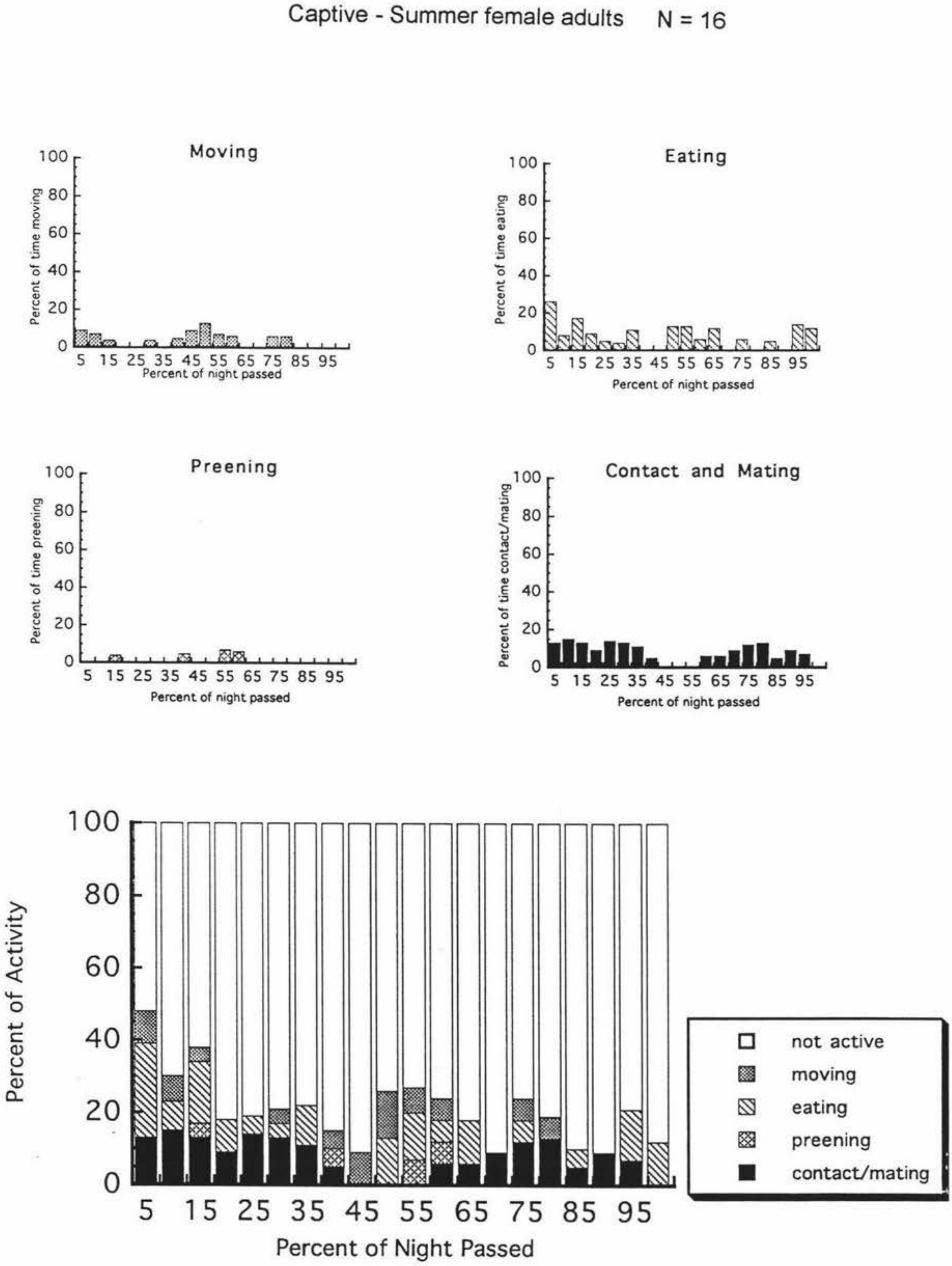


Figure 6.12 Averaged activity levels at 5% intervals during the night of 16 adult female Mahoenui weta in captivity during summer. Each activitywas graphed individually and then combined into one graph.

Captive - Summer nymphs N = 14

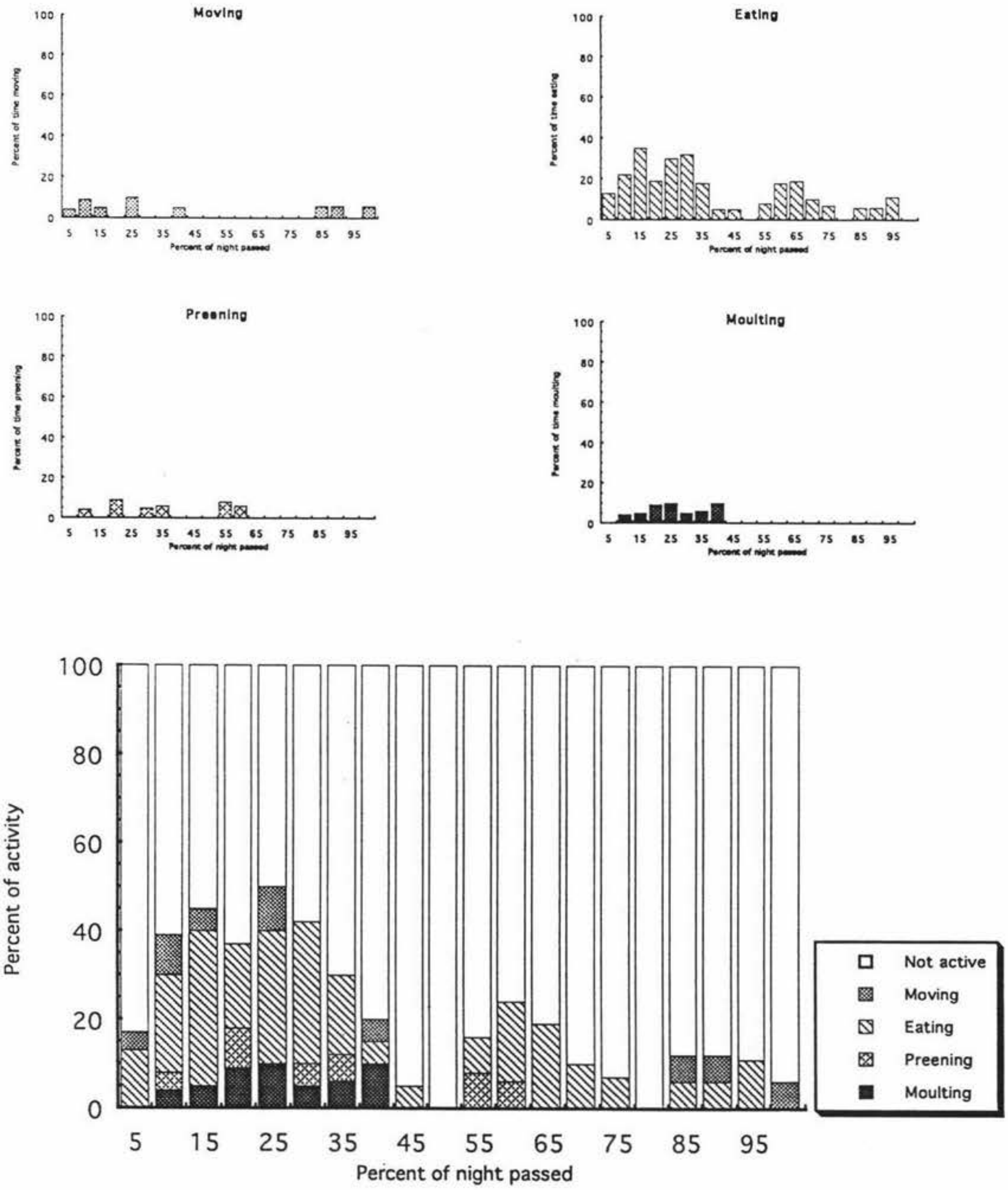


Figure 6.13 Averaged activity levels at 5% intervals during the night of 14 Mahoenui weta nymphs in captivity during summer. Each activitywas graphed individually and then combined into one graph.

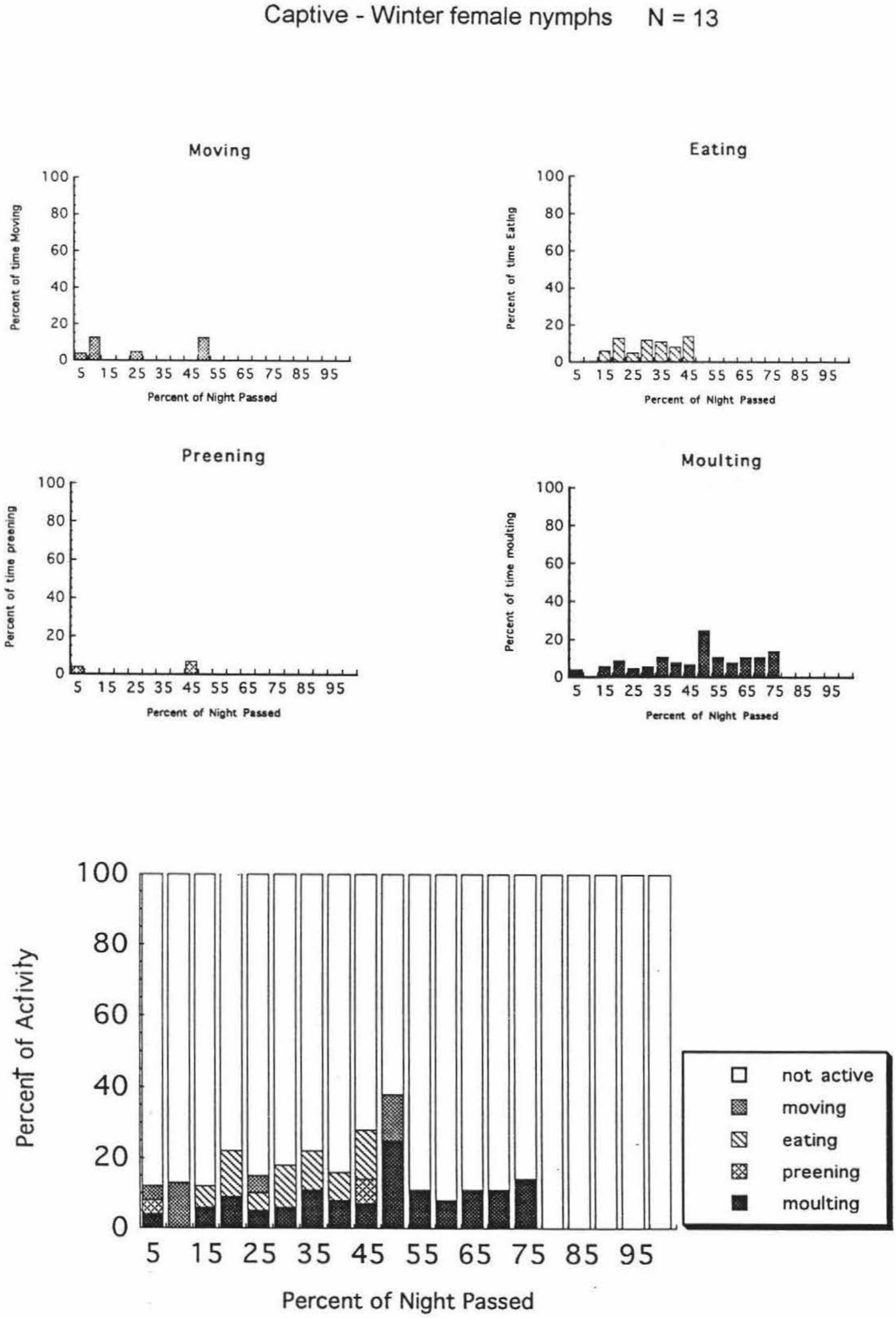


Figure 6.14 Averaged activity levels at 5% intervals during the night of 13 female Mahoenui weta nymphs in captivity during winter. Each activitywas graphed individually and then combined into one graph.

Captive - Winter male nymphs N = 16

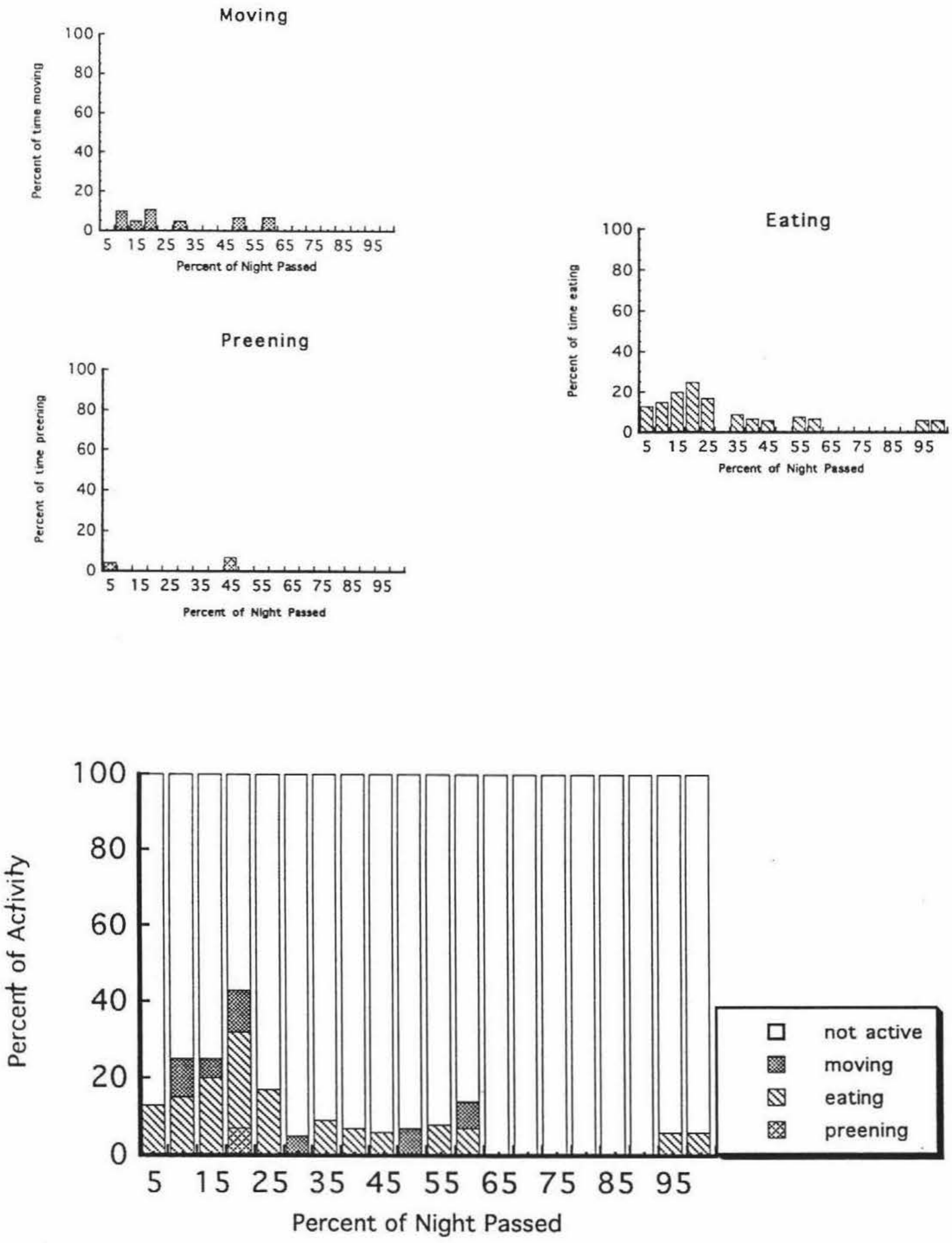


Figure 6.15 Averaged activity levels at 5% intervals during the night of 16 male Mahoenui weta nymphs in captivity during winter. Each activitywas graphed individually and then combined into one graph.

Table 6.1 The proportion of the total mean active period that the weta spent in each activity.

	Reserve	Winter	Reserve	Summer	Captive	Winter	Captive	Summer	Cap. nymphs	Winter	Cap. nymphs	Summer	Cap. adult	Males	Cap. adult	Females
	*	#	*	#	*	#	*	#	*	#	*	#	*	#	*	#
Moving	2.25	31	6.9	33	1.65	17	4.6	13	1.25	15	1.65	9	7.85	16	5.0	17
Eating	4.1	57	11.55	55	6.65	66	10.4	35	5.65	70	8.35	47	15.0	32	8.55	29
Preening	0.9	12	1.25	6	1.65	17	5.0	14	1.25	15	3.3	18	5.7	12	2.15	7
Contact	-	-	1.25	6	-	-	8.85	24	-	-	-	-	14.3	30	9.3	30
Copulation	-	-	-	-	-	-	5.0	14	-	-	-	-	5.0	10	5.0	17
Moulting	-	-	-	-	-	-	-	-	-	-	5.0	27	-	-	-	-
Total activity	7.25	100	20.95	100	10.0	100	36.15	100	8.10	100	18.35	100	47.85	100	30.0	100

* mean percentage of the night period that the weta were active

\# proportion of the total mean active period for this activity

DISCUSSION

During the winter captive weta and reserve weta show that although the total activity period of captive weta was longer the amount of time spent in each activity, and the proportion of the total activity that weta spent in each activity in both groups were very similar. One possible reason why captive weta showed increased activity in winter is because they were kept inside where the temperatures are always a few degrees higher than the outside temperature. Captive weta were also not exposed to other possibly adverse climatic influences such as frost, wind and rain. The decrease in activity that they exhibited in winter compared with summer supports these ideas. Another possible reason why captive weta showed an increased activity time period could be due to a bias in the data collected. Captive weta were confined to a small area where all activities could be readily observed, whereas at the reserve it was often difficult to determine exactly what weta were doing when they were partially obscured by dense foliage. These possible reasons for the increased activity in the captive weta would also be apparent in the summer studies.

In the summer weta studies copulation and contact between weta was significantly increased in captivity because the male and female weta were confined together and were always close to each other. At the reserve the weta are in low density (Sherley and Hayes 1993) and contact is rarely observed between two weta. Most of the increased activity in captive weta was due to the sexual activity (contact). Only one copulation was observed to commence during the night, although day time matings often extended through until about 10:00 pm (Chapter 5).

Knowing that captive weta may spend a higher percentage of the night active and that the large percentage of contact and copulation observations in captivity was consistent with the observations in the field, it can be stated that the captive

Mahoenui weta nocturnal behaviour is representative of field studies for the Mahoenui weta at the reserve. Most published behavioural observations of weta have been of weta in captivity (Richards 1973; Field 1980; Field and Sandlant 1983; Barrett 1990) and it would be encouraging to know that the behaviour in captivity of these other species may well be representative of the behaviour of weta in natural populations.

It is interesting that although the precentage of activity may be largely increased in summer compared to winter, the proportion of the total active period the weta spent in each activity tended to be similar in winter and summer months. This is most clearly observed in the reserve weta studies since there were vitually no new activities occurring in the summer months. When the activities 'contact', 'copulation' and 'moulting' occurred in the summer, the proportion of time spent eating was lessened. The proportion of the activities 'moving' and 'preening' tended to remain relatively constant during winter and summer. Contact and copulation occurred only during the summer months. This was because there were virtually no adults present in the winter months. In *Deinacrida heteracantha* (Richards 1973) adults were present all year round and mating was observed in all months except June, July and August. This suggests that the small percentage of Mahoenui adult weta present throughout the year may mate during spring but are not likely to mate in winter.

The decreased activity of nymphs in winter compared with summer indicate that decreased activity is temperature or climate related rather than a difference caused by the abundance of nymphs in winter and adults in summer, ie: a difference in weta maturity. Moller (1985) found that the activity of *Hemideina crassicruris* varied enormously in response to the weather. The number of weta seen outside galleries per hour per night increased as temperature and humidity increased.

The increased activity period in male adults compared with female adults is not clearly explainable. The males tended to expend more energy in courtship (contact) by constantly pursuing females (Chapter 5) and may need to eat more to sustain this activity.

The periods of activity during the night studies were very similar between captive and reserve weta. In summer, weta were generally active from first dark until dawn. There were two periods of increased activity 1.5-3.5 hours after dark and from about 5 to 5.5 hours after dark until 1 to 1.5 hours before dawn. Movement, feeding and contact were the main contributors to these peak activity periods. There was a decline in activity midway through the night period for 1 to 1.5 hours.

In winter, weta were not active during the entire night period. There was usually a peak activity period between 1.5 to 5.5 hours after dark. Activity usually ceased 3.5 to 5 hours prior to dawn. In the captive weta studies the weta often returned to feed in the last 1 to 1.5 hours before dawn prior to settling for the day.

In summer, weta were active from dark until dawn, a period of 8 to 9 hours. In winter the weta were active until about 65% of the night period which occupied from 6.5 to 8.5 hours. So, although in winter the weta did not remain active for the entire duration of the night, they were active for nearly as long as the weta during the summer.

During the summer there were differences in the activity periods throughout the night between adult males and females and between adults and nymphs. Adult males followed bimodal activity period where movement, eating and contact increased and the peaks in these activities coincided with each other. The adult females' active period varied from the males' because peaks in the activities eating and moving coincided with the lows in the bimodal contact activity, and the overall activity of the female appears more constant throughout the night. The nymphal instars show only one peak activity period which coincided with the first peak activity period in the general summer graph and the graph of adult males in summer. Activity occurred throughout the rest of the night period at a low level. There were no obvious differences between the behaviour of male and female nymphs during the winter.

CHAPTER SEVEN

Habitat choice and movement of Mahoenui weta

AIM: To determine Mahoenui weta habitat preference and their movement within that habitat.

INTRODUCTION:

Only two detailed studies have been published on weta habitat use and movements (Sherley and Hayes 1993; Moller 1985) and almost nothing is known of the nocturnal habitat use of weta. Moller (1985) made estimations of home range, density and biomass of *H. crassicruris* on Stephens Island by marking individual weta and attempting to relocate them on successive nights.

Sherley and Hayes' (1993) study represents the first description of diurnal habitat use by Mahoenui giant weta at Mahoenui reserve. Their research was undertaken in response to a list of urgent research needs outlined in an interim recovery plan (Jowett and Plant 1988) for this species.

Sherley and Hayes (1993) attempted to identify precisely where weta occur in the reserve and to describe the daytime habitat use of weta in gorse. They reported that Mahoenui weta avoided slopes over 21^{o} and preferred north to east facing slopes, perhaps for warmth. They showed an apparent dislike of smaller gorse bushes with stem circumferences of 11-20 cm. Goat activity was important in providing weta habitat as most weta were found within goat browse range and within the dense middle region of the bushes created by goats continuously cropping gorse foliage. Gorse browsed by goats provided excellent concealment and protection for the weta against predators. Goats also browsed regenerating native vegetation which would otherwise over-run the gorse in time.

The main objectives covered in this chaper are:

1. Habitat preference by Mahoenui weta was investigated by examining the following: their preference for goat browsed or non goat browsed regions of

gorse bushes; noting how often they moved about on the ground and where females oviposited; determining densities in gorse bushes with various levels of goat browsing and whether their habitat preference varied during winter and summer. This section follows research carred out by Sherley and Hayes (1993) on the dirunal habitat use of Mahoenui weta at Mahoenui reserve but includes nocturnal habitat preference which is not covered in their report.

2. Movement and range of Mahoenui weta was assessed by investigating how far Mahoenui weta moved during the night, by monitoring the distance moved between successive sightings of individually marked weta and whether their movement altered during winter and summer.

3. The vulnerability of Mahoenui weta to potential predators at Mahoenui reserve was assessed by examining how often weta were visible on the outside of gorse bushes or on the ground. Potential predators present at Mahoenui reserve that are known to prey on other weta species are cats (*Felis catus*), hedgehogs (*Erinaceus europaeus*) (Meads 1990; Moller 1985, Jowett 1989), Moreporks (*Ninox novaeseelandiae*) (Lindsay and Ordish, 1984), and possums (*Trichosurus vulpecula*) (Sherley and Hayes 1993).

Understanding how Mahoenui weta use their habitat is relevant to the maintenance of their existing habitat and it will provide information on how and where to establish new populations in order to secure the Mahoenui weta against extinction.

METHODS:

Monitoring weta movement

Nocturnal movement:

All methods used for recording nocturnal movement of Mahoenui weta at the reserve are described in Chapter Three.

Day to Day movement:

Micro transmitters (Sirtrack NZ Ltd) were used to locate weta on a daily basis (Plate 7.2). These transmitters weighed approximately 1.7 g and were only used on adult or sub-adult weta as they were considered large enough to carry this weight. Transmitters were attached to weta using the same methods used for betalights described in Chapter Three. 8 to 10 hours after the transmitters were attached weta were released where they were captured. The general locations of weta were subsequently found using radiotelemetry once a day for the remainder of each trip. Often a hand search of the bush area was needed to determine the exact position of the weta. Each position was then tagged by tying an identification label to the gorse near the weta. The distance between each tag, the height of each tag, and the distance between the first and last tag was subsequently recorded.

Capture and recapture of weta was also used to monitor weta movement at the reserve. Areas of gorse were hand searched, using leather gloves to prise open bushes and search inside. Weta were measured, weighed and then labelled using a silver paint pen (Pilot Super Colour) before being put back where they were found. When each weta was captured or relocated an identification tag was tied to the gorse near the weta. The height off the ground and the distance in from the bush edge were later measured as a record of their movement.

Study sites:

Gorse bushes along the eastern ridge and western face of the study area were searched in March 1992. Bushes with weta were searched again each subsequent day. Any bushes nearby were also searched in case marked weta moved to them. Daily searches were also carried out in and around these sites on all subsequent trips to the reserve. Occasional night searches were also made of these sites to observe the weta and find other weta. Any unmarked weta located within the sites were labelled, measured, and released.

Eleven sites were selected in March 1992, two additional sites were selected in May 1992 and one other site was selected in November 1992. Sites included isolated bushes, groups of isolated bushes, or bushes that were part of a large area of gorse.

The maximum height and width of each bush in each study site were recorded. Gorse bushes were also classified according to ther size and shape as shown in Figure 7.1. They were classified as either small seedlings (Type 1); a small goat browsed bush (Type 2); goat browsed up to 1 m high with a small amount of unimpeded growth above (Type 3); goat browsed up to 1 m high with a large amount of unimpeded growth above (Type 4); and a large unbrowsed bush (Type 5).

Destructive sampling of gorse bushes:

Gorse bushes were destructively sampled on farmland adjacent to the reserve belonging to Mr N. Rauputu. The dimensions and classificiation of each gorse bush type were noted before a hand search of the bush was carried out using the same methods to locate weta in the reserve. Finally the bush was cut into branches and each branch was thoroughly searched for weta. This included shaking over a plastic sheet.

Search for weta eggs:

Whenever a gorse bush was destructively sampled, three samples were taken for weta eggs in the soil beneath the bush. Occasionally a fourth sample was taken in grass nearby as shown in Figure 7.2. Each sample consisted of an 0.25 m^2 quadrate of soil removed to a depth of at least 5 cm.

Statistical analyses:

See Chapter 3.

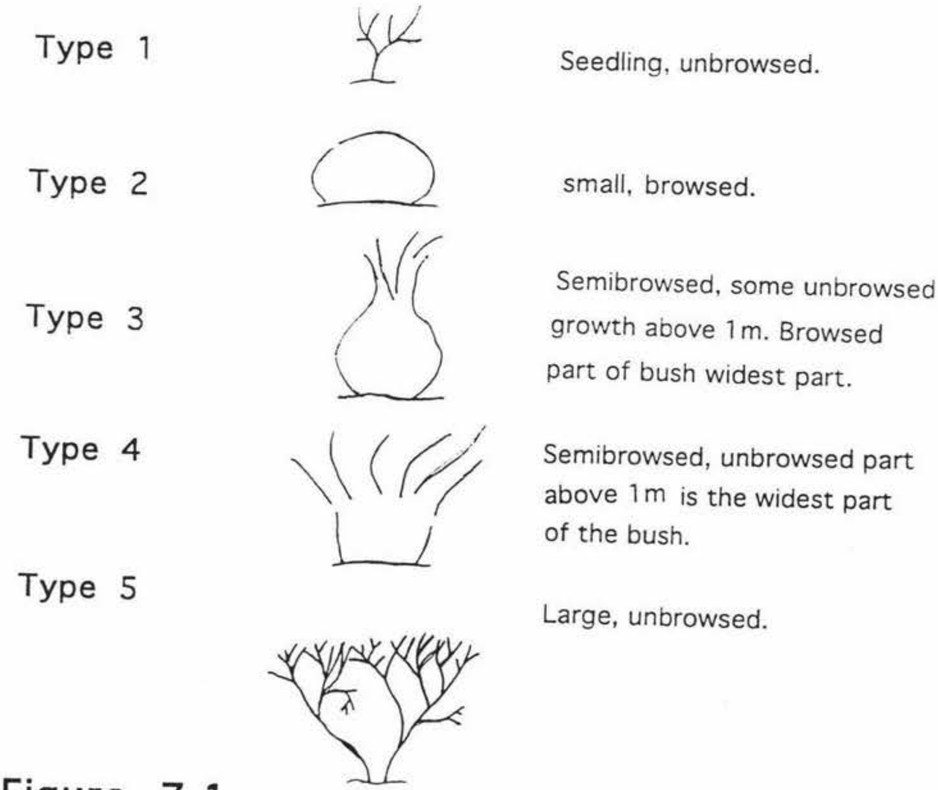


Figure 7.1

Diagrammatic representation of the five types of gorse bushes together with the classification used.

Figure 7.2

Position of soil samples taken for Mahoenui weta eggs in relation to gorse bushes that were destructively sampled.

Position 1. Against the gorse main trunk.
Position 2. 25-35 cm out from the trunk.
Position 3. At the soil/grass boundary.
Position 4. In the grass area out from the edge of the gorse bush.

RESULTS

7.1 Nocturnal habitat choice and movement of Mahoenui weta

7.1.1 **Nocturnal habitat choice**

Weta spent less than 1% of the night on the ground during winter whereas in summer they spent on average 12% of the night there. In winter an average of 57% of the night was spent by weta in the goat browsed region and the remainder of the night was spent in the upper non goat browsed region. Weta spent an average of 40% of the night in the non goat browsed region during summer. There was no significant difference between the time spent in browsed and unbrowsed regions of gorse bushes during winter and summer but generally weta tended to spend a greater percentage of the night within the goat browsed region of a gorse bush during winter. However, weta spent a greater percentage of the night in the upper non goat browsed region in summer (Figure 7.3).

Weta were found on the unbrowsed region of the gorse more frequently towards the middle of the night during winter when 50-70% of weta were found there. At this time of year 70-85% of weta were found in the browsed region of gorse bushes during the first 45% of the night and the last 10%.

Weta were found on the ground more frequently towards the middle of the night during summer (up to 25% of weta on the ground) but they were found there less frequently towards the end of the night. The percentage of weta found on the browsed and unbrowsed regions remained fairly constant throughout the night with a higher percentage of weta on the unbrowsed region (about 70%) than on the browsed region (about 30%) (Figure 7.5)

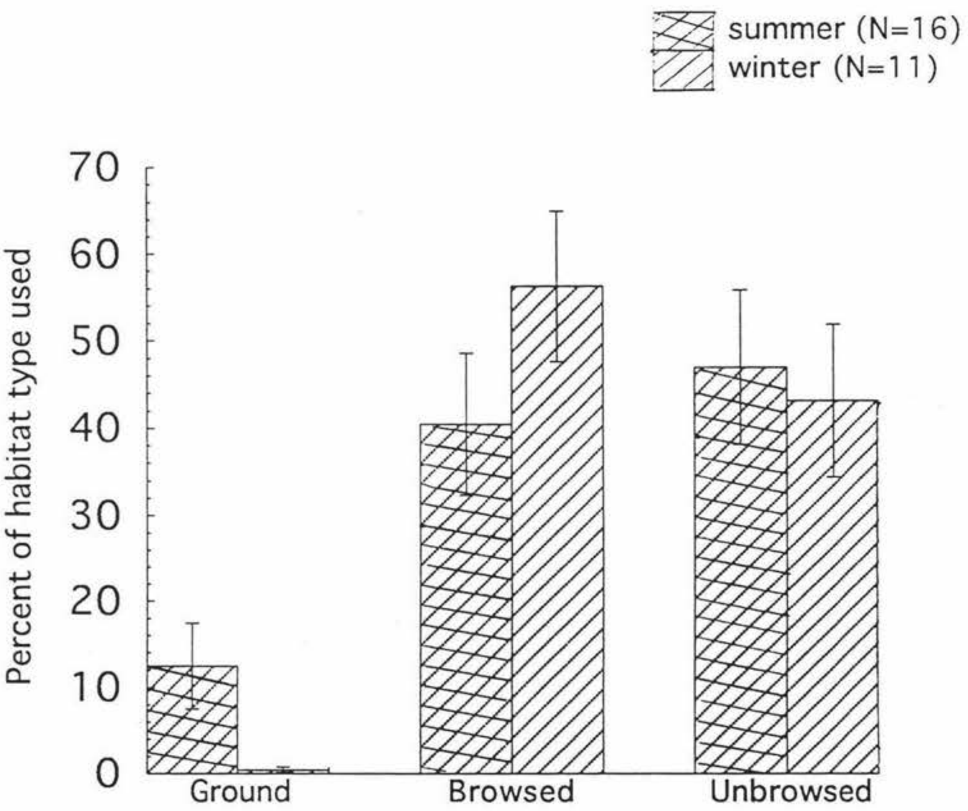


Figure 7.3

The average percentages of the night that weta spent on the ground or in goat browsed or non goat browsed regions of gorse at Mahoenui reserve during winter and summer months. Bars give the standard error.

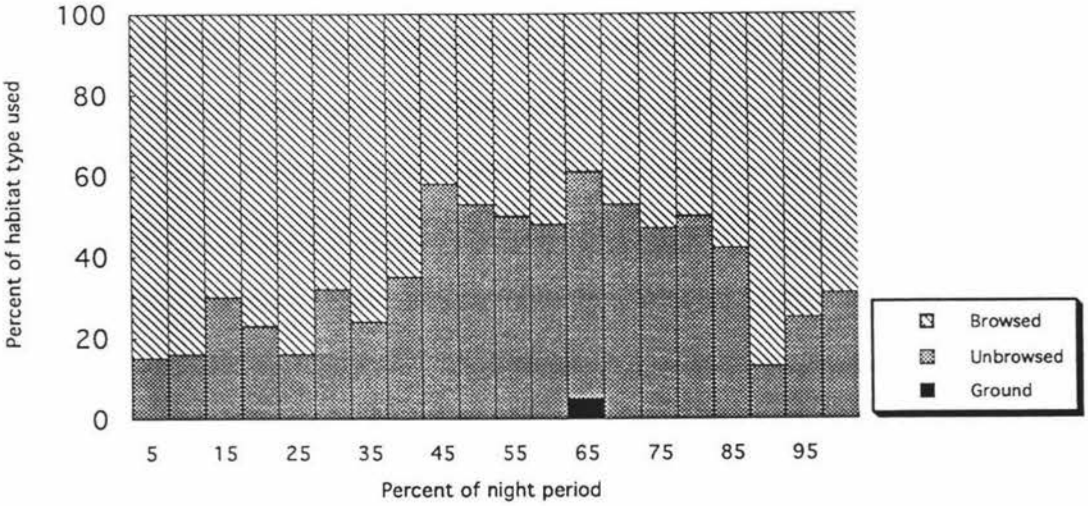


Figure 7.4 **Averaged habitat use of 13 Mahoenui weta during winter.** Percentages of the time spent by weta on the ground or ingoat browsed and non goat browsed regions of the gorse are given for each 5% interval of the night.

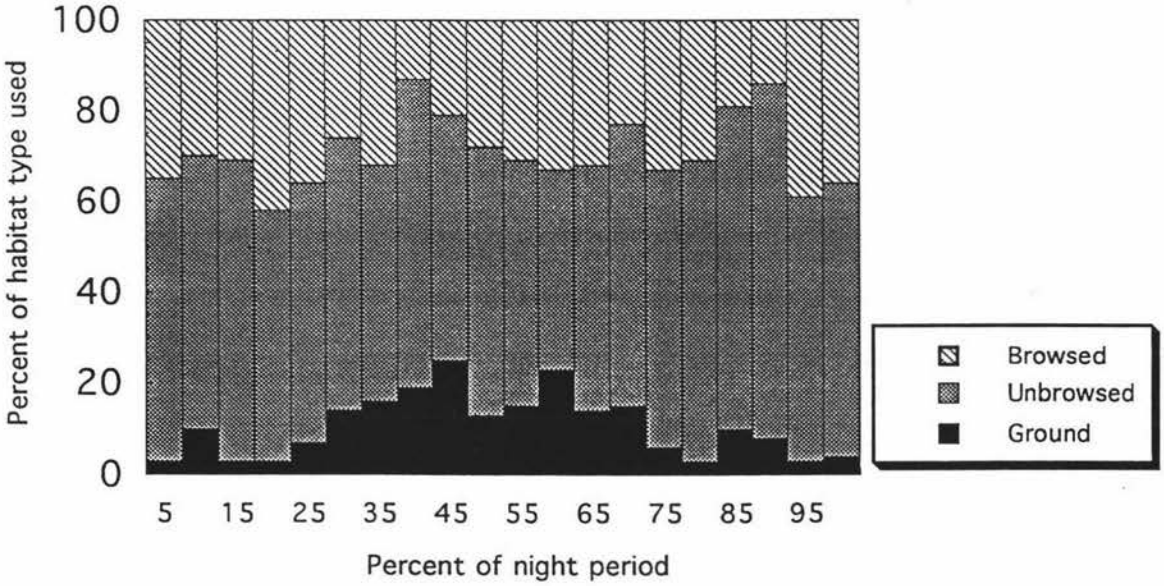


Figure 7.5 **Averaged habitat use of 25 Mahoenui weta during summer.** Percentages of the time spent by weta on the ground or ingoat browsed and non goat browsed regions of the gorse are given for each 5% interval of the night.

7.1.2 Movement

Individual weta showed a lot of variability in the total distance they moved per night (Figure 7.8). Most moved between 0 and 11.0 m per night in all months of the year except February when seven travelled between 12.0 m and 31.0 m.

Weta moved about at an approximate constant rate throughout the night (Figure 7.6). In summer they moved further on average (average total distance = 9.1 m) than during the winter (average total distance = 5.2 m). The average total distances moved for male (10.1 m) and female (8.8 m) during summer was not significantly different (Figure 7.7).

7.1.3 Visibility of Mahoenui weta to observers.

Weta spent more time on the outside of gorse bushes and on the ground during summer than during winter. In winter weta were visible on average for 15.8% of the night; with 15.0% on gorse and 0.8% on the ground. In contrast weta were visible on average for 37.7% of the night during summer. This comprised 28.8% on gorse and 8.8% on the ground (Figure 7.9).

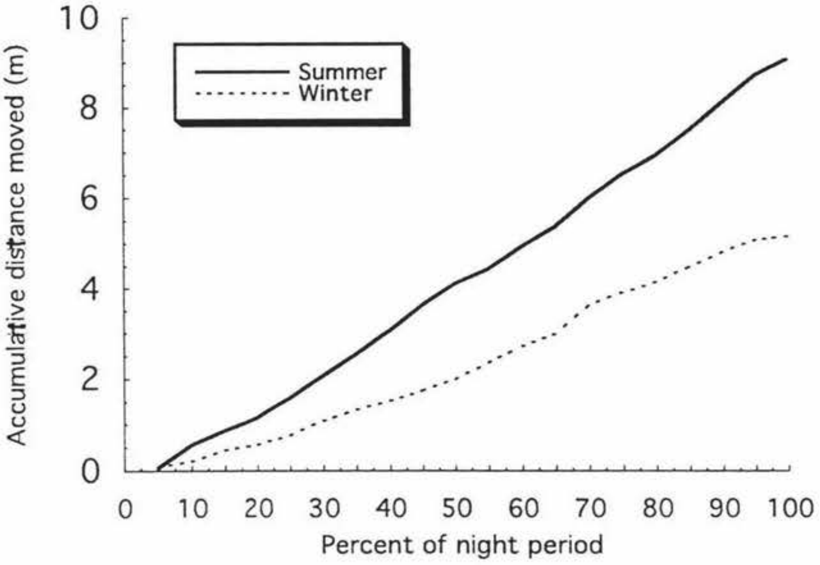


Figure 7.6

Average accumulative distance moved during the night for Mahoenui weta in summer and winter, (Data from 1/4 and 1/2 hour intervals).

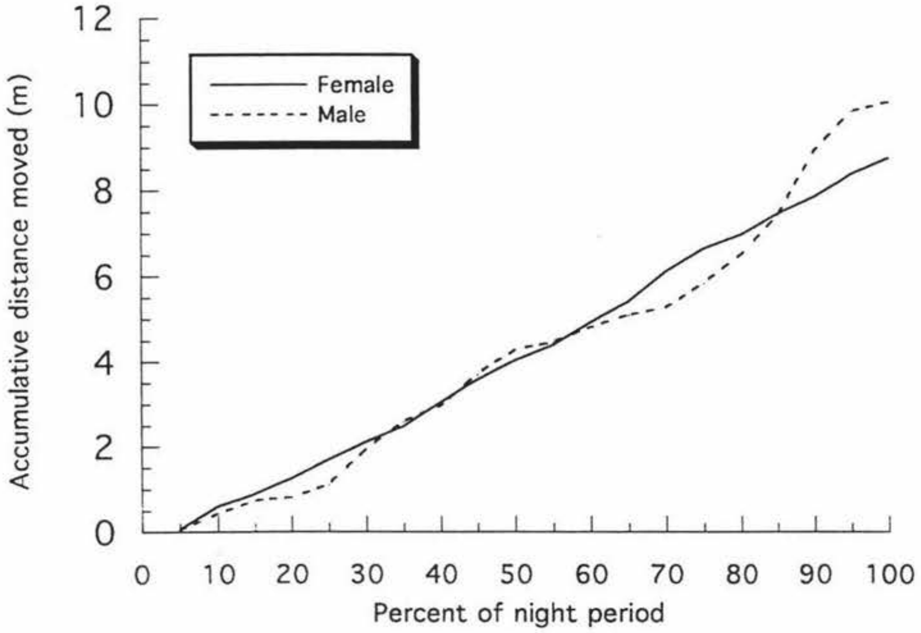


Figure 7.7

Average accumulative distance moved during the night for female and male Mahoenui weta, (Data from 1/4 and 1/2 hour intervals).

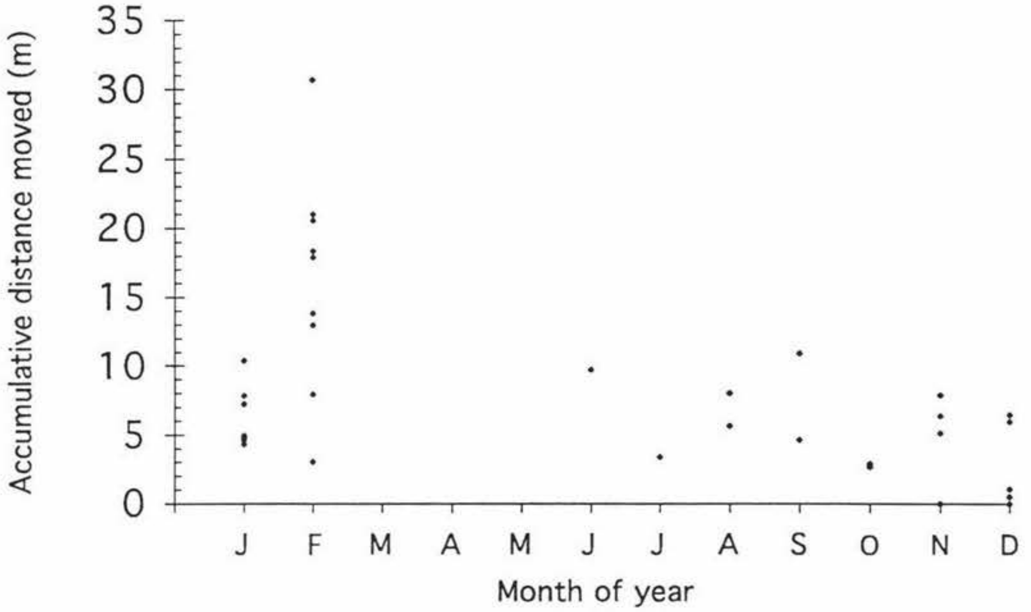


Figure 7.8

Total distances moved per night for individual weta in Mahoenui reserve.

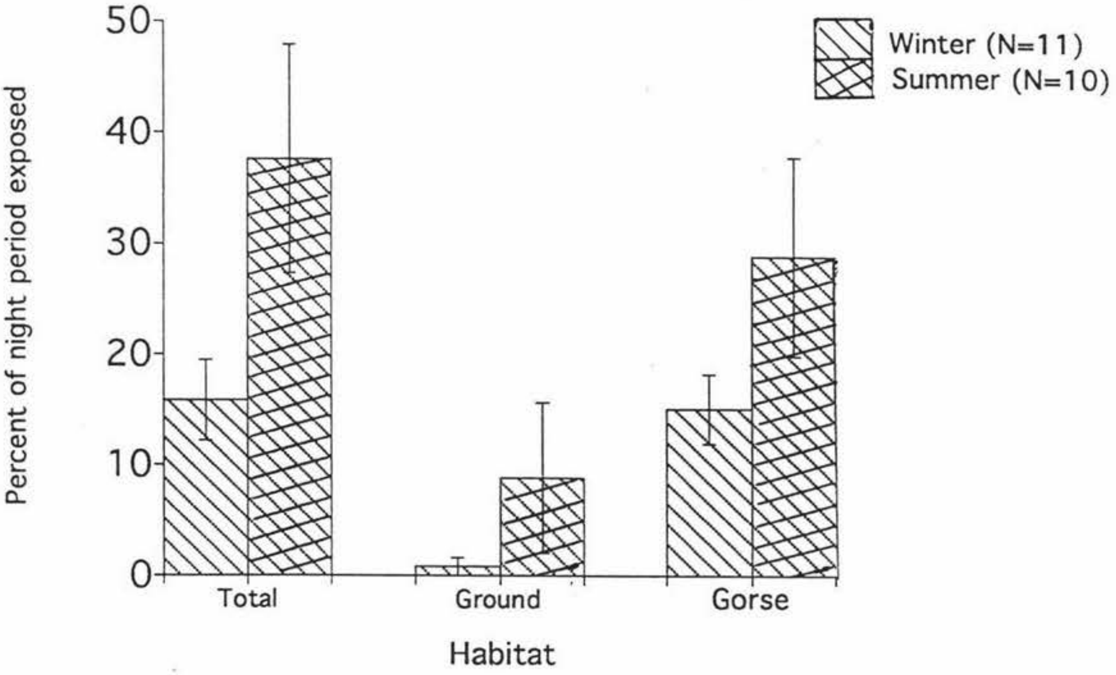


Figure 7.9

The average percentage of the night during winter and summer when weta were visible on gorse or on the ground. Bars give the standard error.

TABLE 7.1

Number of weta found during visual (hand) searches and destructive sampling of gorse bushes.
Type of bush is given in Figure 7.1. The number of Mahoenui weta found in the hand search and destructive search and the total number of Mahoenui (M) and *Hemideina* (H) weta found in the destructive sample are given.

Date	Sample No.	Bush type	Max height	Max circumference	M. Weta found in search	M. Weta found in destruction	Total M. Weta found	Total H. Weta found
26-11-91	1	3	1.9	2.0x2.1	2 subadult	0	2	3
26-11-91	2	3	2.5	2.2x1.8	1 subadult	1 subadult	2	-
26-11-91	3	3	2.1	1.6x1.6	0	1 subadult	1	-
7-3-92	4	3	1.6	1.8x1.8	0	0	0	1
7-3-92	5	4	2.5	2.4x2.0	0	3 nymphs	3	4
8-3-92	6	4	2.8	3.0x3.0	0	1 nymph	1	8
8-3-92	7	4	2.7	1.7x2.0	0	3 nymph	3	4
9-3-92	8	2	1.0	1.5x1.5	0	0	0	0
9-3-92	9	5	2.3	1.0x1.0	0	0	0	0
2-4-92	10	3	1.8	1.2x1.2	0	2 nymphs	2	2
2-4-92	11	5	1.3	2.3x2.7	0	2 nymphs	2	1
23-5-92	12	3	2.1	1.0x1.0	0	0	0	10
23-5-92	13	3	2.1	1.2x1.2	0	0	0	6
17-7-92	14	4	2.5	2.8x2.8	1 nymph	1 nymph	2	-
11-8-92	15	3	1.9	1.5x1.8	0	2 subadult and nymph	2	-
4-9-92	16	3	1.3	1.0x1.4	0	0	0	-
6-10-92	17	4	2.0	1.5x1.8	0	2 subadult and nymph	2	0
1-11-92	18	3	1.45	1.5x1.6	0	1 nymph	1	-
13-1-93	19	4	1.8	1.1x1.1	0	0	0	5
TOTALS					4	19	23	42

7.2 Diurnal habitat use and daily movement of Mahoenui weta

7.2.1 Habitat use

Destructive sampling of gorse bushes showed that searching for weta by hand was a relatively poor way of locating all weta present (Table 7.1). The proportion of Mahoenui weta found in hand searches was low compared to the total number of weta present in nineteen gorse bushes destructively sampled between November 1991 and January 1993. Larger subadults (9th instar) appeared to be more readily located during a hand search than nymphs less than 9th instar. Three out of seven subadults were located in the hand search compared with only one of 17 nymphs. In adition, fewer Mahoenui weta were found in gorse bushes by destructive sampling (23 weta) than *Hemideina* (42 weta).

	No of weta in goat browsed region	% of weta in goat browsed region	No of weta in non goat browsed region	% of weta in non goat browsed region
Autumn (March - May)	71	85	13	15
Winter (June - Aug)	16	70	7	30
Spring (Sept - Nov)	37	70	16	30
Summer (Dec - Feb)	35	50	35	50
TOTAL	160	70	69	30

Table 7.2 Number and percentage of Mahoenui weta found during the day in goat browsed and non goat browsed regions of semibrowsed bushes at Mahoenui reserve

	No of weta < 10cm into bush	% of weta < 10cm into bush	No of weta > 10cm into bush	% of weta > 10cm into bush
Autumn (March - May)	11	39	17	61
Winter (June - Aug)	5	36	9	64
Spring (Sept - Nov)	11	27	30	73
Summer (Dec - Feb)	7	27	19	73
TOTAL	34	31	75	69

Table 7.3 Number and percentage of Mahoenui weta found during the day less than 10cm from the edge of goat browsed regions, or greater than 10cm from the edge of goat browsed regions of gorse bushes at Mahoenui reserve.

Fewer weta were found during the day in goat browsed regions of semibrowsed bushes (50%) in summer, than during winter and spring (70%) or autumn (85%). In summer equal numbers of weta were found in goat browsed and non goat browsed regions of the semibrowsed bushes, whereas in autumn, winter and spring more weta were found in goat browsed regions than non goat browsed regions during the day (Table 7.2).

The foliage at the edge of goat browsed regions of gorse bushes was generally all fresh and green but there was an accumulation of dead foliage further into the browsed region (>10cm from the surface). Throughout the year about 30% of weta were found within the outer 10 cm of goat browsed regions and 70& were found deeper than this amongst the dead foliage (Table 7.3).

On average 1.4 weta were found per bush per month amongst isolated groups of bushes (group 2), more than the number of weta per bush per month found in isolated bushes (group 1) (0.7 weta/bush/month), and bushes joined to a larger area of continuous gorse (group 3) (0.8 weta/bush/month). There was little difference between the number of weta found in isolated bushes (group 1) and bushes joined to a larger area of continuous gorse (group 3).

The average number of Mahoenui weta found per bush was similar for the recapture sites and the destructive gorse samples. Mahoenui weta were found more commonly in large non goat browsed (type 5) (1.0-2.2 weta/bush) and semibrowsed bushes (type 4) (0.7-1.8 weta/bush) than small or heavily browsed bushes (types 2 and 3) (0.9 weta/bush). More *Hemideina* weta were found per bush in heavily goat browsed (type e) (3.7 weta/bush) and semibrowsed bushes (type 4) (4.2 weta/bush) than Mahoenui weta, but possibly fewer in large unbrowsed bushes (type 5) (0.5 weta/bush).

7.2.2. **Weta density**

Throughout the year the average number of Mahoenui weta found per bush at the capture-recapture sites ranged from 0.1 to 3.0 (Figure 7.12) Higher densities of weta were found in March (3.0 weta/bush) and from June to September whereas there were on average lower densities of weta found at the sites in February (0.1 - 0.2 weta/bush). An average of 0.7 - 1.2 weta/bush were found during the remaining months.

The average number of Mahoenui weta found per bush was slightly higher for destructive samples (1.2 weta/bush) but this was not significantly different from

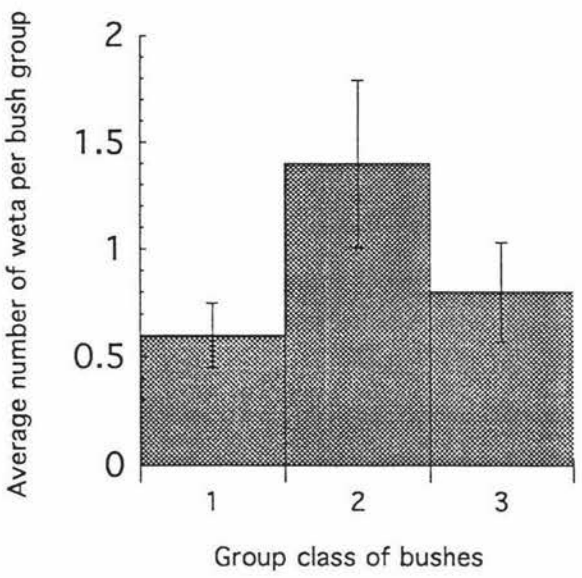


Figure 7.10

Average number of Mahoenui weta found per bush per month ir each of the three groups of gorse: 1, Isolated bush; 2, group of isolated bushes; 3, bushes part of a large area of gorse. Bars give the standard error.

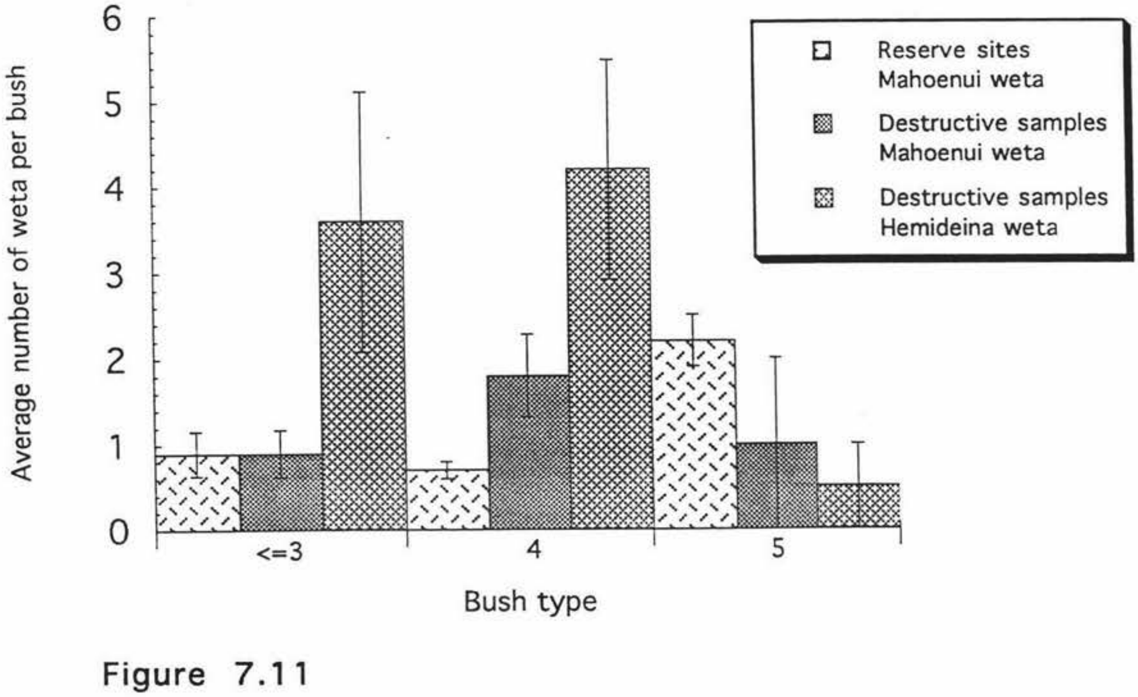


Figure 7.11

Average number of weta found per bush type <=3, 4 and 5 (figure 6.1), for Mahoenui weta in the reserve sites and Mahoenui and Hemideina weta found in destructive gorse searches. Bars give the standard error.

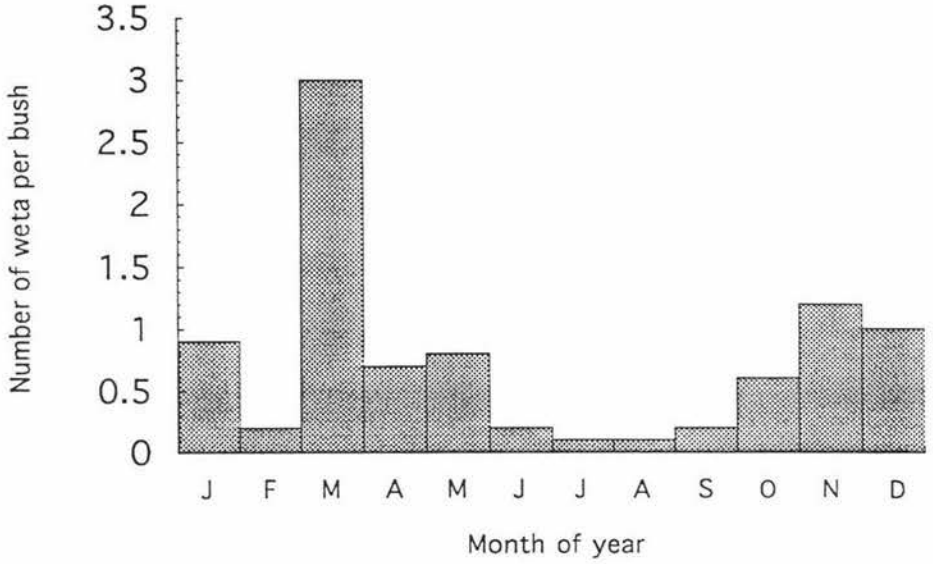


Figure 7.12

Average number of Mahoenui weta per bush observed in Mahoenui reserve sites each month from march 1992 to febuary 1993.

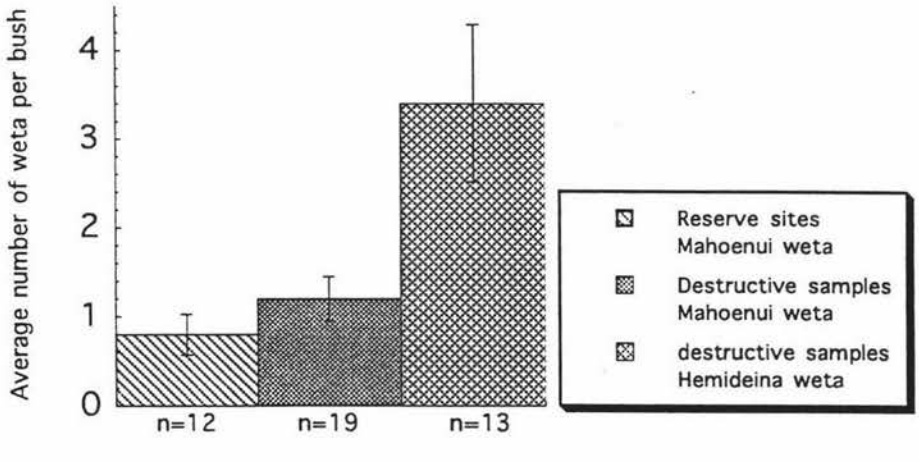


Figure 7.13

Average number of weta per bush for Mahoenui weta in the reserve sites and for Mahoenui and Hemideina weta in the destructive gorse searches. Bars give the standard error.

reserve sites (0.8 weta/bush). The average number of *Hemideina* weta found per bush (3.4 weta/bush), however, was much higher than the number of Mahoenui weta per bush (Figure 7.13).

7.2.3 **Diurnal movement**

The average distance between successive daily rest sites of marked weta was greater in summer than in winter. This was significantly so when betalight and transmitter records were combined (t=2.10, n=60, P<0.05). The latter combined methods indicated that in summer weta moved significantly further between daily sightings (t=3.97, n=87, P<0.05) than the capture-recapture method indicated (Figure 7.14). Male Mahoenui weta moved slightly further on average between daily rest sites than females although there was no significant difference between the sexes. Again combined distances using betalight and transmitter were much higher than indicated by capture-recapture (Figure 7.17) The median values were very similar for all groups studied (Table 7.4). The median values were either 0 distance moved or up to 1 m for all weta except for weta with transmitter and betalight during summer when the median distance moved was between 2 m and 3 m.

Marked weta found after 1 to 7 months showed that most had moved less than 1 m from their original location site (table 7.5).

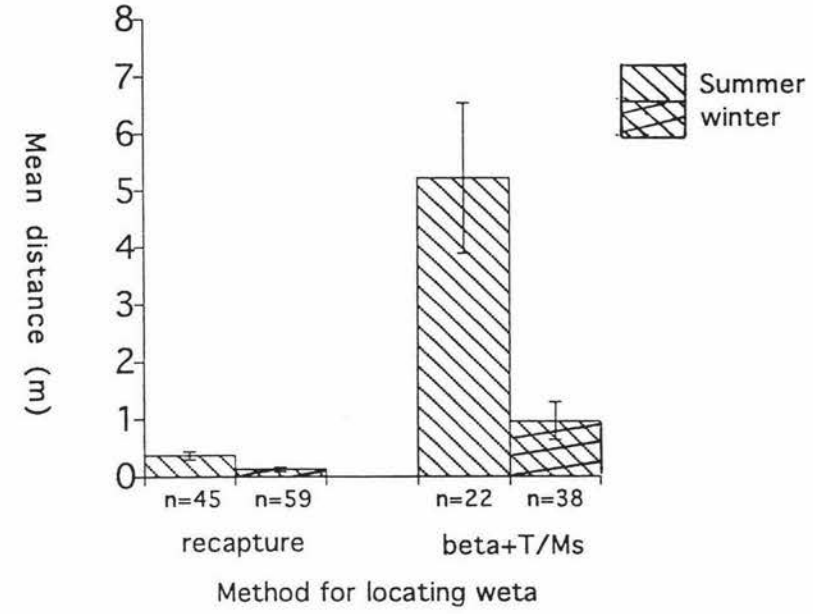


Figure 7.14

Mean distances between daily rest sites for Mahoenui weta during summer and winter using the capture/recapture and combined betalight and transmitter methods. bars give the standard error.

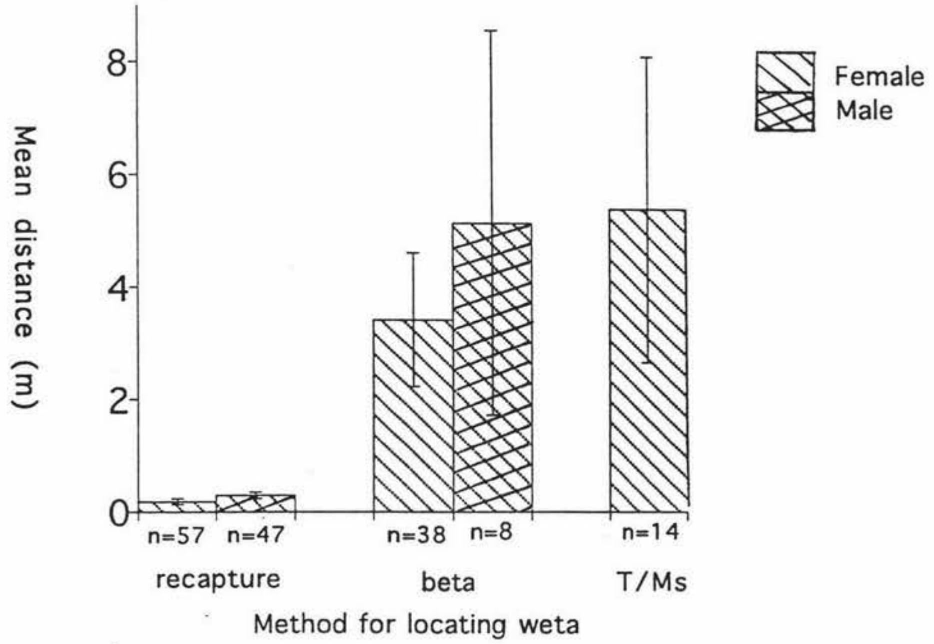


Figure 7.15

Mean distances between daily rest sites for male and female Mahoenui weta using the capture- recapture, betalight and transmitter methods. Bars give the standard error.

TABLE 7.4 The distance moved between daily resightings of Mahoenui weta.

[Distance moved to nearest meter]

		Median	Mean	S. Error	N	0	1	2	3	4	5	6	7	8	9	10	15	18	29	40
Capture/ recapture Method	Female	0	0.5	0.08	57	31	23	3	-	-	-	-	-	-	-	-	-	-	-	-
	Male	1	0.7	0.08	47	17	28	2	-	-	-	-	-	-	-	-	-	-	-	-
	Winter	0	0.4	0.06	59	34	24	1	-	-	-	-	-	-	-	-	-	-	-	-
	Summer	1	0.8	0.08	45	14	27	4	-	-	-	-	-	-	-	-	-	-	-	-
	Total	1	0.6	0.06	104	48	51	5	-	-	-	-	-	-	-	-	-	-	-	-
Betalight & Transmitter Method	Winter	1	1.5	0.31	22	3	14	2	1	0	1	1	-	-	-	-	-	-	-	-
	Summer	3	5.6	1.31	38	1	12	5	3	4	3	1	0	3	1	1	1	1	1	1
	Total	1	4.1	0.87	60	4	26	7	4	4	4	2	0	3	1	1	1	1	1	1

TABLE 7.5 The distance moved between resightings for Mahoenui weta from capture/recapture data.

[Distance moved to nearest meter]

Resightings	Median	Mean	S.Error	N	0	1	2	3	4	5	6	7	8	9	10	15
Within one study week (2-5 days)	1	1.21	0.16	28	3	19	4	1	1	-	-	-	-	-	-	-
Between study trips (1-7 months)	1	1.64	0.39	46	7	34	2	0	0	0	0	0	1	0	1	1

7.3 Locating eggs

Soil samples were taken from under 10 destrucively sampled gorse bushes. Three or four samples were taken under each bush in the positions shown in Figure 7.2. No weta eggs were located in these samples.

Plate 7.1 Effect of goat browsing of gorse at Mahoenui reserve

Plate 7.2 Adult male Mahoenui weta with transmitter attached to pronotum

DISCUSSION:

Mahoenui weta did not occupy galleries or behave territorially towards conspecifics (Chapter 5). This is very different from behaviour reported from Hemideina by Field and Sandlant (1983). Surprisingly, Mahoenui weta still remained more or less within a restricted range (1-3 m^3) for most of their lives. Barrett (1990) noted that captive Mahoenui weta appeared more disturbed if all faecal pellets were removed when he cleaned their cages. Mahoenui weta possibly use pheromones in faecal pellets to guide them back to the area they generally inhabit but there is no evidence of this. Ordish (1992) suggested that pheromones contained in some faecal pellets may act as navigational guides for *Hemideina crassiden* returning to retreats. A similar homing instinct and confinement of range was also reported in *Deinacrida rugosa* by Ramsay (1953) who noted that individuals returned to their same retreat on successive days.

Occasional movement by Mahoenui weta over larger distances across pasture, or via gorse, to new areas was observed most frequently in adults during late summer. This possibly occurred in response to mate seeking or oviposition because of its link to adult behaviour at this time (Chapter 5). It is also possible that weta may also move to a new area if the original habitat becomes unfaourable. These weta would readily cross open areas of pasture to new gorse habitat. Ordish (1992) mentioned that dispersal in *H. crassidens* occurred in early instars and the mature females. It is possible that a certain proportion of the Mahoenui weta population move larger distances in order to effect dispersal. The Mahoenui weta are likely to disperse in the young instars due to their highly cannibalistic nature in captivity (chapter 5), however no instars 1 to 4 were observed at Mahoenui reserve.

Mahoenui weta tended to move further per night during summer than in winter, but individual weta showed a lot of variation in their total distance moved per night. There was no significant difference in the distributions of distances moved between males and females. This was also noted by Moller (1985) in his study of the movement of *Hemideina crassicruris*. During most of the year Mahoenui weta moved no further than 11 m in one night and often they did not move at all during winter, or when close to ecdysis (Chapter 5). During February seven adults were observed to travel greater than 11 m and one male travelled a distance of 31 m. These seven weta all moved across pasture to new areas of gorse for no apparent reason.

Betalights and transmitters were the most accurate methods for monitoring daily movement of Mahoenui weta because marked weta were rarely found after they moved further than two meters from where they had originally been found. Capture-recapture was, however, useful for long term monitoring of individual weta.

Successive sightings of weta in winter showed that the majority were found within 1 m of their previous days rest site. In contrast during summer, many adult weta moved much further between daily rest sites, although 34% were still found within 1 m. Moller (1985) showed that 50% of recaptured *H. crassicruris* only moved 0-1 m during his study of the distance moved between successive resightings at night. The greatest distance he observed was 11.6 m.

Forty-one marked Mahoenui weta were resighted within 1 m of their original location after periods of between one and seven months, and 3 weta were located 8-15 m from where they had originally been sighed. As already mentioned above, the percentage of weta resighted further than 2 m from their previous sighting was very low so a larger percentage than this probably moved greater than 2 m.

Mahoenui weta preferred to eat gorse flowers and pods (Chapter 8) which were most abundant in the upper non goat browsed region of a bush and weta often made their way to this area to feed. During summer nights Mahoenui weta tended to spend more time in the non goat browsed region than on the goat browsed region of a bush. When the weta were less active and did not feed as often (chapter 6) they spent more time within the dense goat browsed region where there was more shelter than amongst the non-browsed areas.

Mahoenui weta were disinclined to move across the ground during much of the year although adults and nymphs were often seen at the base of gorse bushes feeding on pasture species during summer. These weta generally never ventured more than 0.5 m from the bush while feeding before returning. Moller (1985) deduced from his observations on *Hemideina crassicruris* on Stephens Island that these weta were also averse to moving across the forest floor. He only observed 4 weta out of 378 sightings on the ground. Only one of these was a female ovipositing.

During the day Mahoenui weta tucked themselves into junctions of gorse branches or foliage. A single visual search for weta by hand searching a bush only revealed a small percentage of the actual number present and was biased toward larger nymphs. Moller (1985) also noted that smaller weta were less conspicuous, so the true proportion of these out on each night was probably considerably higher than he predicted. It seems likely, however, that repeated visual searches of a bush over several days could give a closer approximation to the actual number present because the densities of weta found in regularly hand searched and desctructively searched gorse bushes were relatively similar (Figure 7.14). Hand searches always produced fewer small nymphs than larger nymphs and adults.

In autumn, winter and spring 70-85% of weta resided in the goat browsed regions of the gorse during the day. Equal amounts of weta occupied the goat browsed and non goat browsed regions in summer. This supports my suggestion that the goat browsed region of a gorse bush affords more protection for Mahoenui weta.

Weta located in the goat browsed region were more commonly found further than 10cm from the edge of the bush (70%) where they were amongst the dead foliage that accumulated there. Dead foliage occupied a larger volume of the bush than the green outer foliage so therefore I conclude that Mahoenui weta probably showed no preference for fresh or dead foliage in the goat browsed region. Sherley and Hayes (1993) deduced that goat activity was important in providing suitable weta habitat as most weta were found within goat browse range (62%) and within the dense middle region of the goat browsed region (75%). I agree that goat browsing does create a preferred habitat for weta, particularly in winter. However the majority of available gorse habitat at Mahoenui reserve consists of large unbrowsed bushes (Stronge 1993) and some weta certainly survive in this (Sherley and Hayes 1993) so although the close cropped habitat created by goats is undoubtedly advantageous to weta it is not crucial to the survival of the Mahoenui weta.

Mahoenui weta were most abundant in areas of isolated groups of gorse surrounded by pasture and in medium to large bushes partially browsed or unbrowsed by goats. Isolated bushes, small bushes, and bushes heavily browsed by goats appeared to be less favourable to weta. Sherley and Hayes (1993) found that Mahoenui weta showed an apparent dislike of smaller trees with stem circumferences of 11-20 cm. Moller's (1985) study reported that very few *H. crassicruris* adults were found on isolated understory plants, but adults were often seen feeding in shrubs which touched larger canopy trees. If weta show a reluctance to cross ground then isolated bushes would be less likely to be encountered by weta. Smaller gorse bushes may also not provide the amount of shelter or food that large bushes do. It is not clear why the Mahoenui weta preferred small clusters of gorse bushes over large areas of continuous gorse although one advantage of the former is accessibility to pasture. Certainly weta were often seen at the base of gorse bushes feeding there.

The number of Mahoenui weta found varied a lot at each site on a monthly basis. Lower numbers of weta were located per bush from June to September (winter) and in February. The highest numbers were found in March. However, results from destructive sampling (Table 7.1) indicated that the numbers of weta remained more constant throughout the year (1.2 - 2.0 weta/bush). Possibly the differences in weta numbers was due to variation in efficiency of visual searches during the year. For example, during winter weta may have been more concealed within gorse because they were relatively inactive at this time (Chapter 6). In support of this four weta captured and marked during May were not located again until October and then they were found in their original bushes.

Mahoenui weta shared their habitat with the tree weta *Hemideina thoracica*. The latter were present in higher numbers per bush (3.4 weta/bush) than Mahoenui weta (0.8 - 1.2 weta/bush). They seemed to prefer goat browsed bushes with unbrowsed growth above the browsed level. Less favoured bushes were large and unbrowsed ones. During the day *H. thoracica* were usually found near or inside the trunks and large branches, but they were sometimes also found in the dead foliage within the goat browsed region of gorse bushes. The ecological niches of *H. thoracica* and Mahoenui weta appear to overlap somewhat, especially at night when both were out foraging in the gorse. No aggression was ever observed between the two species at the reserve and presumably they have co-existed together from the time both first entered the gorse habitat.

Potential predators of Mahoenui weta present at Mahoenui are likely to be adverse to climbing among the prickly foliage of gorse so this provides some protection. Weta when on the ground and when visible on the edges and tips of branches would be vulnerable to some of these predators. My study indicated that weta would be most exposed to ground dwelling predators during the summer and rarely during winter but these would be exposed to avian predators throughout the year when up to 30% of the night was spent on the outside of the gorse foliage. Sherley and Hayes (1993) concluded that there was minimal risk to weta from predators at Mahoenui reserve. Few rats were caught by Jowett (pers. comm.) and no weta remains were found in the stomachs of possums shot or poisoned on or near the reserve (Sherley and Hayes 1993). However, further research is required to confirm whether stoats, cats and rats prey on appreciable numbers of Mahoenui weta. Hedgehog pose some threat to Mahoenui weta as their remains have been identified from hedgehog scats (Jowett 1989). Moller (1985) also reported observing a hedgehog kill and eat two ovipositing female *Hemideina crassicruris*. However I feel that it is important to identify what the predators of Mahoenui weta are, and what their impact is on the population, before control measures are considered.

CHAPTER EIGHT

DIET OF MAHOENUI WETA

AIM:

To identify the plants eaten by Mahoenui weta at Mahoenui reserve and in captivity, and to investigate mortality and weight change in weta reared on gorse, pasture plants, and native plants.

INTRODUCTION

Mahoenui weta are primarily vegetarian but they will also consume some insects (Barrett 1990). Jowett and Plant (1988) suggested that Mahoenui weta were similar to *Deinacrida fallai* and *D. heteracantha* in their original habitat of tawa (*Beilschmieda tawa*) forest, lived in tree tops and seldom ventured onto the ground. Richards (1973) observed *D. fallai* and *D. heteracantha* on branches of canopy and subcanopy trees and walking on the forest floor. She reported that these weta appeared to use areas within the forest where they would have access to a wide diversity of potential food types from leaf litter and fallen fruits to the leaves of canopy trees.

Mahoenui weta living in gorse in Mahoenui reserve have access to only a limited variety of plants. However these plants are obviously sufficiently nutritious to meet the nutritive requirements of the weta since they survive well there. Gorse has an abundant invertebrate fauna and its foliage is probably high in phosphates and nitrates (being a legume) and its pollen is rich in protein (Sherley and Hayes, 1993).

In this chapted I provide a list of food offered to, and eaten by, captive Mahoenui weta and I determine which plant and insect species were eaten preferentially. Observations were made of Mahoenui weta feeding at Mahoenui reserve to establish what the weta ate there. Captive weta were then reared on a diet of either native plants or gorse and pasture species, all of which were consumed by these weta in Mahoenui reserve and their weight changes and mortalities were compared. This information is potentially useful for assessing vegetation of a proposed transferal site for Mahoenui weta.

METHODS:

Rearing methods are given in Chapter 3.

Food preferences of Mahoenui weta

Weta were presented with fresh food twice a week when old food was removed and examined. The amount of each food type consumed was recorded as either none, very little, moderate or large. At the end of the study the food type was given a score from 0 - 3 with 0 being when the food was never eaten; 1 when it was eaten only rarely, 2 if it was eaten moderately on a regular basis and 3 when it was eaten regularly in large quantities

Observations of food consumption of Mahoenui weta in Mahoenui Reserve.

Observations of weta feeding at Mahoenui Reserve were made at night (Methods Chapter 3) using a torch to locate and observe the weta.

Gorse feeding trials.

During this trial the weta were fed daily. Individual weta were housed in 4 litre ice-cream containers with gauze lids. Each container was provided with a plastic tube for shelter, a water dish and a dish with selected food types. Three containers were kept without weta as controls to estimate water loss from food. The temperature was kept at 18^{o}C (plus or minus 1^{o}C) throughout the trial. Each trial lasted for 10 days.

Each weta in trial one was given three green gorse pods, eight gorse flowers and one piece of gorse foliage. In trial two weta were given three green gorse pods, three mature (dry) pods, and ten gorse flowers.

The three food types were weighed and replaced at the same time each day. A visual estimation of the percentage of each food type eaten was also made.

Comparative study of Mahoenui weta fed on exotic vs native plants.

The cage setup is given in Chapter 3. Weta were put into the cages on 6-4-92 and their first weight measurements were recorded on 13-4-92 for the weta in constant 18°C and on 27-4-92 for weta kept at room temperature. The latter ranged from 3-26°C during the study. Weta were weighed each week until the study ended after 36 weeks on 15-12-92. The instar of each weta used in the study are given in Table 8.7. New weta were introduced to replace any which died.

Exotic plants given to weta included gorse (*Ulex europaeus*), plantain (*Plantago major* and *Plantago lanceolata*), dandelion (*Taraxacum officinale*) and various grass species. Native food given to weta included a selection of the plants listed in Table 8.1.

RESULTS:

8.1 Diet Preference

The native plants that were most preferred by captive Mahoenui weta were Broadleaf (*Griselinia littorialis*), Karo (*Pittosportum crassifolium*) and Mountain Holy (*Olearia ilicifolia*) (Table 8.1, 8.2 and 8.3). Less than half the native plant species offered were consumed in moderate quantites. Of the three *Pittosporum* species *P. crassifolium* was a preferred food, *P. eugenioides* was eaten moderately and *P. tenuifolium* was rarely eaten and then it was only the stembark or seed cases that were consumed. For all *Pittosporum* species seed cases and seeds were the parts that were most preferred. *Coprosma repens* and *C. kirkii* were eaten in moderate proportions while *C. robusta* foliage was less favoured. However, the fruit of *C. robusta* was consumed regularly when available. *C. rhamnoides* was seldom eaten.

The exotic species that were most preferred by captive weta were gorse (*Ulex europaeus*), willow (*Salix matsudana* and *Salix tangoio*), Broadleaf plantain (*Plantago major*) and dandelion (*Taraxacum officinale*). Most of the exotic species offered were consumed in moderate amounts. Broom (*Carmichaelia arborea*) was not eaten by the Mahoenui weta.

Insects were provided on occasion to supplement the weta diet. Willow was sometimes infested with aphis and weta consumed these while eating the willow foliage. Willow was also regularly infested with the gall producing sawfly (*Pontania proxima*) and weta would eat these galls containing the small larvae. Crickets (*Teleogryllus commodus*) were consumed by Mahoenui weta if provided as dead food, but live crickets were not eaten.

Table 8.1 Native plant species offered to captive Mahoenui weta

Common name	Taxonomic name	Score[1]	Other parts of the plant eaten besides foliage
Tawa	*Beilschmiedia tawa*	2	
Mahoe	*Melicytus ramiflorus*	2	
Broadleaf	*Griselinia littoralis*	3	
Totara	*Podocarpus totara*	0	
Kohuhu	*Pittosporum tenuifolium*	1	seedcases & seeds
Karo	*Pittosprorum crassifolium*	3	seedpod & seeds
Tarata	*Pittosporum eugenioides*	2	seedpod & seeds
Pohutukawa	*Metrosideros excelsa*	1	
Wineberry	*Aristotelia serrata*	1	
Lacebark	*Hoheria populnea*	0	
Kowhai	*Sophora microphylla*	0	
Karaka	*Corynocarpus laevigatus*	1	
Five Finger	*Pseudopanax arboreum*	1	
Lancewood	*Pseudopanax crassifolium*	2	
Pepper tree	*Pseudowintera colorata*	0	
Ngaio	*Myoporum laetum*	2	
Coprosma	*Coprosma robusta*	2	fruit
Taupata	*Coprosma repens*	2	
Coprosma	*Coprosma kirkii* *(hybrid c. repens x C. acerosa)*	2	
Divaricating coprosma	*Coprosma rhamnoides*	1	
Rangiora	*Brachyglottis repanda*	0	
Akeake	*Dodonaea viscosa*	1	
Kawakawa	*Macropiper excelsum*	1	fruit
Red Beech	*Nothofagus fusca*	0	
Mountain Holly	*Olearia ilicifolia*	3	
Hebe	*Hebe speciosa*	1	
Kakabeak	*Clianthus Puniceus*	1	
Bush lawyer	*Rubus cissoides*	0	

[1] The score gives food preference:
0 = not eaten
1 = rarely eaten
2 = eaten moderately
3 = eaten a lot

Table 8.2 Exotic plant species offered to captive Mahoenui weta.

Common name	Taxonomic name	Score[1]	Other parts of plant eaten besides foliage
Gorse	*Ulex europaeus*	3	pods. flowers
Willow	*Salix matsudana*	3	
Willow	*Salix tangoio*	3	
Poplar	*Poplar Tasman*	2	
Broadleaf plantain	*Plantago major*	3	
Narrowleaf plantain	*Plantago lanceolata*	2	
Dandelion	*Taraxacum officinate*	3	flowers
Spotted catsear	*Hypochoeris radicata*	2	flowers
Sow thistle	*Sonchus oleraceus*	2	
White clover	*Trifolium repens*	2	
Velvet grass	*Holcus lanatus*	1	
Rye grass	*Lolium pereme*	2	
Tree Lucerne	*Medicago sativa*	2	flowers
Broom	*Carmichaelia arborea*	0	
Banksia	*Banksia sp*	2	

[1] The score gives food preference.
0 = not eaten
1 = rarely eaten
2 = eaten moderately
3 = eaten a lot

Table 8.3 List of insects eaten by captive Mahoenui weta

Insect	Comment
Black field cricket *Teleogryllus commodus*	Dead crickets were provided for the weta
Willow sawfly *Pontania proxima*	Grubs inside willow gall were consumed
Aphis	Various species eaten when present on favoured foliage

8.2 Diet of Mahoenui weta at Mahoenui reserve

At Mahoenui reserve weta were observed feeding on gorse foliage (both fresh and dead), green and mature gorse pods and gorse flowers. They were also observed on the ground consuming dandelion, plantain and various grasses in the pasture (Figure 8.1).

Consumption of food types by Mahoenui weta varied significantly between winter/spring and summer/autumn at Mahoenui reserve, P(X^2=20.5; n=97; P=0.005). During summer/autumn gorse pods were consumed more often (61%) than gorse foliage (16%), flowers (12%) and pasture species (11%). During winter/spring gorse flowers were more commonly consumed (62%) than gorse pods (25%) and foliage (13%). Weta were never observed feeding on pasture plants during winter and spring.

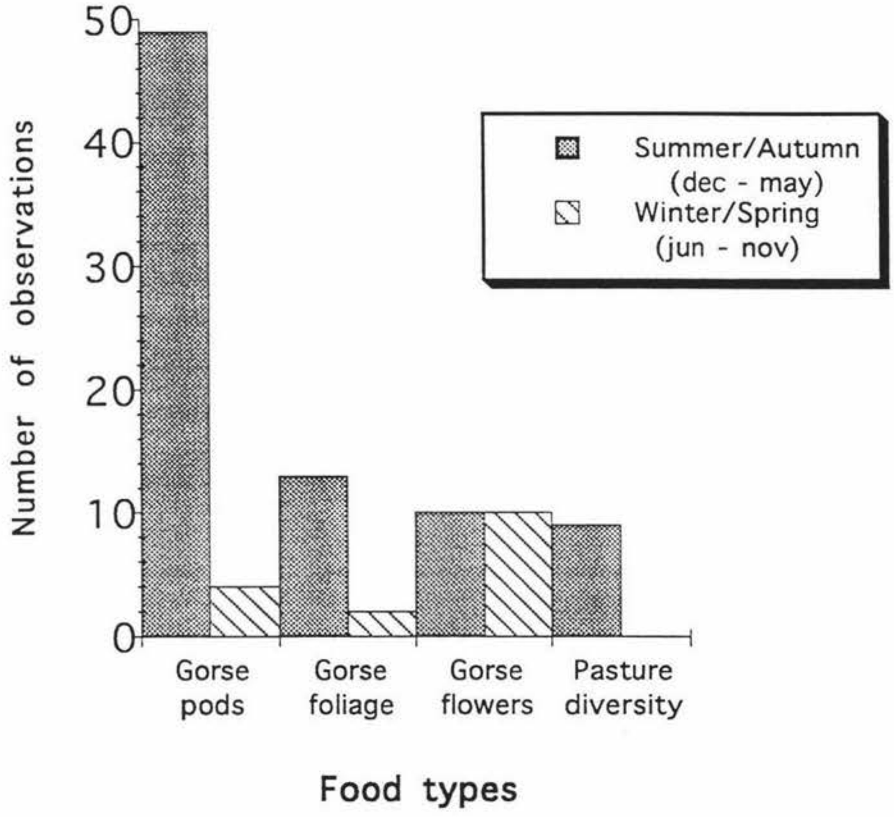


Figure 8.1

Food eaten by Mahoenui weta at Mahoenui reserve. Pasture species included dandelion, plantain and various grasses.

8.3 **Gorse feeding trials**

Table 8.4 Mean percentage of gorse food types consumed by Mahoenui weta during two feeding trials.

		Gorse Food Type			
		Mature pods	Green pods	Flowers	Foliage
Trial 1	Sample size n	-	103	105	not included
28-7-92 - 7-8-92	Mean % consumed	-	2.8%	56.7%	-
(10 weta used in trial)	Standard deviation	-	5.0%	35.5%	-
Trial 2	Sample size	60	60	60	-
21-9-92 - 1-10-92	Mean % consumed	2.3%	1.6%	41.2%	-
(6 weta included in the trial)	Standard deviation	2.68%	2.4%	26.0%	-

In trial 1 gorse flowers were consumed most (57%). Based on visual estimates of the percentage of food types consumed by Mahoenui weta (Table 8.5) green pods were consumed in small quantities (2.8%) but the percentage of foliage eaten was unable to be quantified visually and was omitted from the results although it was only a small proportion of the diet. In trial 2 gorse flowers were again consumed in the largest quantities (41%) and green and mature pods were eaten in small quantities (1.6% and 2.3% respectively) (Table 8.4). The calyx of mature pods was eaten but the hardened pod capsule never was. In both trials gorse flowers were the favoured part of the gorse, although all other parts of the gorse included in the trials were consumed in small amounts.

8.4 Comparison between Mahoenui weta fed exotic and native plants.

Weta in constant 18^{o}C however reached maturity earlier than weta kept in the laboratory where temperature varied (Table 8.5). The latter experienced cooler temperatures during winter. However, storage temperature had little effect on either body weight or weta mortality. In contrast both of these factors were affected by diet (Figure 8.2).

Of nine weta fed exotic plants exclusively during the study, one female died in the 18^{o}C environment and none died in the variable temperature environment. Eleven weta were fed on native plants. Two males and one female died at 18^{o}C and three females and three males died in the variable temperature environment (Table 8.5). The mortality rate of weta fed native plants (9 died out of 11) was significantly higher than for weta fed exotic plants (1 out of 9 died) (X^2=9.8; n=20; P=0.005). The cause of death was largely unknown except for two weta fed native plants that failed to complete ecdysis successfully in the native fed treatments.

At the beginning of the study the mean weights of weta in each treatment ranged from 3.0 to 3.5 grams at week 3 (Figure 8.3), but after 10 weeks weta fed exotic plants were on average heavier than weta fed native plants. After 20 weeks weta kept at 18^{o}C and fed exotic plants were the heaviest and all were adults (Table 8.5). Those fed exotic plants and kept at variable temperature had similar mean weights to weta fed native plants and kept at a constant 18^{o}C. Only one of these weta (fed exotic plants) had developed to adulthood after 20 weeks. Weta that experienced variable temperature and fed native plants were lighter on average than those in the other treatments. After thirty weeks weta at 18^{o}C and fed exotic plants were still the heaviest but those in variable temperature and fed exotic plants and weta in 18^{o}C fed native plants were closer in weight to these because most were adult. The one weta that experienced variable temperature and was fed native plants that survived to the end of the trial was still a nymph and was much lighter than all other weta in the study.

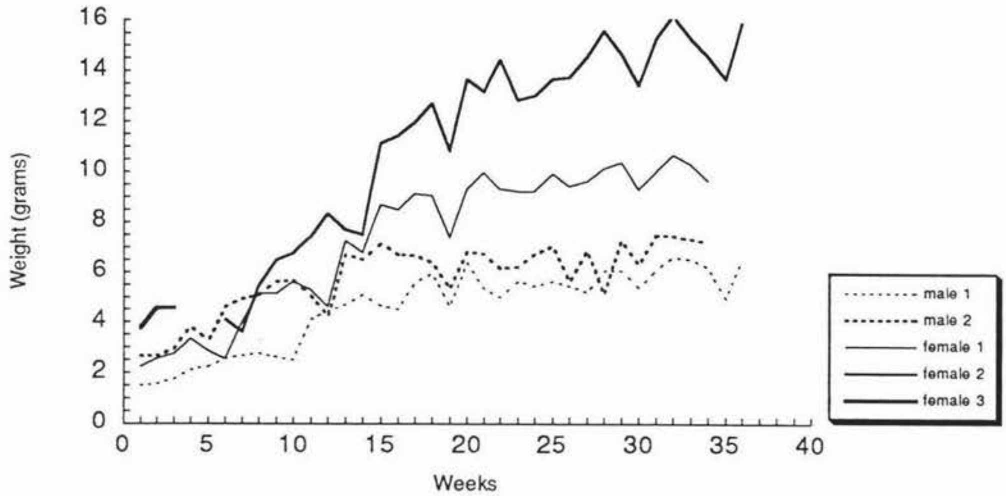


Figure 8.2 (a)

Change in mass of five weta kept at 18 C and fed a diet of gorse, dandelion and plantain. Start of experiment = 13-4-92.

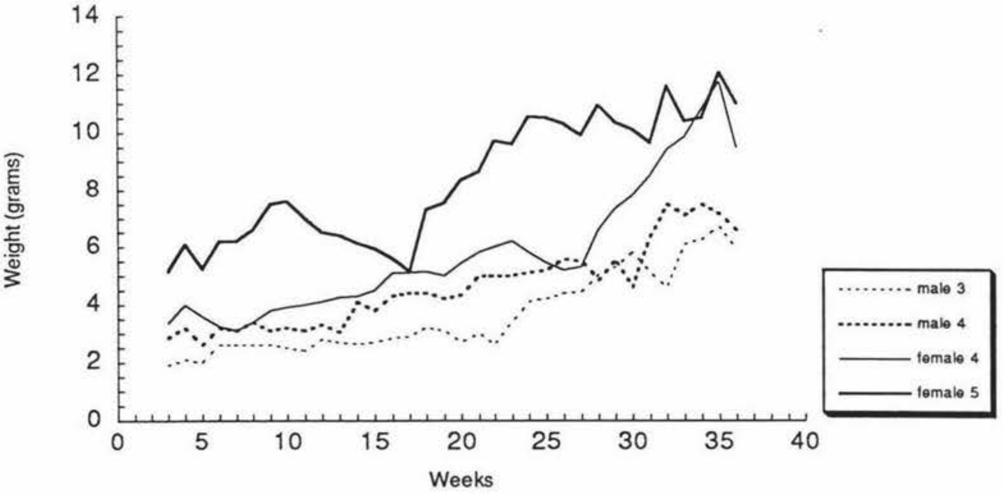


Figure 8.2 (b)

Changes in mass of weta kept in a laboratory at variable temperature and fed a diet of gorse, dandelion and plantain. Start of experiment = 27-4-92.

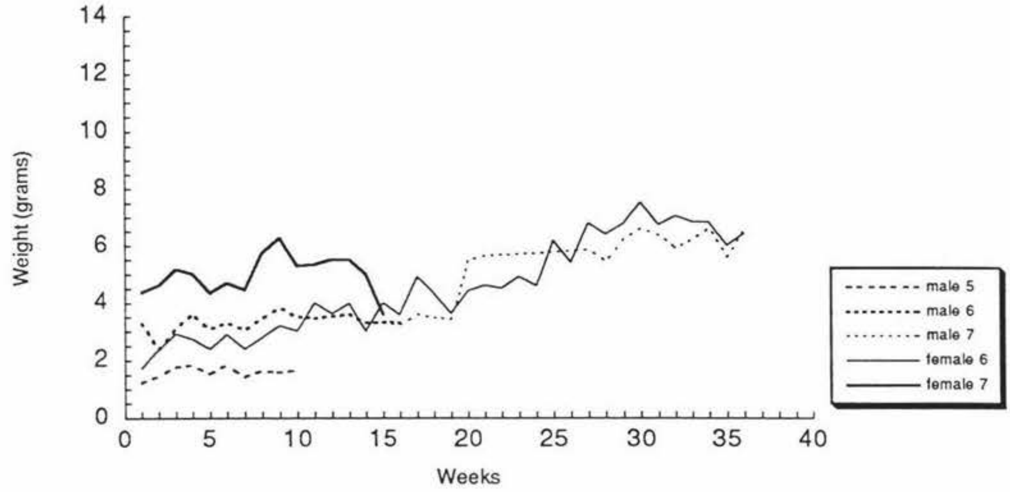


Figure 8.2 (c)

Change in mass of weta kept at 18 C and fed on a diet of native plants. Start of experiment = 13-4-92.

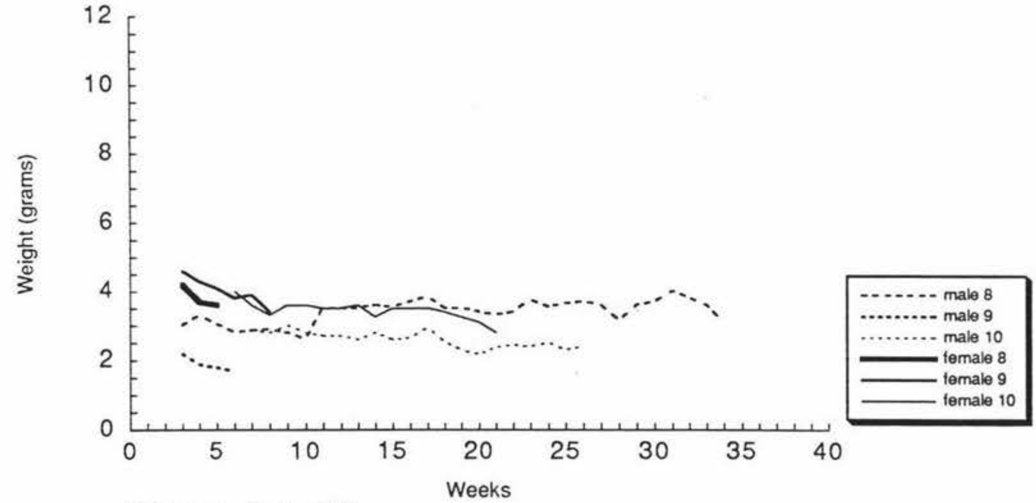


Figure 8.2 (d)

Change in mass of weta kept in a laboratory at variable temperature and fed a diet of native plants. Start of experiment = 27-4-92.

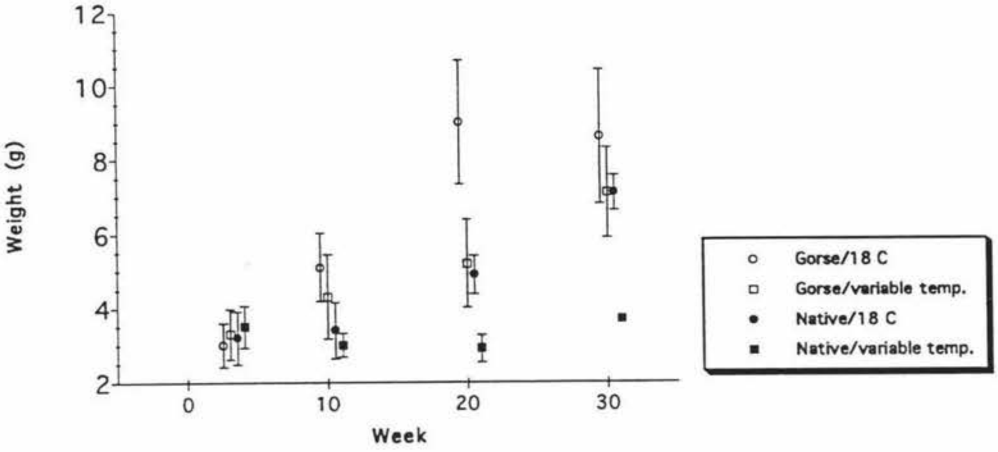


Figure 8.3

Mean weights of weta during the four treatments; 18 C and and exotic plant food; variable temperature and exotic plant food; 18 C and native plant food; variable temperature and native plant food. The weta were weighed at weeks 3, 10, 20 and 30. Bars give standard error.

Table 8.5 Mortality and development of weta in the four treatments:
18°C and exotic plant food;
Variable temperature and exotic plant food;
18°C and native plant food;
Variable temperature and native plant food.
Times are given in weeks from the start of the experiment.

Treatment	Weta	Instar when introduced	Week introduced	Week deceased	Instar at death	Cause of death	Week weta became adult
Exotic 18°C	Male 1	7	1	-	-	-	17
	Male 2	8	1	34	10	old age	12
	Female 1	8	1	34	10	old age	13
	Female 2	9	1	3	9	unknown	-
	Female 3	8	6	-	-	-	14
Exotic variable temperature	Male 3	8	3	-	-	-	32
	Male 4	8	3	-	-	-	30
	Female 4	8	3	-	-	-	28
	Female 5	9	3	-	-	-	17
Native 18°C	Male 5	7	1	10	7	unknown	-
	Male 6	7	1	16	8	unknown	-
	Male 7	8	15	-	-	-	28
	Female 6	8	1	-	-	-	24
	Female 7	9	1	15	9	failed ecdysis	-
Native variable temperature	Male 8	7	3	34	7	failed ecdysis	-
	Male 9	7	3	7	7	unknown	-
	Male 10	8	7	26	8	unknown	-
	Female 8	8	3	5	8	unknown	-
	Female 9	9	3	8	9	unknown	-
	Female 10	8	6	22	8	unknown	-

DISCUSSION:

I found that the foliage of plants was most commonly eaten although in some the flowers, seeds, seedcases or fruit were preferred when available. Bark and stems were also eaten often. Barrett (1990) noted that insect matter was eaten more often by younger nymphs than by older nymphs and adults.

Mahoenui weta varied in their preference to species within the same plant genus. Some species were preferred over others whilst some were not eaten at all. Bernays and Graham (1988) reported that the great majority of all herbivores have a restricted host plant range (specialist), but some (generalists) include a large number of different food plants in their diet. Generalists often seem to include the largest possible number of food plants in their diet (Pulliam 1975; Westoby 1978). Mixed diets are eaten by very different animals. In orthopterans the majority of grasshoppers are said to be polyphagous (Bernays and Bright 1991). Although Mahoenui weta favoured some plants over others, each was never the only food eaten, even when other less favoured plants were the only other available option. A plant consumed in large quantities one week may be consumed in only small amounts the following week.

Different factors may result in animals eating mixed diets. Such diets may be favoured because they keep the levels of individual toxins from different plant species low (Freeland and Janzen 1974; Freeland, Calcott and Anderson 1985). In general, plants contain different proportions of nutrients. A mixed diet can provide all nutrients in optimal proportions (Cohen *et al.* 1987; Schull, Waldbauer and Friedman 1988, 1989; Simpson *et al.* 1990; Bernays and Bright 1991). New food plants may become available at any time of the season, and the chemical composition of plants may change over time. Rockwood (1976) suggested that under these circumstances herbivores have to sample all available plants constantly in order to be able to choose the best foods. In many cases, several of these mechanisms may operate simultaneously to cause animals to eat mixed diets (Clarke 1982).

I found that Mahoenui weta consumed a large variety of plants and some insects. Barrett (1990) also noted the wide range of plant and insect matter Mahoenui weta consumed and was intrigued by the amount of insect food these weta were willing to sample. He reported that gorse, taupata and willow were the favoured plants consumed of those he offered to Mahoenui weta in captivity.

It appears that most species of weta show a willingness to sample a variety of food types (Barrett 1990). Field (1980) observed *Deinacrida connectens* in the field feeding on the stem bases and seedpods of mountain spaniard (*Aciphylla sp*) and they consumed a variety of vegetables, fruit and insects in captivity. Richards (1973) reported that *D. heteracantha* from Little Barrier Island were found predominantly in the Kanuka forest, but they were also found in areas of *Muehlenheckia complexa* communities of boulder banks, amongst stones 35-40 cm above the high tide level. They were also seen on the trunks and fronds of various European fan palms and on the forest floor near the fan palm grove. Around the homestead they were found in woodpiles, fruit trees and amongst the bases of canna lillies. Richards did not say what the weta ate in these habitats but the range of plants avilable would have been different in each of these. In captivity both *D. heteracantha* and *D. fallai* weta showed a marked preference for lettuce over native foliage species found in their natural habitat (Richards 1973).

The Mahoenui weta's readiness to consume a variety of plant and insect species may have been the key to their survival in moving from forest remnants into the gorse habitat. In addition, the gorse appears to provide all the nutrients they require for most of the year. Captive Mahoenui weta reared from 7th instar to adult solely on gorse and pasture species had low mortality and gained weight much more steadily than weta reared on native vegetation only. Thus gorse and pasture evidently was sufficient to sustain weta during their development, whereas those fed solely on native plants appeared to lack some vital element necessary for successful development to adulthood. This effect was more pronounced in a variable temperature environment. Some essential dietery requirement for growth and development that was present in gorse must therefore have been lacking in the native foliage. Weta living in native forest may have obtained these essential elements from sources other than native foliage and fruits. For instance they may be available in other areas denied in laboratory experiments such as bark and epiphytes in the canopy or amongst leaf litter on the forest floor. The gorse tended to harbour more invertebrates than the native vegetation offered to the weta and these invertebrates may have supplemented the diet of weta in the exotic treatments. The much preferred gorse flowers were available in abundance during winter and spring and these were followed by succulent green pods. Only in late summer when pods were mature and hard, and the growth of gorse foliage slowed were weta seen on the ground feeding on pasture species. Mahoenui weta ate a small amount of woody material such as bark and dead leaves and this was available throughout the inner gorse bushes. Gorse was also rich in invertebrates and many of these would have been readily accessable to Mahoenui weta. For instance they may be available in other areas denied in laboratory experiments such as bark and epiphytes in the canopy or amongst leaf litter on the forest floor.

CHAPTER NINE:

CONCLUSIONS

Chapter Four:

- Total lifespan of Maheonui weta from egg to adult death is generally about 3 years. Incubation time for eggs is 10 months and the weta pass through 9 instars during 24 months to become adult at 10th instar.

- Adult Mahoenui weta were most frequently found during summer.

- Weta development is reduced for 3-6 months during winter. This occurs commonly between May and October. They overwintered at any instar so the duration in each instar varied considerably between individuals. Most overwinter twice during their nymphal stage and possible also in the egg.

- Three main cohorts of weta are present in the population throughout the year.

- Percentage hatch is low and mortality of young nymphs is very high in captivity. Mortality rate decreases with age.

Chapter Five:

- Cannibalism was commonly observed in weta between 1st to 5th instar in captivity. Cannibalism occurred during or soon after ecdysis.

- Weta ceased feeding for 1 - 2 weeks prior to ecdysis and resumed feeding 3 days following ecdysis.

- The most commonly employed defence behaviour observed for Mahoenui weta was either abdomino-femoral stridulation or running away. Defensive strategies varied with the age of the weta and also between individuals.

- In general Mahoenui weta tolerated each other at close proximity. Mild aggression was observed between captive male adults in the presence of receptive females. Homosexual interactions were observed between these males.

- Mating occurred over a long period (1 - 14 hours) with several copulations taking place during this period. Copulation was observed most often during the day although night copulations were observed on two occasions.

- Ovipoisition by females was observed both during the day and night. Eggs were laid in groups of 1 to 30 eggs.

Chapter Six:

- Six general behaviour patterns were observed for Mahoenui weta during activity studies. These were moving, eating, preening, moulting, courtship and copulation. The latter two activities were only observed in adult weta during summer.

- Behaviour of captive weta appeared to be representative of behaviour in the field studies providing the temperatures in the two environments were consistent with each other.

- Weta were more active in summer than during winter. Adults showed two peak activity periods during summer, 1.5 to 3.5 hours after dark and from 5 hours after dark until 1.5 hours prior to dawn. Nymphs had only one major activity period 1.5 to 4.0 hours after dark. During winter weta activity was maximal between 1.5 and 5.5 hours after dark and usually ceased 3.5 to 5 hours prior to dawn.

Chapter Seven

- Mahoenui weta usually remained within a small area (1 - 3 m^3) for much of their lives and often returned to their same retreat on successive days.

- During late summer adult weta moved greater distances to new gorse. They often crossed open areas of pasture (up to 40 m).

- Mahoenui weta were most commonly found in large gorse bushes with little or no goat browsing. Isolated bushes and small, heavily browsed bushes, were less favoured.

- Weta occupying semi-browsed bushes spent more time in the goat browsed regions during winter and equal time in browsed and unbrowsed regions during summer.

- Weta appeared to be more vulnerable to predators during summer. They were more active and spent longer periods of time in the upper, more exposed, regions of gorse in summer and they spent time on the ground feeding and moving between bushes.

Chapter Eight

- Mahoenui weta are generalist feeders and consume both plant and insect matter.

- Weta consumed gorse flowers, pods and foliage as well as pasture species in the Mahoenui reserve.

- Weta reared solely on gorse and pasture plants had low mortality (1 died from 9) and they gained weight more steadily than weta reared on native vegetation. Mortality was significantly higher when reared on native plants (9 died from 11).

CHAPTER TEN:

APPLICATION OF MY RESEARCH TO THE MANAGEMENT AND CONSERVATION OF THE MAHOENUI GIANT WETA

This chapter outlines the relevance of my research towards management and conservation of Mahoenui giant weta. Conservation measures for this weta have been proposed in two major reports (Jowett and Plant 1988; Meads 1990).

Meads (1990) reported that the information base is too limited for effective management for most weta species. He suggested that research efforts should be directed towards the following:-

1. Establish the conservation status of the weta. This would clarify whether specific research on biology and ecology of the species is necessary before taking any recovery action.

2. Clarify the taxonomic status of the weta. The Mahoenui weta is still awaiting formal description. A specific description is necessary in order to prevent confusion, duplication and doubt in terms of The Wildlife Act 1987.

3. Investigate the biology and ecology of the weta. Information about the following are required before effective conservation efforts can be implemented: diet, feeding behaviour, population dynamics, breeding biology, dispersal and mortality.

Jowett and Plant (1988) in their outline of a management recommendation for the Mahoenui weta suggested that the most important requirement was to preserve and manage the existing habitat. This involved firstly making the area a reserve. Following this they suggested that the gorse be maintained by the construction of fire breaks, maintaining and monitoring the current grazing regime, monitoring and controlling predation and the rehabilitation of the tawa forests by excluding grazing animals to let the understory plants recover, and then re-establishing the weta into the stand. Their second recommendation was to establish new populations of Mahoenui weta both to mainland gorse sites and offshore islands. They also recommended that taxonomic and biological studies were necessary to aid management and conservation of these weta.

Research on Mahoenui weta has been published by Jowett (1989) on predation threats, Sherley and Hayes (1993) on diurnal habitat use, lifecycle and aspects of behavioural ecology in Mahoenui reserve; Stronge (1993) on the effects of feral goats in the Mahoenui reserve. My research has provided additional as well as new information on biology and ecology. These studies together with appropriate management recommendations should provide a basis for successful conservation of the Mahoenui weta. However, there are some aspects of the weta ecology where research is still needed. Predation on ovipositing females and the effects of cattle and goat damage of oviposition sites cannot be done until egg laying females are observed and oviposition sites are located at Mahoenui reserve. Knowledge of the behaviour, ecology, and predation on instars 1 to 3 in the field is also lacking.

The gorse habitat appears to satsify the habitat requirements for the Mahoenui weta. It provides shelter and food and affords some protection against predators. The transfer of weta to other gorse habitats has provided some security against extinction, however with the proposed introduction of biological controls against gorse in New Zealand these habitats may themselves become threatened. I believe that the introduction of weta to islands, in particular those that are predator free and covered in native forest, is an important step in the long term conservation of the Mahoenui weta.

Appendix 1 Data taken from each weta collected from farmland adjacent to Mahoenui Reserve and kept for captive study. (Measurements taken at time of collection).

Date Collected	Weta/Sex	Prothorax Length (mm)	Head Width (mm)	Ovipositor Length (mm)	Weight (gms)
26-11-91	Female MK	12.8	11.5	27.5	16.5
26-11-91	Male MK	10.0	9.5	-	6.0
6-1-92	Female UMK	11.8	11.0	24.0	14.5
6-1-92	Male UMK	9.5	9.0	-	6.5
7-3-92	Female A	9.0	8.2	9.4	3.0
7-3-92	Male B	6.3	5.8	-	2.0
7-3-92	Female C	6.5	5.6	4.4	1.75
8-3-92	Male D	5.7	5.6	-	-
8-3-92	Male E	7.7	7.0	-	-
8-3-92	Male F	6.3	6.2	-	-
8-3-92	Male G	6.0	5.7	-	-
9-3-92	Male H	5.9	5.9	-	-
11-3-92	Female I	8.4	7.8	10.6	-
11-3-92	Female J	7.6	7.0	9.3	-
11-3-92	Female K	6.9	6.6	5.5	-
11-3-92	Male L	7.0	7.0	-	-

[Appendix 1 continued]

Date collected	Weta/sex	Prothorax length (mm)	Head width (mm)	Ovipositor length (mm)	Weight (gms)
11-3-92	MaleM	6.7	6.0	-	-
11-3-92	Female N	8.0	7.1	9.3	-
11-3-92	Female O	6.0	5.5	4.3	-
11-3-92	Female P	7.6	6.8	9.9	-
11-3-92	Male Q	8.2	7.0	-	-
11-3-92	Male R	6.1	6.1	-	-
11-3-92	Female S	8.1	7.4	10.7	-
11-3-92	Male T	7.3	6.8	-	-
11-3-92	Male U	5.5	5.5	-	-
12-3-92	Female V	7.9	7.3	10.5	-
23-5-92	Female W	9.6	8.7	20.3	6.6
16-6-92	Male X	7.9	7.2	-	3.5
16-6-92	Male Y	7.5	6.9	-	3.0
16-6-92	Male Z	9.9	9.5	-	7.0
16-6-92	Male AA	7.7	6.8	-	3.0
16-6-92	Female AB	8.9	8.5	17.8	6.0
16-6-92	Female AC				

[Appendix 1 continued]

Date collected	Weta/Sex	Prothorax length (mm)	Head width (mm)	Ovipositor length (mm)	Weight (gms)
16-7-92	Male AM	7.7	7.4	-	-
16-7-92	Female AI	7.6	7.2	10.0	-
17-7-92	Female AD	8.5	7.7	-	-
17-7-92	Male AE	8.0	7.2	-	-
17-7-92	Female AG	9.8	8.7	18.2	-
6-10-92	Female AK	10.0	9.3	19.5	5.5
6-10-92	Female JS	3.6	3.4	-	< 1.0
6-10-92	Male JB	4.1	4.5	-	< 1.0

Appendix 2 Longevity of Mahoenui adult weta reared in captivity.

Weta	Date adult	Date deceased	Total days adult	Mean	S.E.	N
Male JB	14-4-93	01-11.93	201			
Male B	31-10-92	27-9-93	331			
Male X	29-9-92	19-4-93	202			
Male R	16-11-92	6-4-93	141			
Male Q	28-9-92	8-3-93	130			
Male AF	27-11-92	10-1-93	44			
Male AA	6-11-92	10-1-93	65			
Male AE	13-11-92	5-1-93	53			
Male F	27-7-92	5-1-93	162			
Male E	26-6-92	8-12-92	165			
MALES				149	27	10
Female AK	4-12-92	31-8-93	270			
Female AI	27-11-92	18-11-93	356			
Female S	11-7-92	24-5-93	317			
Female A	29-7-92	15-2-93	201			
Female AG	23-9-92	30-3-93	188			
Female N	16-10-92	11-1-93	97			
Female W	24-9-92	4-1-93	102			
Female AB	29-8-92	14-12-92	107			
Female O	20-9-92	21-12-92	92			
Female C	1-7-92	7-12-92	159			
FEMALES				189	31	10
Total: Males and females				169	20	20

Appendix 3a Numbers of weta of each instar recorded at Mahoenui reserve during autumn, winter, spring and summer.

	No. of Females..............				No of Males.................				Combined Male and Female			
Instar	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
4											1	
5							2	1			2	1
6	1				2		-	2	3		-	2
7	16			6	23	3	2	6	39	3	2	12
8	44	11	13	5	47	12	10	1	91	23	23	6
9	4	14	27	11	-	7	22	14	4	21	49	25
10	3		7	42	3	2	2	29	6	2	9	71
Total	68	25	48	64	75	24	38	53	143	49	86	117

Appendix 3b The percentage of each instar weta recorded at Mahoenui reserve during autumn, winter, spring and summer.

	Percentage Female				Percentage Male				Combined Male and Female ...			
Instar	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
4			2.1								1.2	-
5							5.3	1.9			2.3	0.9
6	1.5				2.7		-	3.8	2.1		-	1.7
7	23.5			9.4	30.7	12.5	5.3	11.3	27.3	6.1	2.3	10.3
8	64.7	44.0	27.1	7.8	62.7	50.0	26.3	1.9	63.6	46.9	26.7	5.1
9	5.9	56.0	56.3	17.2	-	29.2	57.9	26.4	2.8	42.9	57.0	21.4
10	4.4		14.6	65.6	4.0	8.3	5.3	54.7	4.2	4.1	10.5	60.7

Appendix 4a Numbers of weta of each instar taken for captive weta during autumn, winter, spring and summer.

Season ....

Instar	Autumn	Winter	Spring	Summer
1	-	-	-	18
2	7	-	-	4
3	14	-	-	-
4	18	1	1	-
5	9	5	4	-
6	4	7	8	1
7	12	5	9	2
8	18	14	8	2
9	12	15	18	1
10	1	4	16	21
TOTAL	95	51	64	49

Appendix 4b The percentage of captive instars during autumn, winter, spring and summer.

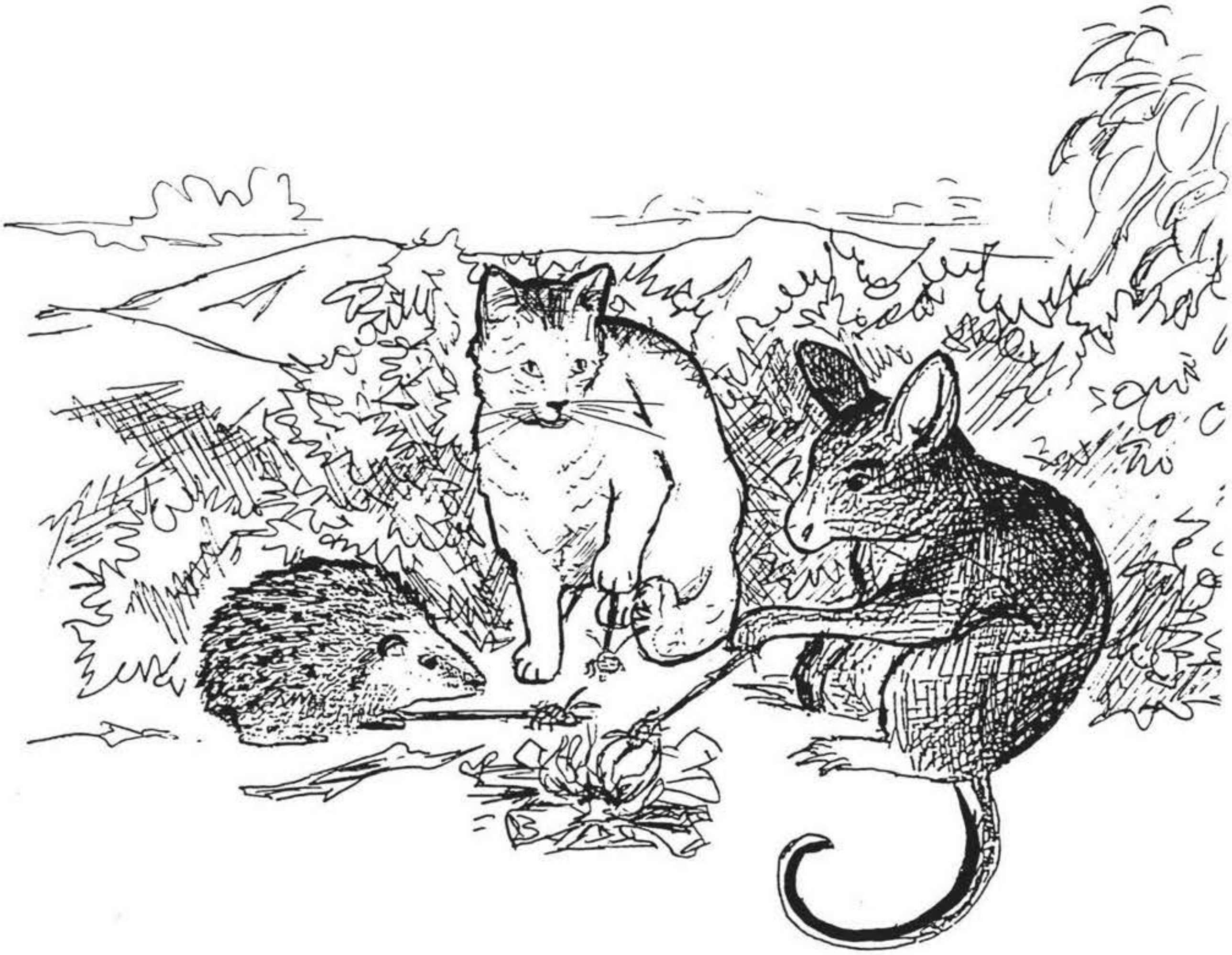
Percentages ....

Instar	Autumn	Winter	Spring	Summer
1	-	-	-	36.7
2	7.4	-	-	8.2
3	14.7	-	-	-
4	18.9	2.0	1.6	-
5	9.5	9.8	6.3	-
6	4.2	13.7	12.5	2.0
7	12.6	9.8	14.1	4.1
8	18.9	27.5	12.5	4.1
9	12.6	29.4	28.1	2.0
10	1.1	7.8	25.0	42.9

Appendix 5

Means and Standard Error values for the activity levels of Mahoenui weta (Graphs 6.1 - 6.6).

	Reserve	Winter	Reserve	Summer	Captive	Winter	Captive	Summer	Cap. nymphs	Winter	Cap. nymphs	Summer	Cap. adult	Males	Cap. adult	Females
	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E
Moving	7.25	1.95	20.95	3.9	10.0	3.75	36.15	5.85	8.1	3.65	18.35	5.9	47.85	7.65	30.0	6.65
Eating	2.25	1.05	6.9	2.15	1.65	1.2	4.6	1.55	1.25	1.25	1.65	1.05	7.85	2.85	5.0	1.9
Preening	0.9	0.6	1.25	0.55	1.65	0.85	5.0	1.8	1.25	0.8	3.3	2.45	5.7	2.55	2.15	1.45
Contact	-	-	1.25	0.85	-	-	8.85	2.8	-	-	-	-	14.3	4.15	9.3	4.7
Copulation	-	-	-	-	-	-	5.0	14	-	-	-	-	5.0	10	5.0	7
Moulting	-	-	-	-	-	-	-	-	-	-	5.0	5.0	-	-	-	-



"Are these **really** an aphrodisiac?"

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