Food of Cook Strait giant wētā, *Deinacrida rugosa* on Matiu/Somes Island: do plant nutrient levels influence wētā distribution?

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Introduction

Cook Strait giant wētā, *Deinacrida rugosa* Buller, 1871 (Orthoptera: Anostostomatidae) has been one of the most frequently translocated insects for conservation purposes in New Zealand with 538 individuals being involved in seven translocations between 1977 and 2010 (Watts et al. 2008; Sherley *et al.* 2010 and references within).The second translocation was made in 1996 when 62 individuals were released at the north end of Matiu/Somes Island, Wellington Harbour (Gascoigne 1996). We subsequently studied the giant wētā population on Matiu/Somes Island between 2007 and 2016, and found that its geographic distribution changed with time. In 2008, most wētā were found at the north of the island and were rarely encountered at the south end because they were still becoming established there (Watts *et al.* 2009). Conversely, by 2013 most wētā were encountered in the southwest of the island and few were found in the north. This remained the distribution in 2015 and 2106 (Watts et al. in prep).

Dr George Gibbs (unpublished data) previously found that the Wellington tree wētā *Hemideina crassidens* (Blanchard, 1851) also underwent a similar distributional shift after this insect was released at the north of Matiu/Somes Island in 1996 and 1997. He found that adult males in the north were smaller than those in the south, and that those in the south were of similar size to adult males from Mana Island, from where the insects had been originally taken. He speculated that these changes in size and distribution might be related to some nutritional factor that is perhaps present in higher concentrations in the south (Dr George Gibbs, pers. comm.). This follows because Dr Gibbs found that male *H. crassidens* develop into larger adults when fed more animal protein (unpublished results).

In this study we have recorded what we observed *D. rugosa* feeding on in the field and obtained basic nutrient compositions of the three most commonly eaten foods plus the leaves of a tree eaten by both *H. crassidens* and *D. rugosa.* In addition, we measured the sizes of adults found throughout the island to determine if the size of adult *D. rugosa* varied geographically. The aims of the research were (1) investigate whether the size of adult *D. rugosa* varied over Matiu/Somes Island, (2) record what plants adult *D. rugosa* were observed eating, and (3) analyse the nutrient levels in the three main food items eaten by *D. rugosa* together with the leaves of taupata (*Coprosma repens*) which is frequently eaten by both Wellington tree wētā and *D. rugosa* to determine if there was a relationship between nutrient levels and geographic distribution of these wētā.

Methods

Visual searches

A visual search using spotlights was made each night over four nights from 2120 to 0130 hours along six transects on Matiu/Somes Island in February 2013, 2015 and 2016. The path and up to ca 1 m on both sides, together with vegetation up to ca 2 m high, were systematically and thoroughly searched by three people without disturbing the vegetation. When an adult wētā was found, a position was recorded using a GPS and the wētā was marked with small individually numbered labels. The length of the pronotum (a surrogate for wētā size) was measured in the dorsal mid-line using digital callipers.

Feeding

Each adult wētā found was recorded as not eating or eating, and if it was eating then what it was feeding on was also noted. Wētā were scored as eating if they had vegetation or animal material in their mandibles or if their jaws were close to a leaf or part of an animal showing fresh visible damage. The latter were considered to have stopped eating when illuminated and become motionless.

Plant nutrient analysis

Chemical analyses were performed on leaves of taupata and on three of the plants most frequently observed eaten by *D. rugosa* (clover, *Trifolium repens*; plantain, *Plantago coronopus*; stinking camomile, *Anthemis copula*). Samples of fresh leaves were collected from each species at three different locations in the northern and southern end of Matiu/Somes Island (six collection locations, 24 samples). The locations were >5 m apart but were otherwise the first places where all four plant species were found within a 1-m radius while walking either south along the North transect or walking east along the Southwest transect. At each location, clover leaves from numerous plants were collected together in a brown paper bag whereas leaves from three different individual plants of the other species were collected together and kept segregated in brown paper bags. Bags were labelled with the GPS position for the collection location and later oven dried for 24 h at 60°C. Nitrogen, phosphorus, potassium, S, calcium, magnesium, sodium, iron, manganese, zinc, copper, and boron concentrations were determined on 10 g of each sample by Hill Laboratories, Hamilton, New Zealand. We used nitrogen content as a proxy for protein content.

Analysis

The relationship between wētā size (pronotum length) and geographic location (north-south or east-west) was explored using linear regression in R (version 3.0.1) (R Core Team 2014).
Two-way ANOVAs, blocked by collection location, was used to compare the average nutrient content of leaves between the four species on the north and south of Matiu/Somes Island. The ANOVA were fitted using GenStat 17 (VSN International 2014).

Results

Geographical variation in size of adult wētā

Overall, the pronotum lengths of female adult wētā varied from 10.7 mm to 15.6 mm (mean ± SE, 13.09 ± 0.10 mm) and 10.2 mm to 13.4 mm in males (11.58 ± 0.14 mm). The pronotum length of males did not vary along either north-to-south (slope of linear regression: P = 0.400) or east-to-west (P =

0.129) of Matiu/Somes Island, whereas the pronota of females captured in the west were slightly longer than from those in the east (slope –0.000842±0.000339 mm m^{-1}, P = 0.0138) but there was no change from north to south (slope P = 0.963; Fig. 1).

Food eaten by adult wētā

When illuminated by torch light some wētā continued to feed but most froze and ceased feeding with their mandibles adjacent to or touching damaged leaves. In some cases, leaf material was still in their mouths. Of a total of 324 females and 147 males examined, we were unable to determine whether seven females (4.3%) had been eating. A higher proportion of females (48.1%) were feeding or had apparently just stopped feeding when observed, compared with males (22.5%). Those that were not feeding included two pairs of males and females observed *in copula* and five females observed ovipositing. Of wētā that were eating, most (74.4% F; 78.1% M) were consuming clover, plantain, stinking camomile or grass (Table 4).The remainder mostly ate a variety of other plants including buttercup (*Ranunculus repens*), convolvulus (*Calystegia tuguriorum*), daisy (*Bellis perennis*), dandelion (*Taraxacum officinale*), dry macrocarpa foliage (*Cupressus macrocarpa*), empty flax seed case (*Phormium tenax)*, native spinach (*Tetragonia tetragonioides*) and moss. Six females and one male were eating material of animal origin consisting of a feather, bird faeces (two observations), a dry dead *Mimopeus opaculus* beetle, a dead skink, a tree wētā, and a ground wētā (*Hemiandrus* sp.); both wētā appeared to have died recently (Table 1).

Chemical composition of food plants

The average chemical content of leaves differed among the four species sampled (clover, stinking camomile, plantain and taupata) but no differences were detected between leaves from the north and south of Matiu/Somes Island, although sample sizes were small. Calcium and sodium levels came close to having different concentrations between north and south and their interactions between location and plant species came close to significance. Thus the concentrations of calcium tended to be higher in the south in three of the plant species whereas in plantain it tended to be lower in the south. Sodium, in contrast, tended to be higher in north except in taupata where it tended to be higher in the south (Appendices 1 and 2). In addition, since no differences were detected in nitrogen levels then it is likely that there were no detectable differences in overall protein concentrations between plants in the north and south (Appendix 1 and 2).

Figure 1. Variation in pronotum length of adult *D. rugosa* in relation to location on Matiu/Somes Island. Position is given as GPS co-ordinates (New Zealand Transverse Mercator 2000) of northing and easting. Only females showed a significant change in size from east to west (shown as a regression line; $R^2 = 0.032$). Solid circles = females; open circles = males.

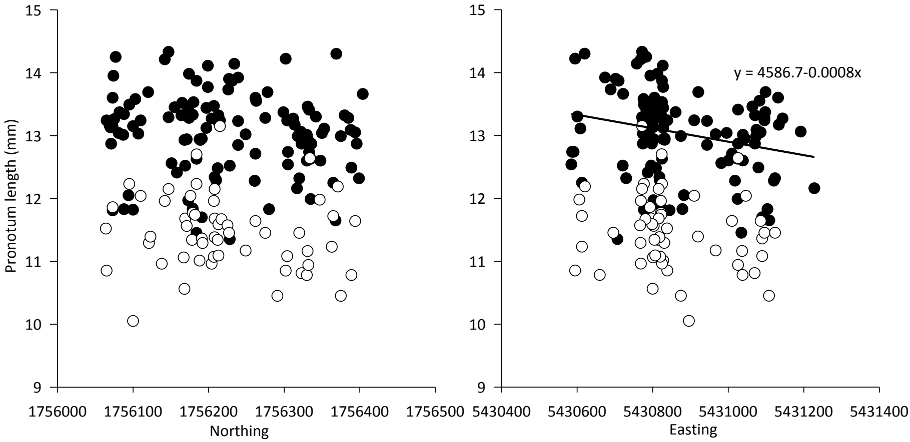

Table 1. Proportions (%) of adult *D. rugosa* wētā feeding when found and the proportion of different foods they were eating.

Food item	Female (%)	Male (%)
Feeding	48.2	22.5
Clover	11.1	2.8
Plantain	9.6	6.3
Stinking camomile	9.0	4.9
Grass	6.2	3.5
Taupata	2.8	2.8
Dandelion	2.5	0
Other plants	5.2	1.4
Animal	1.9	0.7
Unsure if feeding	2.2	0

Discussion

Chemical composition of plants in relation to wētā size and distribution

We found no evidence that nutrient levels differed from north to south amongst the three main plant species we observed *D. rugosa* eating. We also detected no north to south difference in nutrient levels in leaves of taupata bushes which are eaten by both *D.* rugosa and *H. crassidens*. Our investigation was a preliminary one and further samples both from the same plant species and from additional food species may show that nutrient levels in the plants eaten do vary geographically. The latter seems likely because adult male tree wētā had slightly longer metatibiae than those found on Mana Island (Watts *et al.* 2009) and Dr George Gibbs (unpublished data), as noted above, found that adult Wellington tree wētā matured at later instars when fed more animal protein, thereby becoming larger. In addition, adult female *D. rugosa* in the west were slightly larger than those in the east (estimated mean ± SEM for adult female pronotum length: maximum observation west 13.10±0.05 mm; maximum observation east, 13.15±0.6 mm; these observations were 643 m apart) indicating a possible difference in available nutrient levels but this was not investigated further. Species of *Deinacrida* are not known to develop through variable numbers of instars so their adults are expected to vary less in size than adult males of *Hemideina* species (Spencer 1995; Stringer and Cary, 2001). Both *D. rugosa* and *H. crassidens* will eat animals when they can although they are primarily herbivorous, so availability of animal food may be more important than plant nutrition but we did not investigate this (Ramsay 1955; Barrett and Ramsay 1991).

Conclusions

It is still not clear why numbers of both *D. rugosa* and *H. crassidens* diminished in the north following their releases there and remained high in the southwest once they reached that location. One possibility is that nocturnally active geckos, which are insectivorous, were abundant where few wētā were found so their presence may have depressed the numbers of both tree and giant wētā Other causes suggested for *D. rugosa* are changes in the availability of suitable habitat (the lawn alongside paths that this wētā frequents at night diminished between 2008 and 2016 but the reduction was not measured), and the harvesting of *D. rugosa* from Matiu/Somes Island for translocation elsewhere (Watts *et al*. in prep). However, we have not demonstrated that the changes in distribution were due to differences in chemical composition of food plants. We acknowledge that there are many other components in food which we did not investigate, and that some of these may well affect the geographic distribution of these species.

Acknowledgements

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Appendix 1. Nutrient concentrations of plant leaves collected in 2013 from northern and southern ends of Matiu/Somes Island. (mean ± se)

Plant species	Nutrient	**North**		**South**	
		Mean	**SE**	**Mean**	**SE**
Clover	B (mg/kg)	24.6	0.7	22.3	1.5
Plantain	B (mg/kg)	23.3	0.3	25.7	0.9
Stinking camomile	B (mg/kg)	48.3	1.7	66.7	11.9
Taupata	B (mg/kg)	27.0	3.6	36.3	4.4
Clover	Ca (%)	1.33	0.07	0.80	0.15
Plantain	Ca (%)	2.20	0.04	1.80	0.23
Stinking camomile	Ca (%)	1.19	0.07	0.98	0.13
Taupata	Ca (%)	1.01	0.08	1.32	0.20
Clover	Cu (mg/kg)	11.0	1.5	9.3	0.7
Plantain	Cu (mg/kg)	14.7	1.2	16.7	0.67
Stinking camomile	Cu (mg/kg)	14.3	1.2	13.7	0.7
Taupata	Cu (mg/kg)	10.0	0.6	10.0	2.6
Clover	Fe (mg.kg)	200.0	60.3	206.0	56.9
Plantain	Fe (mg.kg)	128.0	30.0	116.7	29.6
Stinking camomile	Fe (mg.kg)	73.0	2.5	140.0	36.7
Taupata	Fe (mg.kg)	66.7	10.0	68.0	5.1
Clover	Mg (%)	0.39	0.02	0.35	0.02
Plantain	Mg (%)	0.55	0.05	0.49	0.05
Stinking camomile	Mg (%)	0.42	0.03	0.42	0.02
Taupata	Mg (%)	0.29	0.06	0.30	0.06
Clover	Mn (mg/kg)	66.0	9.1	70.0	10.5
Plantain	Mn (mg/kg)	61.3	4.4	109.0	24.5
Stinking camomile	Mn (mg/kg)	216.7	6.7	347.0	83.2
Taupata	Mn (mg/kg)	160.7	75.5	240.0	41.6
Clover	N (%)	3.93	0.21	4.76	0.27
Plantain	N (%)	2.80	0.12	3.00	0.10
Stinking camomile	N (%)	2.93	0.35	2.47	0.27
Taupata	N (%)	1.87	0.09	1.93	0.24
Clover	P (%)	0.25	0.02	0.35	0.02
Plantain	P (%)	0.43	0.02	0.41	0.02
Stinking camomile	P (%)	0.32	0.05	0.35	0.06
Taupata	P (%)	0.30	0.05	0.35	0.03
Clover	K (%)	2.63	0.27	2.46	0.16
Plantain	K (%)	2.57	0.41	2.97	0.27
Stinking camomile	K (%)	3.73	0.03	3.27	0.72
Taupata	K (%)	3.10	0.40	3.03	0.52
Clover	Na (%)	0.261	0.040	0.520	0.055
Plantain	Na (%)	0.808	0.136	0.699	0.036
Stinking camomile	Na (%)	0.777	0.044	1.026	0.109
Taupata	Na (%)	0.151	0.019	0.199	0.046
Clover	S (%)	0.19	0.01	0.23	0.01
Plantain	S (%)	0.37	0.05	0.35	0.05
Stinking camomile	S (%)	0.18	0.02	0.17	0.02
Taupata	S (%)	0.27	0.01	0.23	0.02
Clover	Zn (mg/kg)	43.3	3.0	68.6	22.7
Plantain	Zn (mg/kg)	51.7	6.6	108.0	46.8
Stinking camomile	Zn (mg/kg)	61.3	1.9	126.7	38.1
Taupata	Zn (mg/kg)	46.3	8.8	86.3	12.9

Appendix 2. Resulting probabilities from two-way ANOVAs comparing mean chemical content of leaves from four plant species (clover, plantain, stinking camomile, taupata) blocked by collection location (north, south).

Element	Plant species	Location	Plant species x Location
Boron	<0.001	0.177	0.136
Calcium	<0.001	0.083	0.052
Copper	<0.001	0.943	0.476
Iron	0.012	0.609	0.670
Magnesium	0.004	0.438	0.855
Manganese	<0.001	0.139	0.500
Nitrogen	<0.001	0.374	0.083
Phosphorus	0.031	0.130	0.513
Potassium	0.055	0.866	0.602
Sodium	<0.001	0.098	0.067
Sulphur	<0.001	0.720	0.405
Zinc	0.332	0.097	0.781