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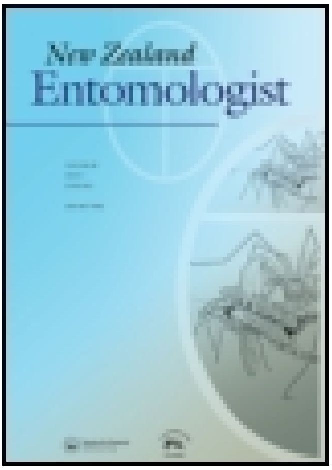

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A preliminary survey of altitudinal variation in two ground wētā species, Hemiandrus maculifrons (Walker) and Hemiandrus pallitarsis (Walker) (Orthoptera: Anostostomatidae)

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A preliminary survey of altitudinal variation in two ground wētā species, *Hemiandrus maculifrons* (Walker) and *Hemiandrus pallitarsis* (Walker) (Orthoptera: Anostostomatidae)

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Species' ranges along altitudinal clines are probably influenced by their ability to adapt to a range of abiotic factors. Physical adaptations in response to lower temperatures at higher altitudes often include changes in body size. We investigated the distribution and potential change in body size with altitude of two species of ground wētā, *Hemiandrus maculifrons* and *Hemiandrus pallitarsis* in the Moehau Ecological Area on the Coromandel Peninsula, North Island, New Zealand. Over eight nights of searching, 17 adult *H. maculifrons* and 28 adult *H. pallitarsis* were found. *Hemiandrus maculifrons* was the smaller of the two species and was found at higher altitudes compared with *H. pallitarsis* (91–577 m and 27–207 m, respectively). No ground wētā were caught in baited and unbaited live-catch pitfall traps (40 set at 211–242 m above sea level; 40 at 620–626 m above sea level). Despite what appeared to be a tendency for the size of male *H. maculifrons* to increase with altitude, we found no evidence of intraspecific variation in body size with altitude although sample sizes were small. Nevertheless, these two species of ground wētā appear well suited to further investigations into aspects associated with factors that influence body size, distributional range shifts and climate change.

Keywords: New Zealand; invertebrate; elevation; cline; body size

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Introduction

Ground wētā in the genus *Hemiandrus* (Orthoptera: Anostostomatidae) have 11 described species and approximately 30 undescribed species in New Zealand (Johns 1997, 2001; Jewell 2007; Taylor Smith et al. 2013). They are nocturnal, burrowing, flightless insects that range in body size from 12 to 45 mm, and occur throughout the New Zealand archipelago (Johns 2001; Pratt et al. 2008).

The two species of interest in this study are both common and widespread: *Hemiandrus pallitarsis* (Walker, 1869) which occurs across most of the North Island, and *Hemiandrus maculifrons* (Walker, 1869) which is found in both the North and South Islands (Pratt et al. 2008; Chappell et al. 2012; although it is probably a species complex; B Taylor Smith, pers. comm. 2013). They differ morphologically, most obviously in body colour and pattern, and in ovipositor length (Johns 2001; Gwynne 2005).

Based on previous sightings of *H. maculifrons* and *H. pallitarsis* in the North Island, it may be possible that abiotic factors such as temperature and altitude limit the distributional range of each species. For example, at some higher altitudes, such as Otanewainuku Forest

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(440 m) and Raurimu in the central North Island (∼600 m), we found only *H. maculifrons* (Chappell et al. 2014). The primary aim of this study is to investigate an area where both species are present and assess the altitudinal range of each. Based on anecdotal evidence of their current distributions, we hypothesize that *H. maculifrons* will be found at higher altitudes than *H. pallitarsis*.

In addition, we are interested in the effects of any altitudinal cline within the study species. Where individuals of a species are found across an altitudinal cline, Bergmann's rule states that individuals at higher altitudes tend to be larger than those of the same species at lower elevations (Bergmann 1847). However, there are many cases where the converse of Bergmann's rule applies, especially in some Orthoptera (Bidau & Martí 2007; Eweleit & Reinhold 2014), as well as in other ectotherms (Mousseau 1997; Blanckenhorn & Hellriegel 2002). The secondary aim of this study is to test if body size in *H. maculifrons* or *H. pallitarsis* increases with altitude.

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Methods

Ground wētā were sampled using live-catch pitfall trapping and searching within the Moehau Ecological Area on the Coromandel Peninsula, North Island, New Zealand (36°30′S, 175°25′E). Live-catch pitfall traps were used due to the presence of nationally rare fauna within the sampling area such as Archey's frog, *Leiopelma archeyi*. Each trap was constructed from a 1.5 L plastic bottle (c. 8.5 cm diameter), cut in half with the tapered end inverted inside the other half of the bottle to create an entrance funnel. These were set vertically with the funnel opening at ground level. Plastic covers (c. 225 cm^2), secured approximately 4 cm above each trap by two wire pegs provided protection from rain. Forty traps were placed between 211 and 242 m above sea level (a.s.l.) and 40 were placed between 620 and 626 m a.s.l. At each altitudinal location 20 traps baited with Harraway's Rolled Oats and a teaspoon of Woolworth's Select Smooth Peanut Butter were placed on one side of an access path at 5-m intervals, and 20 unbaited traps were placed on the opposite side of the path approximately 3 m away from the baited traps. All traps were one-third filled with a combination of moss and leaf litter dampened with water. Each trap was cleared and reset daily from 4 to 6 April 2011.

Manual searching for ground wētā was undertaken along Department of Conservation pest trapping line 'Y' on the 18–19 March, 2–6 April and 21 April 2011, between sea level (36°30′41.91″S, 175°25′31.93″E) and 627 m a.s.l. (36°31′58.78″S, 175°25′01.73″E). The path and approximately 1 m of vegetation on either side was searched by two people using headlamps, beginning ∼45 minutes after sunset and ending at midnight. The entire path could not be surveyed in a single night, and therefore, the starting point each night alternated between the bottom of the path, one-third of the way up, and the top (walking back down). Hence, each section of the path was surveyed at approximately the same time of night.

Broad vegetation types along the path consisted of grazed pasture (0–29 m a.s.l.), kanuka forest (*Kunzea ericoides* (A. Rich) J. Thompson) (30–320 m a.s.l.), kānuka–conifer/broadleaf forest (321–400 m a.s.l.), conifer/broadleaf forest (400–620 m a.s.l.), and subalpine vegetation (>620 m a.s.l.).

Using a 10× magnification hand lens, adult specimens were identified as follows: female *H. pallitarsis* by the presence of the well-developed 'spanner' on the sixth abdominal sternite (Gwynne 2005); female *H. maculifrons* by the fully developed ovipositor (Johns 2001); and both male *H. pallitarsis* and *H. maculifrons*, where possible, by the visibility of blackened hooks on the last tergite (Johns 2001). For each ground wētā found, species, sex and altitude (m a.s.l.) were recorded. Each wētā was then placed in a clear plastic ziplock bag and the lengths of the pronotum and metafemur were measured using digital vernier callipers (resolution: 0.01 ± 0.02 mm; Prograde, USA). Individuals were then marked with coloured queen bee marking paint (Ecroyd Beekeeping Supplies Ltd, Christchurch, New Zealand) on the pronotum to ensure that they were not measured again before being released at the capture site.

Statistical analyses were performed on measurements from adults using R version 2.15.2 (R Development Core Team 2013). Pearson's correlation analysis was used to assess relationships between morphometric measurements. Metafemur measurements were not normally distributed (Shapiro–Wilk normality test; $P < 0.05$), and so were log-transformed. Two-tailed t-tests were carried out to: 1) test for differences in metafemur length between the two species using measurements from males (females were not included because of the small sample sizes); and 2) test for differences in altitudinal range between the two species. Bergmann's rule was tested by linear regression of log-transformed metafemur measurements (a proxy for body size) against altitude, for both sexes of each species except for female *H. maculifrons*.

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Results and discussion

Over the eight nights of searching, 17 adult *H. maculifrons* (4 females, 13 males), 28 adult *H. pallitarsis* (9 females, 19 males) and seven juveniles were found. No marked wētā were recaptured and no ground wētā were found in any of the 80 baited or non-baited live pitfall traps over the three survey nights. However, 29 cave wētā (Rhaphidophoridae) were caught in the traps (76% were in baited traps).

The two body measurements recorded, metafemur length and pronotum length, were highly correlated ($r = 0.71$, $P < 0.001$), so further analyses were conducted using the larger metafemur length. Metafemur lengths of *H. maculifrons* were 10.51–13.12 mm (mean ± SD: 11.90 ± 1.12) for females and 8.66–12.09 mm (10.81 ± 1.14) for males; metafemur lengths of *H. pallitarsis* were 13.52–15.15 mm (14.43 ± 0.53) for females and 9.47–14.94 mm (12.19 ± 1.79) for males. Male *H. pallitarsis* were the larger of the two taxa according to metafemur length ($t = -2.48$, $P < 0.05$). The sample size was too small to test sexual size dimorphism for *H. maculifrons,* but adult males are generally smaller than adult females in both species (Chappell et al. 2012, 2014). However, as a result of the difficulty of accurate identification in the field, the smaller *H. maculifrons* individuals measured may be late instars rather than adults. For example, our mean femur length for *H. maculifrons* (10.81 mm) is similar to that found by Cary (1981) (10.8 mm), but our recorded range, 8.66–12.09 mm, includes Cary's mean length for penultimate instars (8.6 mm).

Almost all *H. pallitarsis* (37/38) and more than half *H. maculifrons* (10/17) were found within kānuka forest habitat. The remaining *H. maculifrons* were found in conifer/broadleaf forest and a single *H. pallitarsis* was recorded in the low pasture habitat. In the same area on Moehau, Rate (2009) also found more orthopterans, including ground wētā, in kānuka forest at 200 m a.s.l. compared with the higher podocarp/hardwood forest (400 m a.s.l.).

With regard to the altitudinal distribution of each species, *H. maculifrons* was found from 91–577 m a.s.l. (mean = 329.1), whereas *H. pallitarsis* was found from 27–207 m a.s.l. (mean = 107.4), and had the higher range ($t = 4.64$, $P < 0.001$). This finding supports our hypothesis that *H. maculifrons* tends to be found at higher altitudes; however, we note that this study was carried out along a single path and therefore the altitudinal

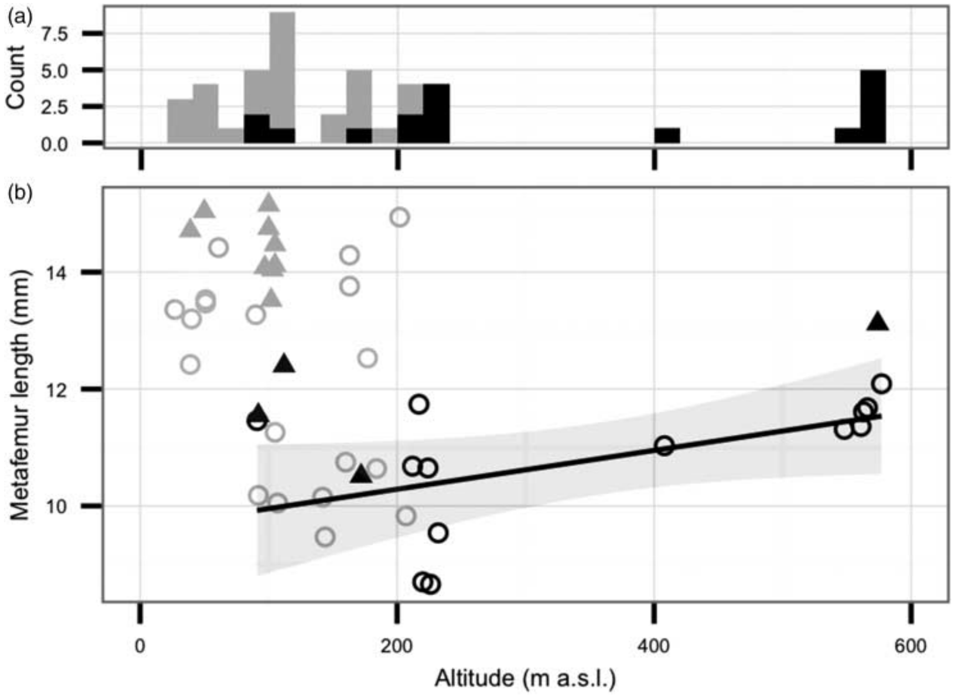

Figure 1. Altitudinal distribution and body size measurements of two ground wētā species (*Hemiandrus maculifrons* [●] and *Hemiandrus pallitarsis* [●]) collected along an altitudinal gradient from Mount Moehau, Coromandel Peninsula, New Zealand, between 18–19 March, 2–6 April and 21 April 2011. **a)** Count of each species collected from 20-m altitudinal bands; **b)** metafemur length grouped by species and sex (male [○], female [▲]) in relation to altitude. The details for the regression line are presented in the text and the grey band around the line represents the 95% confidence interval.

gradient was not accurately replicated. Currently, the full distribution of *H. maculifrons* in the North Island is unknown so the full overlap in the two species' ranges is also unknown. However, there are indications that populations of *H. maculifrons* may be isolated in Taranaki, central North Island, Ruahine Ranges, Bay of Plenty, and now possibly also the northern Coromandel (Johns 2001; Chappell et al. 2014). If the populations of *H. maculifrons* in the South Island are the same taxon as in the north, and if each of the northern populations are restricted to higher altitudinal ranges (compared with *H. pallitarsis*), then it may be likely that *H. maculifrons* is adapted to cooler climates than *H. pallitarsis.* In the tree wētā *Hemideina crassidens* and *Hemideina thoracica*, genetic and mapping data indicate that the elevational ranges of these species shifted on Mount Taranaki during Pleistocene glacial–interglacial cycles (Trewick & Morgan-Richards 1995; Bulgarella et al. 2013) and it may be that *H. maculifrons* and *H. pallitarsis* underwent similar changes. If so, these two ground wētā species would provide interesting examples to further examine range shifts in altitude and latitude with respect to current and historic climate change.

However, as it stands, it is not possible to disentangle whether habitat, altitude or some other combination of factors, was the key driver for the distribution of *H. maculifrons* and *H. pallitarsis*. Given that these two species differ in burrowing behaviour (soil versus moss; Cary 1981; Johns 2001), much higher replication paired with intensive sampling assessing

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a range of microhabitat variables, such as slope, temperature, soil moisture, altitude, forest type and understorey cover (e.g., Christie et al. 2006), would be required to identify any environmental factors that may be key drivers of their distribution.

Although we found no evidence for either Bergmann's rule or converse Bergmann's rule intraspecifically for male and female *H. pallitarsis* ($F_{1,17} = 1.59$, $P = 0.22$, $r^2 = 0.09$ and $F_{1,17} = 1.94$, $P = 0.206$, $r^2 = 0.22$, respectively) or for male *H. maculifrons* ($F_{1,11} = 4.03$, $P = 0.07$, $r^2 = 0.27$), a trend of increasing body size (metafemur length) with altitude may have been masked by insufficient sampling in the case of *H. maculifrons* (Figure 1; $n_{(\text{male})} = 13$) (note, female *H. maculifrons* were not analysed because of the small sample size). In a recent review of latitudinal and altitudinal clines across insect groups, Shelomi (2012) found that most studies show no clinal variation in body size with altitude, and where Orthoptera are concerned, ~86% of studies found either no cline or converse Bergmann's rule, in approximately equal proportions, compared with ~13% of studies that complied with Bergmann's rule. In terms of interspecific results, we found that the smaller of the two species (*H. maculifrons*) occurred at higher elevations than the larger species, and hence this follows the converse Bergmann's rule. However, as Shelomi (2012) also emphasized, we suggest that further research is required to test these theories in a mechanistic manner, that is, in a laboratory experiment to determine what factors affect body size in ground wētā and in particular, what effect temperature has on body size when independent of altitude.

Our study provides early evidence that *H. maculifrons* and *H. pallitarsis* may be at least partially separated spatially with respect to elevation. Consequently, we believe that ground wētā provide an interesting set of taxa for further investigating range shifts with respect to changing climatic conditions. We believe that these wētā would be well suited to experimentally investigating theories such as Bergmann's rule and aspects relating to sexual size dimorphism, such as sexual selection and abiotic influences.

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References

Bergmann K. 1847. Über die verhältnisse der warmeökonomie der Thiere zu ihrer Grösse. Göttinger Studien 3: 595–708.

Bidau CJ, Martí DA. 2007. Clinal variation of body size in *Dichroplus pratensis* (Orthoptera: Acrididae): inversion of Bergmann's and Rensch's rules. Annals of the Entomological Society of America 100: 850–860.

Blanckenhorn WU, Hellriegel B. 2002. Against Bergmann's rule: fly sperm size increases with temperature. Ecology Letters 5: 7–10.

Bulgarella M, Trewick SA, Minards NA, Jacobson MJ, Morgan-Richards M. 2013. Shifting ranges of two tree weta species (*Hemideina* spp.): competitive exclusion and changing climate. Journal of Biogeography 41: 524–535.

Cary R. 1981. The biology of the weta *Zealandosandrus gracilis* (Orthoptera: Stenopelmatidae) from the Cass region. (Unpublished MSc thesis). University of Canterbury, Christchurch, New Zealand.

Chappell EM, Trewick SA, Morgan-Richards M. 2012. Shape and sound reveal genetic cohesion not speciation in the New Zealand orthopteran, *Hemiandrus pallitarsis*, despite high mitochondrial DNA divergence. Biological Journal of the Linnean Society 105: 169–186.

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Chappell EM, Webb DS, Tonkin JD. 2014. Notes on sexual size dimorphism, sex ratio and movements of adult ground weta *Hemiandrus maculifrons* (Walker) (Orthoptera: Anostostomatidae). New Zealand Entomologist 37(2): 83–92.

Christie JE, Kemp J, Rickard C, Murphy EC. 2006. Measuring stoat (*Mustela erminea*) and ship rat (*Rattus rattus*) capture success against micro-habitat factors. New Zealand Journal of Ecology 30: 43–51.

Eweleit L, Reinhold K. 2014. Body size and elevation: do Bergmann's and Rensch's rule apply in the polytypic bushcricket *Poecilimon veluchianus*? Ecological Entomology 39: 133–136.

Gwynne DT. 2005. The secondary copulatory organ in female ground weta (*Hemiandrus pallitarsis*, Orthoptera: Anostostomatidae): a sexually selected device? Biological Journal of the Linnean Society 85: 463–469.

Jewell T. 2007. Two new species of *Hemiandrus* (Orthoptera: Anostostomatidae) from Fiordland National Park, New Zealand. Zootaxa 1542: 49–57.

Johns PM. 1997. The Gondwanaland weta: family Anostostomatidae (formerly in Stenopelmatidae, Henicinae or Minermidae): nomenclatural problems, world checklist, new genera and species. Journal of Orthoptera Research 6: 125–138.

Johns PM. 2001. Distribution and conservation status of ground weta, *Hemiandrus* species (Orthoptera: Anostostomatidae). Science for Conservation, No. 180. Department of Conservation, Wellington. 25p.

Mousseau TA. 1997. Ectotherms follow the converse to Bergmann's rule. Evolution 51: 630–632.

Pratt RC, Morgan-Richards M, Trewick SA. 2008. Diversification of New Zealand weta (Orthoptera: Ensifera: Anostostomatidae) and their relationships in Australasia. Philosophical Transactions of the Royal Society B: Biological Sciences 363: 3427–3437.

R Development Core Team. 2013. R: A Language and Environment for Statistical Computing. Version 2.15.2. R Foundation of Statistical Computing, Vienna, Austria.

Rate SR. 2009. Does rat control benefit forest invertebrates at Moehau, Coromandel Peninsula? Research & Development Series, No. 316. Department of Conservation, Wellington. 25 p.

Shelomi M. 2012. Where are we now? Bergmann's rule sensu lato in insects. The American Naturalist 180: 511–519.

Taylor Smith BL, Morgan-Richards M, Trewick SA. 2013. New Zealand ground wētā (Anostostomatidae: Hemiandrus): descriptions of two species with notes on their biology. New Zealand Journal of Zoology 40: 1–16.

Trewick SA, Morgan-Richards M. 1995. On the distribution of tree weta in the North Island, New Zealand. Journal of the Royal Society of New Zealand 25: 485–493.

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