Morphological variation in adult Cromwell chafer beetles *Prodontria lewisi*

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Abstract

Adult Cromwell chafer beetles *(Prodontria lewisi)* from the Cromwell area were investigated for sex-specific morphological variation. Material from the National Arthropod Collection, Landcare Research Auckland and the Otago Museum that had been collected since the 1940s was examined. Females were significantly larger than males, but size-related variables were not effective in distinguishing between sexes in multivariate space. However, hindleg lengths of males were longer than females and sexes were separated according to this gradient in multivariate space. Sex-specific variation of variables were unimodal and characterised by small standard deviations. The findings support the present taxonomic distinctiveness used to assign a Category A conservation status to this species.

1. Introduction

Variation is the essence of biology and is the central feature of evolutionary theory. Biological variation is epitomised by the vast numbers of species involved in various interactions both on an ecological and evolutionary time scale (Price 1988). Morphological variation within species has been the basis of species classification with methods relying on minimising variation within taxonomic groupings (taxa) (Mayr 1963). However, species are often characterised by morphological variation with variants often geographically separated (for examples see Burrows 1965, Van Horn 1965, Peterson 1968).

During field excursions and conservation monitoring (Ferreira & McKinlay 1998) of Cromwell chafer beetles, *Prodontria lewisi* (Broun 1909), potential variation in body size, particularly of adult males, was noted. Emerson & Barratt (1997) used morphological measurements to describe species following a phylogenetic construction of the species constituting the genus *Prodontria*. However, the exact sample size used for each species and population representing a species was not specified. It is likely that, due to the genetic emphasis, few samples were taken from each population.

The Cromwell chafer is a threatened species and is ranked by the Department of Conservation as a Category A; taxonomic distinctiveness is one of the criteria used to make this assessment (Tisdall 1994). Taxonomic distinctiveness is at present scored as three. Cromwell chafers are recognised at the species level and are genetically or morphologically highly distinct from other members of the genus (Emerson 1995). It follows that morphological variation within the single extant population of Cromwell chafers (Ferreira & McKinlay 1998) may potentially indicate the possibility of more than one species occurring in the one viable population remaining on the Cromwell Chafer Beetle Reserve. This may have conservation management implications for the continued existence of Cromwell chafers. This study was therefore directed at investigating the following hypotheses (stated as alternative hypotheses):

Hypothesis 1: Sex-specific differences in morphology characterise adult chafer beetles occurring on the Cromwell Chafer Beetle Reserve.

Hypothesis 2: Intra-sex variation in morphological measurements are characterised by a multi-modal distribution.

We used the information obtained to discuss the implications for conservation of Cromwell chafer beetles.

2. Material and methods

Data were collated from Armstrong (1987) and included sex-specific total body length and elytra width. We obtained additional specimens from Brian Patrick's and A. Harris collection at the Otago Museum, the National Arthropod Collection in Auckland, and specimens held by the Department of Conservation in Dunedin. The following body measurements (mm) using a vernier caliper (± 0.02 mm) were taken for each individual:

Total length: Total length measured along the dorsal midline from the tip of the clypeus to the end of the elytra.

Clypeus length: Clypeus length measured along the dorsal midline.

Clypeus width: Clypeus width measured between the eyes.

Pronotum length: Pronotum length measured along the dorsal midline.

Pronotum width: Pronotum width measured across the widest part.

Elytral length: Elytral length measured along the dorsal midline from the posterior margin of the pronotum to the end of the elytra.

Elytral width: Elytral width measured across the widest part of the elytra.

Elytral height: Elytral height measured across the highest part of the elytra.

Femur length: Femur length of the third pair of legs measured from the joint with the body to the joint with the tibia.

Tibia length: Tibia length of the third pair of legs measured from the joint with the femur to the joint with the hind foot.

Hindfoot length: Hindfoot length of the third pair of legs measured from the joint with the tibia to the most distal tip of the foot.

We used the lamae structure on antenae to identify sexes (Armstrong 1987). Groupings of individuals within multivariate space were investigated using principal component analysis. Differences in morphological characteristics between groupings within multivariate space were tested using discriminant analysis (Ludwig & Reynolds 1988). Sex-specific differences in various morphological variables were investigated using Student's t-test (Sokal & Rohlf 1969). To investigate Hypthesis 2, we constructed frequency distributions using 15 class intervals defined by the range of values measured for each variable and documented the occurrence of multimodal distributions.

3. Results

Adult chafer beetles differed morphologically between sexes (Wilk's $\lambda = 0.48$, $F_{11,50} = 4.95$, $p<0.01$) and were represented by two distinct groups within a two-dimensional component space derived from a suite of morphological characteristics (Figure 1). Factor 1 represented a negative gradient of body size while Factor 2 represented a negative gradient of hindfoot length (Table 1). Only 62% of the total morphological variation present in adult beetles could be explained by these two factors (Table 1). A number of additional factors were required to explain the remaining variation, but none of these factors had eigen values larger than one.

Four morphological variables differed significantly between sexes. Female total length and elytra width were significantly larger than in males (Table 2). However, the ratio of elytra width to total length did not differ between sexes (Females: 0.60±0.03, n=79; Males: 0.60±0.03, n=196; $t_{273}=0.18$, $p=0.86$). Male tibia length and hindfoot length were significantly larger than in females (Table 2), which resulted in the ratio of hindleg length to total length being significantly larger for males (Females: 0.99±0.05, n=23; Males: 1.11±0.09, n=39; $t_{60}= -6.27$, $p< 0.01$). All the morphological variables were characterised by unimodal frequency distributions for males as well as females.

4. Discussion

The results illustrate that morphological variation in adult Cromwell chafers is most evident between sexes. However, these sex-specific differences are of small scale. Females are slightly larger than males, but total length to width ratios are the same between the sexes. Size variables were located on Factor 1 in principal component analyses and could not distinguish between the sexes along this gradient. In other words, the slightly larger size of females could not distinguish sexes in multivariate space. Factor 2 represented a negative gradient of hindfoot length which separated sexes along this gradient. Males have significantly longer legs than females, which is reflected in the hindleg length to total body length ratios.

Ferreira & McKinlay (1998) suggested that females move shorter distances than males and that, together with locally abundant resources, resulted in females engaging in minimal dispersal activities. Our results reflect a morphological advantage (longer legs) for males to move around more efficiently. This finding supports Ferreira & McKinlay's (1998) suggestion. Females therefore emerge and remain in restricted areas while males do all the searching for females to mate with. Abundant resources at the emergence sites of females (Ferreira & McKinlay 1998) result in females obtaining enough energy for body maintenance, survival and egg production while waiting for males to find them and mate with them.

Geographical variation in genetic as well as morphological features in the genus *Prodontria* is the basis on which species have been identified within this genus (Emerson 1995). This classification suggested that within species, variation of members of this genus should therefore be relatively small. In contrast to this suggestion, it has been proposed, following incidental field observations (S.M. Ferreira, personal observations), that Cromwell chafer adults are characterised by large morphological variation. The results proved the opposite. All sex-specific morphological variables measured were characterised by small standard deviations (only elytra height and hindfoot length were characterised by a coefficient of variance larger than 10) (see Table 2). Furthermore, all variables were characterised by unimodal frequency distributions.

Our results therefore illustrate sexual differences in morphology, supporting Hypothesis 1. Furthermore, unimodal distributions characterise all sex-specific morphological variables, falsifying Hypothesis 2. These findings reflect positively on the conservation status of Cromwell chafer beetles. The findings here support the taxonomic distinctiveness score assigned to this species using Tisdall's (1994) scoring methods. The Cromwell chafer beetle is the only species of the genus *Prodontria* occurring on the Cromwell Chafer Beetle Nature reserve and is genetically or morphologically highly distinct from other members of the genus.

5. Acknowledgements

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Table 1. Factor scores of morphological variables on two components derived through principle component analysis. Variables located on each factor are in bold.

Variable	Factor 1	Factor 2
Total length	-0.78	0.24
Clypeus length	-0.71	0.15
Clypeus width	-0.59	0.09
Pronotum length	-0.72	0.10
Pronotum width	-0.93	0.09
Elytra length	-0.85	0.25
Elytra width	-0.64	0.25
Elytra height	-0.64	-0.12
Femur length	-0.65	-0.36
Tibia length	-0.68	-0.56
Hindfoot length	-0.30	-0.74
Eigen value	5.62	1.23
Percentage explained	51.12	11.21

Table 2. Comparison between sex-specific morphological variables (mm, mean ± standard deviation) of adult Cromwell chafer beetles. The values in brackets represent sample sizes and bold values indicate significant p-values.

Variable	Females	Males	t-value	-value
Total length	14.12±0.95 (79)	13.54±0.97 (196)	t273=4.50	<0.01
Clypeus length	3.79±0.28 (31)	3.75±0.31 (49)	t78=0.60	0.55
Clypeus width	3.21±0.22 (31)	3.14±0.22 (49)	t78=1.51	0.13
Pronotum length	3.28±0.26 (31)	3.26±0.18 (49)	t78=0.31	0.75
Pronotum width	6.83±0.30 (31)	6.79±0.31 (49)	t78=0.46	0.65
Elytra length	10.51±0.56 (31)	10.33±0.51 (49)	t78=1.54	0.13
Elytra width	8.46±0.58 (80)	8.10±0.60 (197)	t275=4.55	<0.01
Elytra height	4.27±0.61 (31)	4.19±0.50 (49)	t78=0.60	0.55
Femur length	4.80±0.46 (31)	4.99±0.49 (49)	t78= -1.67	0.10
Tibia length	4.43±0.37 (31)	4.72±0.42 (49)	t78= -3.09	<0.01
Hindfoot length	5.35±0.97 (24)	6.06±0.71 (40)	t62= -3.41	<0.02

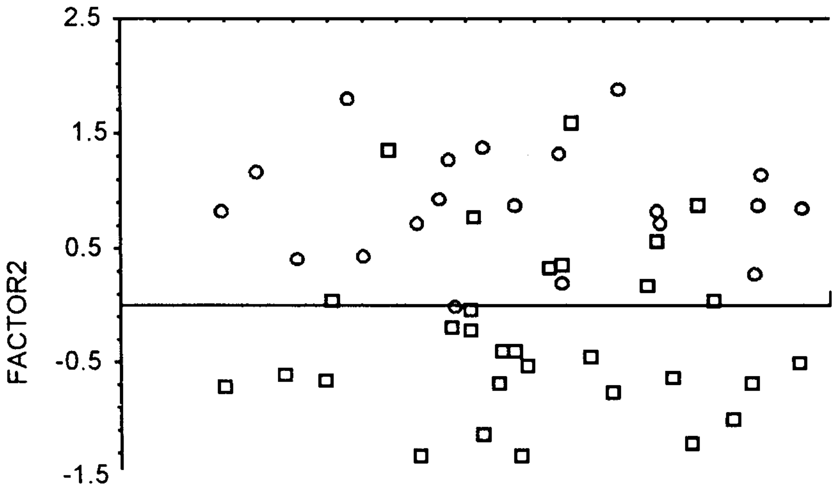

Figure 1. Principal component scatterplot representing variation in 11 morphological variables of adult Cromwell chafer beetles. The open circles represent females and the open squares males. See text for a description of factor loadings.