Distribution and abundance of *Sigaus childi* Jamieson (Orthoptera: Acrididae), a Central Otago endemic grasshopper

SCIENCE FOR CONSERVATION 110

Colleen D. Jamieson

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DOC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed.

ISSN 1173-2946
ISBN 0-478-21820-6

This publication originated from work done under Department of Conservation Investigation no. 1926, carried out by Colleen D. Jamieson, Jamieson Ecology, 9 Eagle Street, Burkes, Dunedin. [ColleenJ@xtra.co.nz]. It was approved for publication by the Director, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

Cataloguing in Publication
Jamieson, Colleen Dusk, 1954-
Distribution and abundance of Sigaus childi Jamieson (Orthoptera: Acrididae), a Central Otago endemic grasshopper / Colleen D. Jamieson. Wellington, N.Z. : Dept. of Conservation, 1999.
1 v. ; 30 cm. (Science for conservation, 1173-2946 ; 110.)
Includes bibliographical references.
ISBN 0478218206
1. Sigaus childi. 2. Grasshoppers—New Zealand—Otago Region.
I. Title. II. Series: Science for conservation (Wellington, N.Z.) ; 110.
595.726099394 20
zbn9--028510

CONTENTS

Abstract

Sigaus childi is a distinct grasshopper species which is restricted to the Alexandra area, Central Otago. It has a one year life cycle: mating and oviposition occurs in the spring, development occurs during the summer and autumn, and it over-winters as a late instar hopper (juvenile stage) or adult. Five male and six female instars have been identified. Recommendations are made for grasshopper reserves, and a monitoring programme is suggested.

1. Introduction

Of the fifteen species of short-horn grasshopper (Orthoptera, Acrididae) described by Bigelow (1967), six were placed in the genus *Sigaus* which is distinctive in possessing a mesal dorsal protuberance on the ectophallis of the male genitalia. This study began as a study on the Alexandra population (Bigelow) of *Sigaus minutus* Bigelow, but during the study it was found to be a distinct species. The new species has since been described as *Sigaus childi* (Jamieson 1999).

Bigelow (1967) originally identified the Alexandra grasshopper population (Figure 1) as *S. minutus*, on the basis of observations of the external morphology of males. He was unable to compare the male genitalia of the two populations as his original descriptions of *S. minutus* were based only on females from the Mackenzie Country. Confusion arose because of the very similar external morphology of the two species. Patrick (1994) followed Bigelow in using the same name *S. minutus* for the Alexandra area population.

Bigelow (1967) also commented on the rarity of *S. minutus* and suggested it may be nearing extinction. Department of Conservation interest in the low numbers of the grasshopper in the Alexandra area, and in its disjunct distribution with the Mackenzie Country population (Patrick 1994) led to a pilot study on what was known as *S. minutus* in Central Otago (Jamieson 1996). In this study it was found that most populations were confined to small *Raoulia australis* Beauv. dominated islands within pasture, and were vulnerable to extinction. However, the importance of this plant to *S. minutus* was not established, and further research was recommended. It was also recommended that the species status of *S. minutus* should be checked.

The present study was conducted to establish the requirements for the long-term conservation of what has become known as *S. childi* in Central Otago. As part of this work the morphology of the Mackenzie Country and Alexandra populations are compared, the life cycle and the juveniles stages are described, and the distribution of the species in Central Otago is mapped. Also, the fauna and flora of a promising conservation site are listed and recommendations are made for its boundaries. A simple method for monitoring the grasshopper population is outlined.

Figures 1, and 9–12 are coloured photographs. They are presented as Plates following the References.

2. Methods

Adult grasshoppers were collected from the Mackenzie Country and Alexandra for comparisons of external morphological features and male genitalia. Drawings of structures were made with the aid of an Olympus dissecting microscope and an eyepiece graticule.

Regular monthly counts as described by Jamieson (1996) were made at the 'grid site' on Crawford Hills Rd, Alexandra from September to May during 1995, 1996, and 1997. Grasshoppers found were identified and recorded as adults or juveniles. At the same time individuals were collected from other sites for accurate staging and measurement in the laboratory, and drawings were made as described above.

Surveys were carried out in the wider Alexandra area for the grasshopper during 1996 and 1997. Likely sites as identified by Jamieson & Manly (1997) were specifically targeted, and the late Peter Child's insect collection (now in Otago Museum) provided information for the identification of further sites. Locations of the population (a scattered fragmented population) were recorded on a map.

Monthly light trapping and pitfall trapping was carried out at the large *Raoulia australis* site on Galloway Station (Jamieson 1996) from December 1996 to March 1997. The area was also sampled with a hand-net. A floral survey was made of the same area in December 1995. Both flora and fauna were identified with the assistance of experts (Otago Museum: Brian Patrick, Lepidoptera and plants; Anthony Harris, various insects particularly Hymenoptera. Canterbury Museum: John Ward, Tricoptera; Roy Harrison, Diptera). Sampling effort was concentrated on the north-facing slopes where *R. australis* is dominant.

3. Results and discussion

3.1 COMPARISON OF MACKENZIE COUNTRY AND ALEXANDRA POPULATIONS

Microscopic examination of grasshoppers collected from the Mackenzie Country and from Alexandra showed significant morphological differences between the two species. External morphological features are shown in Figures 2–4. A full description of the taxonomic differences is given in Jamieson (1999). A modification to the key (couplet 6) given by Bigelow (1967) to distinguish *S. minutus* from *S. childi* is given below.

Figures 1, and 9–12 are coloured photographs. They are presented as Plates following the References.

Modification to key, couplet 6

1 Very small rugose species. Fastigium concave with upraised margins and bumps laterally on posterior margin (Figure 4). Posterior margin of pronotum sinuate with broad indent medially (Figures 2 and 3). Pronotum not broadening noticeably at third sulcus .... *minutus*

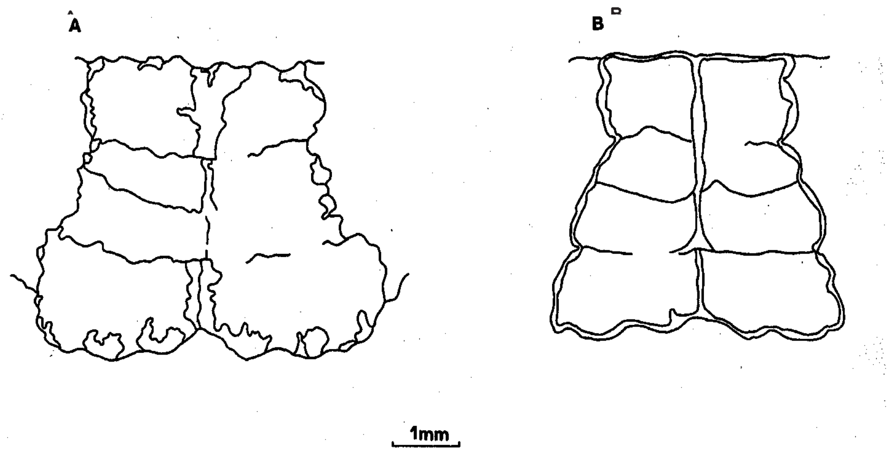

Figure 2. Dorsal view of female pronotum; **A** *S. childi*, **B**. *S. minutus*.

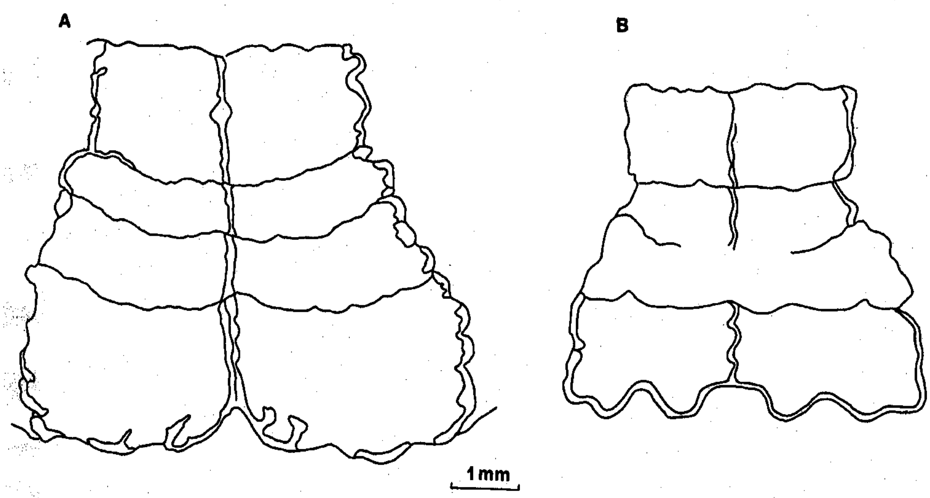

Figure 3. Dorsal view of male pronotum; **A** *S. childi*, **B** *S. minutus*.

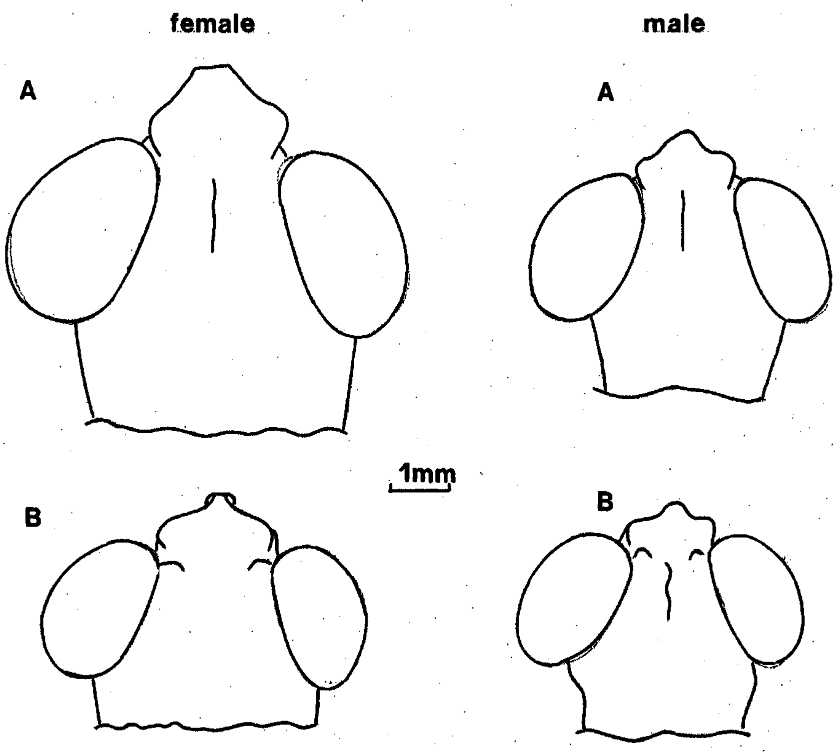

Figure 4. Dorsal view of female and male fastigia; **A** *S. childi*, **B** *S. minutus*.

2 Medium-sized, stout, rugose species. Fastigium longer than broad but blunt anteriorally (Figure 4). Posterior margin of pronotum sinuate with v-shaped indent medially, pronotum broadening at level of third sulcus (Figures 1, 2, and 3) .... *childi*

3.2. LIFE CYCLE OF *Sigaus childi*

Numbers of grasshoppers recorded at the 'grid site' during the 1995/96 and the 1996/97 seasons are shown (Figure 5). Grasshoppers were not found during the winter even on bright sunny days. Adult and late stage juveniles (IV, V, and VI) emerge in spring when daytime temperatures are reaching 18±1°C. The time of emergence, therefore, varies from year to year. Grasshoppers were first recorded for the season on 25 October in 1995, on the 27 September in 1996, and in 1997, after a particularly mild winter, a single male grasshopper was seen at the 'grid site' on 24 August. Spring grasshopper numbers usually increased to reach a peak in November before decreasing. Throughout this time late stage hoppers were developing into adults. By the end of December, adult grasshoppers had mostly disappeared although some individuals persisted for another two months.

Juvenile grasshoppers were first recorded in early January 1996 and 1997, and identified as stage III hoppers. Obviously stage I and stage II hoppers are present earlier (November/December) but are too small to be seen with the regular sampling method. Stage I and stage II hoppers were found at other sites during late November and early December. Numbers of hoppers increased during January and February with progressively later stage hoppers being recorded later in the season. By early April numbers of grasshoppers had decreased in both 1996 and 1997, and with the onset of cooler weather fewer and fewer grasshoppers were found. In 1997 only one grasshopper was found at the beginning of May.

Numbers of grasshoppers were higher during summer–autumn 1996 than in summer–autumn 1997, despite very low numbers in spring 1995. During sampling in 1996 it became evident that two separate size classes were developing. The following summer only one size class was seen. Summer 1996 was particularly wet and warm which resulted in prolific plant growth in the region. Farmers had two and three crops of hay from paddocks which were normally only cropped once. Warm, wet weather is associated with high grasshopper numbers in other arid regions. Numbers were also higher the following spring (a maximum of 8 recorded) than in the preceding spring (maximum of 2). For both years approximately 20% of the maximum number recorded in the autumn over-wintered.

From these data the following annual life cycle is proposed: *S. childi* over-winters as a late stage hopper (IV–VI) or adult. As most individuals found in the spring are stage VI or adult it suggests that the later stages have higher survival rates over the winter. The presence of stage I and II hoppers in November and December indicates mating and oviposition in the spring. The time difference between emergence of over-wintering grasshoppers and the detection of stage I hoppers (6 weeks, in spring 1996) supports this hypothesis.

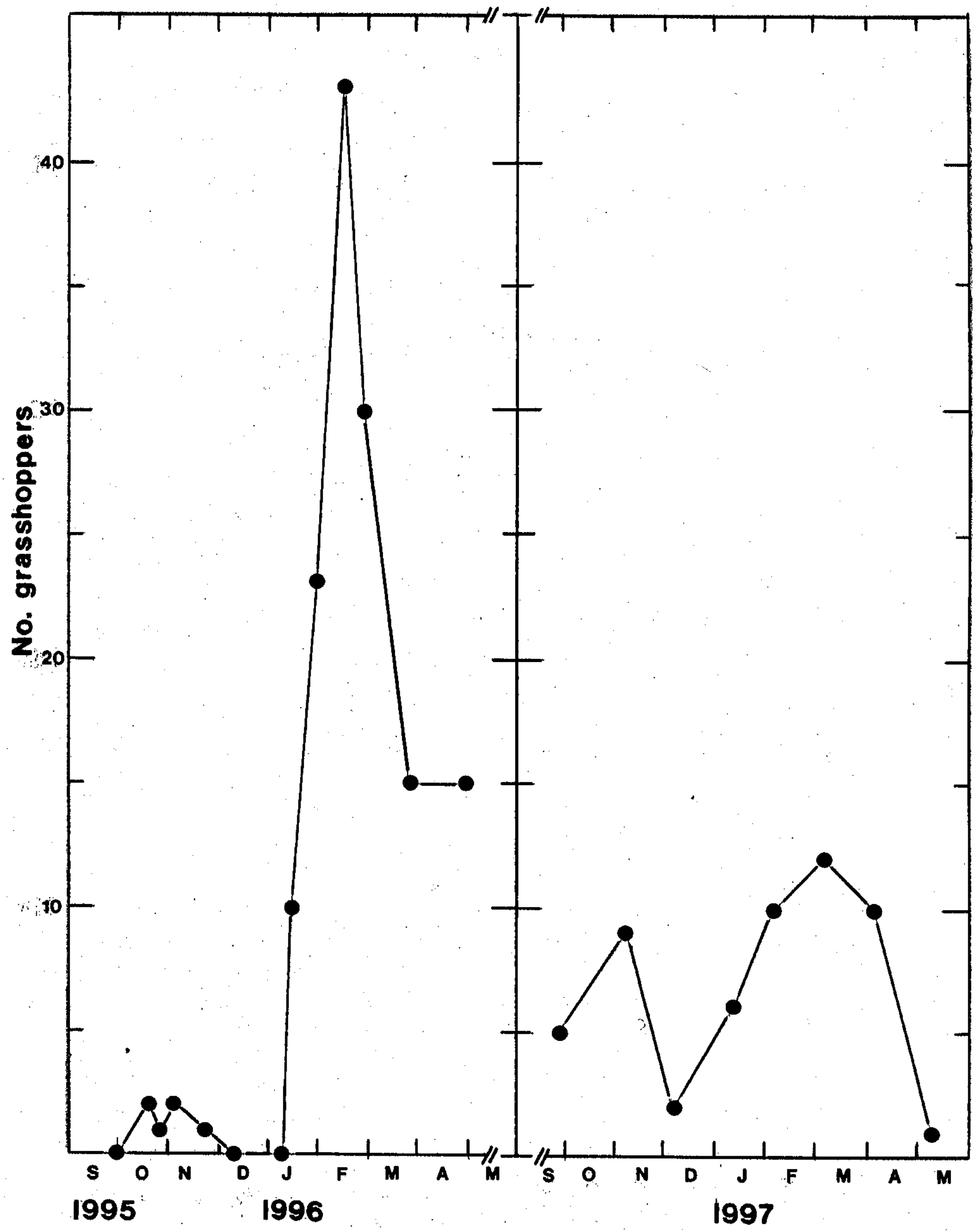

Figure 5. Number of grasshoppers recorded at the 'grid site' Crawford Hills Rd during 1995/96 season and 1996/97 season.

3.3 IDENTIFICATION OF JUVENILE STAGES (HOPPERS)

The developing genitalia of both female and male *S. childi* hoppers are shown in Figures 6 and 7, and described in Table 1. All stages of *S. childi* have distinctive sparse, but long, hairs on the final abdominal segments, the cerci and paraprocts. The development of the hoppers contrasts with that of other New Zealand species described by Hudson (1970) in that sclerotization of the female genitalia is visible from the fourth instar onwards and in the male the paraprocts become obscured by the developing subgenital plate. Five male hopper instars and six female hopper instars have been identified. This is reasonably common

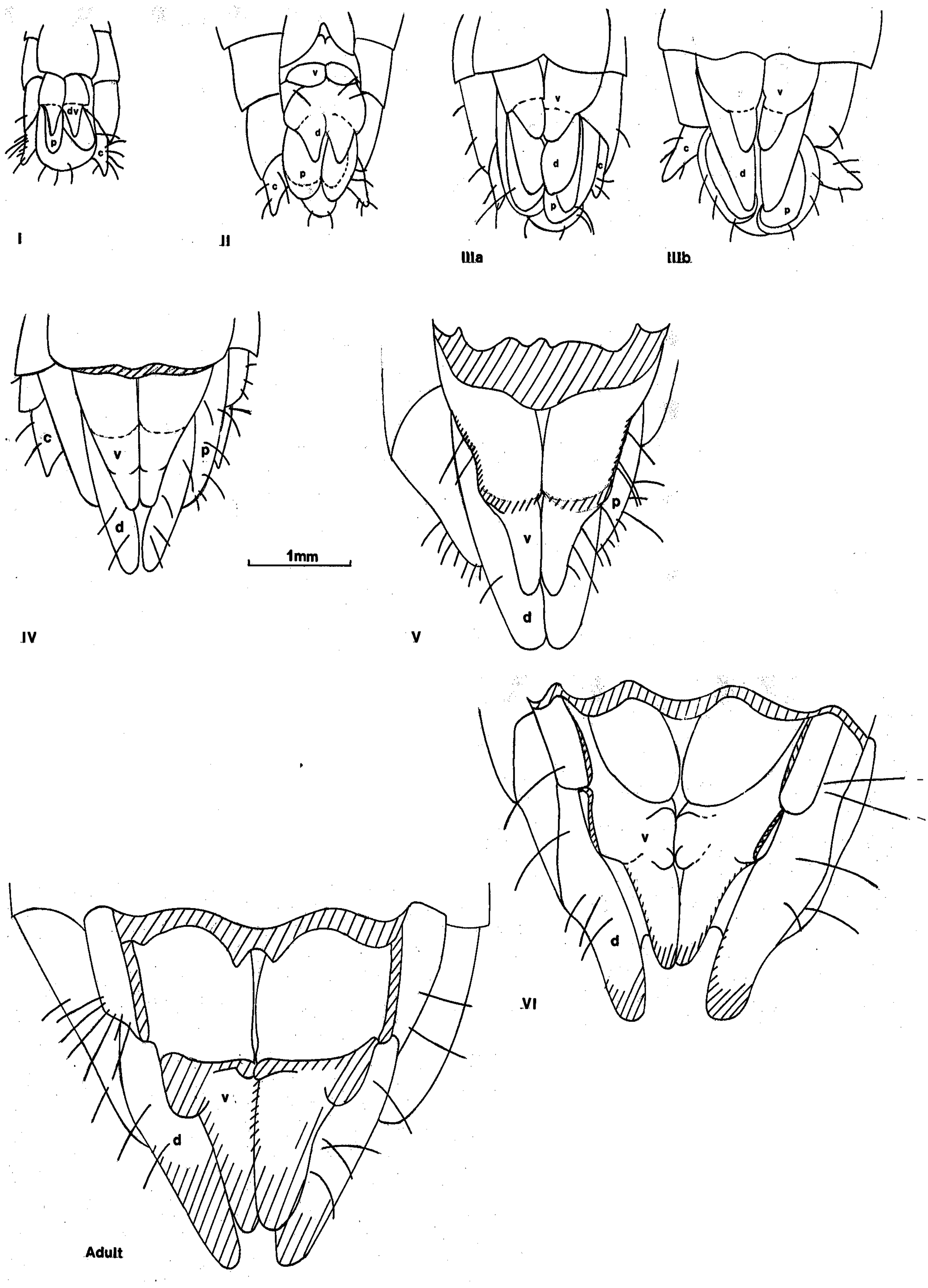

Figure 6. Ventral view of female genitalia in developing hoppers (stages I–VI, and adult). c = cerci, d = dorsal valves, p = paraproct, v = ventral valves.

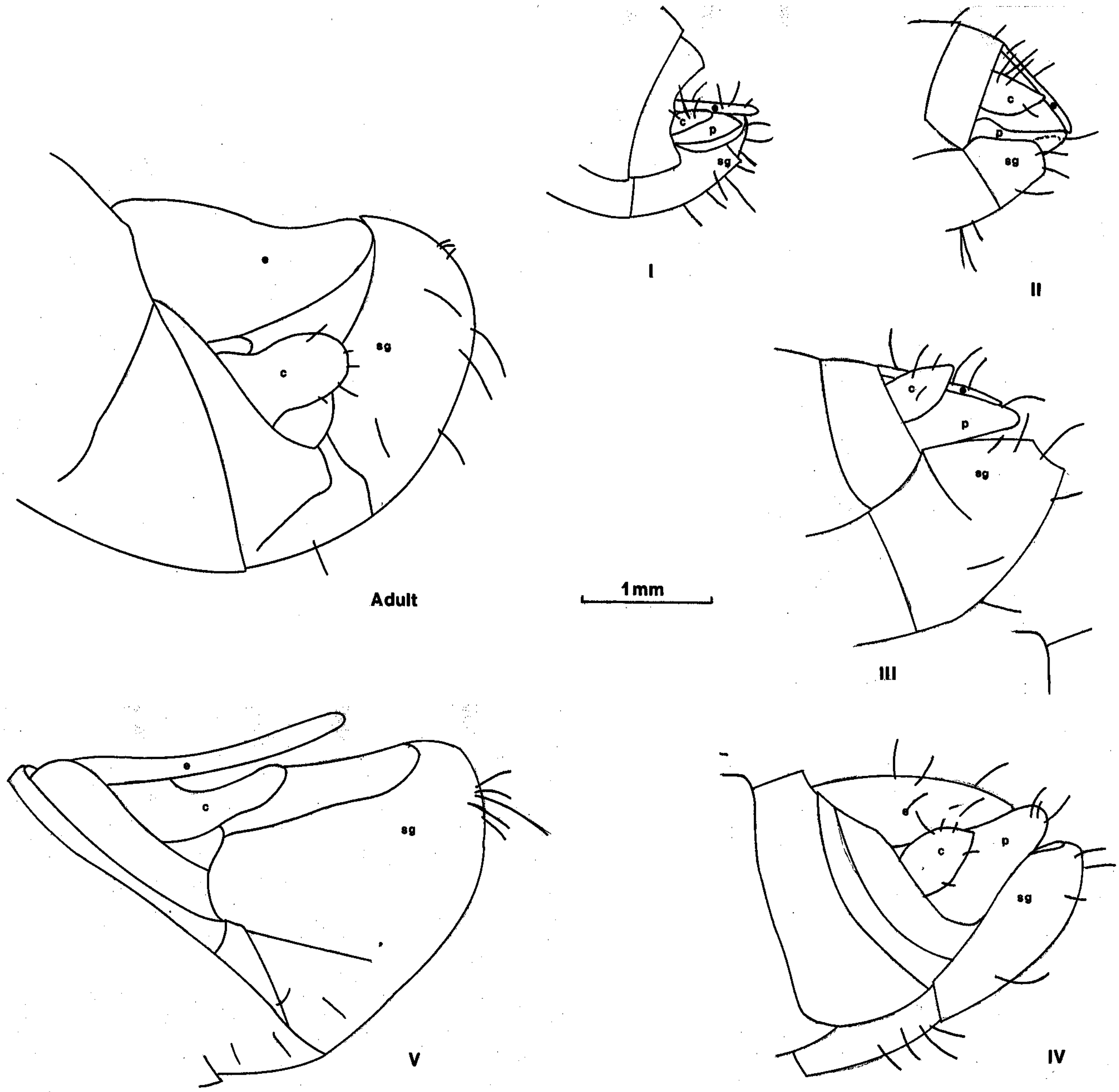

Figure 7. Lateral view of male genitalia in developing hoppers (stages I–V, and adult). c = cerci, e = epiproct, p = paraproct, sg = subgenital plate.

among species with notable sexual size dimorphism (Uvarov 1966), but contrasts with other New Zealand species described by Hudson (1970). The development of the tegmina and wings has not been described as the wings are particularly small and changes difficult to observe. Similarly, developmental changes to the antennae have not been described as the number of segments may vary and are often difficult to count accurately (Burnett 1951). The structure of the pronotum (as shown in Figures 1 and 2) are consistent throughout development, as noted by Jamieson (1996).

Sizes of hoppers increase with each moult but tend to be very variable in the older instars. Presumably these changes result from variations in food and temperature conditions for developing hoppers (Uvarov 1977). They can not be used reliably to identify the hopper instar.

3.4 DISTRIBUTION OF *Sigaus childi* IN CENTRAL OTAGO

The location of populations of *S. childi* are shown on Figure 8. More populations were found on and near Little Valley Station than in other areas in the Alexandra area. This area is particularly dry and barren. A survey of targeted sites as identified by Jamieson & Manly (1997) on a four-wheel drive trail resulted in a probability of P = 0.5 of finding *S. childi* in January 1995. In February 1996, a four-wheel-drive excursion on a different trail on the same property located populations at 10 out of 12 potential sites visited (P = 0.8). Unfortunately these areas are currently being developed for more intensive grazing (Figure 9) and the long term prospects for these populations are bleak.

TABLE 1. DESCRIPTIONS OF THE CHANGES IN THE FEMALE AND MALE GENITALIA DURING HOPPER DEVELOPMENT.

INSTAR	DESCRIPTION
Female	
I	Upper ovipositor valves short, triangular at apex and separated by a transverse fold at base. Paraprocts shorter and contained within the final abdominal segment.
II	Increased length and size of paraprocts which are now nearly as long as the cerci. Only the end of the abdomen is visible. Upper ovipositor valves longer, acute and separated by broad excision. Lower valves represented by a medially separated transverse fold at the base of the upper valves.
IIIa	Further increase in the length of the paraprocts to extend beyond the cerci. Upper ovipositor valves nearly as long as the cerci and broader. Lower ovipositor valves fully separated, extend halfway down upper valves.
IIIb	Further increase in length of paraprocts which almost cover the final abdominal segment and extend well beyond the cerci. Upper ovipositor valves lengthen to extend beyond cerci, fully separated along the middle line. Lower valves lengthen.
IV	Upper ovipositor valves lengthen to lie well beyond paraprocts. Lower valves also lengthen and are now as long as the paraprocts. Sclerotization along the margin of the sub-genital plate.
V	Lengthening and enlarging of both upper and lower ovipositor valves. Sclerotisation of lower ovipositor valves.
VI	Increased sclerotization of upper and lower ovipositor valves. Upper ovipositor valves widely spaced. Lower ovipositor valves have developing ventral notch.
adult	Increased sclerotization of upper and lower ovipositor valves. Fully developed ventral notch on lower ovipositor valves. Sclerotization along the margin of the sub- genital plate is not consistent within instars or for adult females.
Male	
I	Subgenital plate semi-circularly folded and extending beyond paraprocts. Epiproct extending beyond paraprocts.
II	Subgenital plate semi-circularly excised and extending two thirds along the length of the paraprocts. Epiproct and paraprocts of similar length and meet at apex.
III	Subgenital plate with broadly parabolic apex extending beyond paraprocts. Paraprocts extend beyond the epiproct.
IV	Subgenital plate curving around to form narrow parabolic apex beyond paraprocts.
V	Subgenital plate curved around to form broad parabolic curve but does not meet apex of epiproct. Paraprocts obscured.
adult	Subgenital plate forms smooth broad parabolic curve that extends well beyond epiproct but returns to meet apex of epiproct and end of cerci.

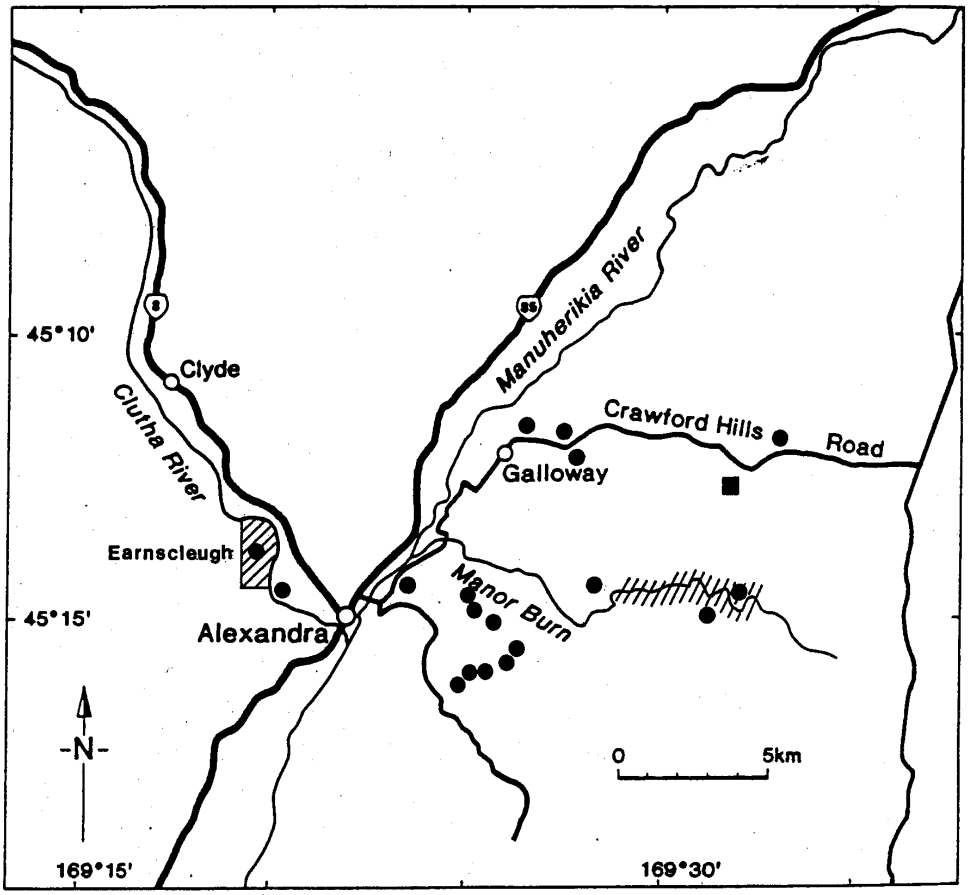

Figure 8. Distribution map of *S. childi* populations (solid dots) in Central Otago. square = grid site. Diagonal shading = proposed reserves.

An extensive population of *S. childi* was also found on the Earnscleugh Tailings Historic Reserve (see Figure 10) (Jamieson 1998a). Some grasshoppers were located in areas where *Thymus vulgaris* L. was sparse, but they were absent in areas where it became thicker.

No populations were found at targeted sites surveyed in the Conroys Dam and Fraser Dam areas and on north facing slopes, farmed as part of Earnscleugh Station, on the true right of the Clutha River. Similarly no populations were found on targeted sites on Rockdale Station, and on the Ida Valley side of the Crawford Hills, nor on the Clutha River side of Little Valley Road which is heavily infested with thyme. Suitable sites were not identified on Olrig Station. B.H. Patrick collected a single specimen near the Chatto Creek Hotel on 27 September 1993. The identity of juvenile hoppers collected in the Lindis Pass was not confirmed. All known populations of *S. childi* were found in dry barren areas around Alexandra.

Figures 1, and 9–12 are coloured photographs. They are presented as Plates following the References.

To summarise, two large populations were located, the first on the Earnscleugh Tailings Historic Reserve and the second on the steep sides of the Manor Burn on Galloway Station (Figure 11). Small scattered populations were also present in the Alexandra area on farmland. Some of these became extinct during the study. On large sites *S. childi* are sparsely distributed, but on small sites populations become dense. Only seven grasshoppers were seen when a 10,000 m^2 site was searched on Galloway Station and three of these grasshoppers were on the bulldozer track. Two small sites that were grid sampled on Crawford hills Road had denser populations (ten grasshopper to 2 m^2, and 20 to 100 m^2). The population at one small site had disappeared by spring 1995 (Jamieson 1996) and at the other small site had disappeared by spring 1997. This difference in population density suggests that dense populations are a consequence of a restricted site. High population density may provide a useful indicator of shrinking habitat boundaries. Habitat boundaries may shrink as a result of plant overgrowth (e.g. *T. vulgaris* invasion of Galloway Station) or as a result of soil consolidation on stony areas.

More grasshoppers were regularly seen on a bulldozer track at the Galloway site than on the undisturbed hillsides in the same area. This may indicate a preference for disturbed habitat. Such a preference would maintain *S. childi* on bare sites and prevent them from being marooned on small clear patches of ground surrounded by taller plants. It may also give some protection from predators, e.g. skinks, if the skinks were slower colonisers of disturbed habitat.

These observations suggest large reserves are more suitable for this species than several small reserves. De Vries & den Boer (1990) also found that large sites were more suitable than small sites for the carabid beetle *Agonum ericeti* which cannot bridge distances that exceed 200 m between sites suitable for reproduction. Over a period of 24 years the beetle had become extinct at 10 out of 11 small sites. However, at the large site the populations had persisted. They proposed, that in the large habitat, the species was protected from extinction by the existence of independently fluctuating subpopulations which were sufficiently close together to allow outbreeding and recolonisation.

3.5 IMPORTANCE OF *Raoulia australis* TO *Sigaus childi*

The common mat daisy *R. australis* is not important to *S. childi.* The Earnscleugh Tailings population of *S. childi* was found without *R. australis* . The plant species does occur in the tailings, but is very uncommon. Thus, the observed co-occurrence is coincident rather than necessary (Jamieson & Manly 1996). *R. australis* was proposed as a possible site for oviposition and/or hibernation, however, it now appears that *S. childi* is a rock-loving species and finds shelter among rock crevices. *S. minutus* was observed ovipositing among pebbles underneath a rock overhang (Jamieson 1998b), and it is possible that *S. childi* has a similar behavioural adaptation. Nevertheless, *R. australis* is a useful indicator of potential sites for *S. childi* as it can be seen from a distance and does support the species.

Figures 1, and 9–12 are coloured photographs. They are presented as Plates following the References.

3.6 FAUNAL AND FLORAL SURVEY OF GALLOWAY SITE

The flora and fauna found at the large *R. australis* site on Galloway Station (Figures 11 and 12) are listed in Tables 2 and 3. Fewer endemic plant specimens are found here compared to similar areas on Little Valley Station. A large (>40) goat herd grazes the Galloway area and regularly removes the palatable species. A wild cat family was also seen, as well as numerous rabbits.

The insect fauna has been described as typical (R. Harrison, B. Patrick, pers. comm.) for the dry areas around Alexandra. *S. childi* and the clapping cicada (*Amphipsalta strepitans)* are, however, noteworthy for their rarity. A native skink population *Coligosoma* sp. thrives on the rocky hillsides and frequently appeared in pitfall traps.

TABLE 2. PLANTS FOUND AT THE LARGE *Raoulia australis* SITE ON GALLOWAY STATION.

SCIENTIFIC NAME	COMMON NAME
**Anagallis arvensis* L.	scarlet pimpernel
**Anthoxanthum odoratum* L.	sweet vernal
Asplenium flabellifolium Cav.	
**Bromus tectorum* L.	
**Carduus nutans* L.	nodding thistle
Carmachaelia petriei Petrie	native broom
Cheilanthes humilis	
**Circisium vulgare* Sari	scotch thistle
**Dipsacus fullonum* L.	teasil
Discaria toumatou Raoul	matagouri
**Echium vulgare* L.	Viper's bugloss
Festuca novae-zealandiae Cockayne	hard tussock
**Hieracium pilosella* L.	mouse-ear hawkweed
**Hypochaeris radicata* L.	catsear
**Marrubium vulgare* L.	horehound
Muehlenbeckia complexa (A. Cunn.) Meissn.	pohuehue
Olearia odorata Petrie	native tree daisy
Oxalis exilis A. Cunn.	native oxalis
Pimelea aridula Ckn.	native daphne
Poa colensoi Hook.f.	blue tussock
Poa maniototo Petrie	desert poa
Raoulia australis Beauv.	scabweed
**Rumex acetosella* L.	sheep's sorrel
Rytidosperma gracile (Hook. f.) Connor & Edgar	
**Sedum acre* L.	stonecrop
**Thymus vulgaris* L.	thyme
**Trifolium aureum* Pollich	golden clover
**Trifolium arvense* L.	haresfoot trefoil
**Trifolium pratense* L.	red clover
**Verbascum thapsis* L.	woolly mullein
**Verbascum viragatum* Stokes	moth mullein
**Vulpia bromoides* L.	vulpia hair grass

* = exotic

TABLE 3. INSECTS FOUND AT THE LARGE *Raoulia australis* SITE ON GALLOWAY STATION.

ORDER	FAMILY	SCIENTIFIC NAME
Coleoptera	Cerambycidae	*Zorion minutum* Fabricius
	Cicindelidae	*Neocicindeia laticincta* White
	Scarabaeidae	*Costelytrea zealandica* White
	Scarabaeidae	*Prodontria modesta* Broun
	Tenebrionidae	*Mimopeus opaculus* Bates
Diptera	Agromyzidae	*Chromatomyza syngensiae* Hardy
	Calliphoridae	*Pollenia* sp.
	Calliphoridae	unnamed species
	Chironomidae	unnamed species
	Chloropidae	*Gaurex flavoapicalis* Malloch
	Chloropidae	*Gaurex neozealandica* Malloch
	Drosophilidae	*Scaptomyza flavella* Harrison
	Drosophilidae	*Scaptomyza granumum* Fallen
	Ephyridae	*Psilopa metallica* Hutton
	Mycetophilidae	11 unnamed species
	Phoridae	2 unnamed species
	Stratiomyiidae	*Neoexaireta spiniger* Wiedemann
	Syrphidae	*Allograpta pseudorapata* Miller
	Tachninidae	*Polyhystricia alcis* Walker
	Tachninidae	6 unnamed species
	Tipulidae	1 unnamed species
	Typetidae	*Tephritis thoracica* Malloch
Hymenoptera	Apidae: Apinae	**Bombus terrestris* Linnaeus
	Apidae: Colletinae	*Leioproctus monticola* Cockerell
	Ichneumonidae	*Netelia productus* Brulle
	Ichneumonidae	unnamed species
Hemiptera	Cicadidae	*Amphipsalta strepitans* Kirkaldy
	Lygaeidae	*Nysius huttoni* Buchanan-White
Lepidoptera	Crambidae	*Delogenes limodoxa* Meyrick
	Crambidae	*Eudonia submarginalis* Walker
	Crambidae	*Orocrambus ramosellus* Doubleday
	Crambidae	*Orocrambus vittellus* Doubleday
	Geometridae	*Pasiphila* n. sp.
	Geometridae	*Asaphodes abrogata* Walker
	Geometridae	*Declana junctilinea* Walker
	Geometridae	*"Hydriomena" rixata* (F & R)
	Geometridae	*"Hydriomena" deltoidata* Walker
	Lycaenidae	*Lycaena boldenarum* White
	Noctuidae	*Euxoa admirationis* Guenée
	Noctuidae	*Graphania lithias* Meyrick
	Noctuidae	*Graphania mutans* Walker
	Noctuidae	*Graphania nullifera* Walker
	Noctuidae	*Graphania plena* Walker
	Noctuidae	*Tmetolophota atristriga* Walker
	Noctuidae	*Tmetolophota propria* Walker
	Tortricidae	*Capua semiferana* Walker
	Tortricidae	*Harmologa scoliastis* Meyrick
Orthoptera	Acrididae	*Sigaus australis* Hutton
	Acrididae	*Sigaus childi* Jamieson
	Acrididae	*Phaulacridium otagoense* Ritchie & Westerman
	Stenopelmatidae	unnamed species
	Gryllidae	*Nemobius* sp.
	Tettigoniidae	*Conocephalus semivittatus* Walker
Trichoptera	Conoesucidae	*Pycnocentrodes aeris* Wise
	Conoesucidae	*Pycnocentria evecta* McLachlan
	Hydrobiosidae	*Psilochorema mataura* McFarlane
	Leptoceridae	*Hudsonema aliena* McLachlan
	Leptoceridae	*Hudsonema amabilis* McLachlan
	Leptoceridae	*Oecetis unicolor* McLachlan
	Leptoceridae	*Triplectides cephalotes* Walker
	Polycentropidae	*Polyplectropus puerilis* McLachlan
	Rhyacophilidae	*Psilochorema* sp.

* = exotic

3.7 GRASSHOPPER MONITORING

Regular grid counts of *Sigaus childi* following the method of Jamieson (1996) should be made in early autumn (late February–early March) when grasshoppers are large enough to see and the population is usually at its annual maximum. Maximum numbers were recorded at this time three years in succession (section 2). These counts should be made when the temperature is 18±1°C on a clear day, as the number of grasshoppers seen is dependent on temperature, but seems to be independent of time of day (Table 4). When repeated counts were made on the same day, numbers were highest when the temperature was close to 18°C. It is suggested that no more than two grid counts are made per day as observer concentration can be difficult to maintain. Each grasshopper disturbed needs to be clearly identified, as it is easy to confuse *S. childi* with other species. Annual counts should be carried out at the large *Raoulia australis* site on Galloway Station, Earnscleugh Historic Reserve, and at the grid site on Crawford Hills Road.

However, it should be noted that the distribution and abundance of grasshoppers on small sites contrasts with their distribution and abundance on large sites (section 3.4). Grid sampling on large sites is often difficult and time consuming because of sparsely distributed grasshopper populations and difficult terrain. If grid width is increased the monitoring method has much less power to detect significant population declines. Thomas & Abery (1995) detected greater declines of British butterflies with a 2 km grid than with a 10 km grid. Alternative monitoring methods such as 'signs of use' surveys (Kendall et al. 1992) may be more suitable for endangered populations of this type. If these were combined with presence and absence surveys (Jamieson & Manly 1997) a more complete picture of population trends may emerge. Van Strien et al. (1997) investigated the statistical power of two butterfly monitoring schemes to detect trends, and found that for species present at less than 25 sites it is most effective to increases the number of sampling sites, but for species present at more than 50 sites a further increase does not improve power. Both these methods, 'signs of use' and presence and absence, require development for use in New Zealand.

TABLE 4. NUMBER OF *Sigaus childi* RECORDED AT THE GRID SITE (CRAWFORD HILLS RD) AT DIFFERENT TIMES AND TEMPERATURES DURING THE 1996/97 SEASON.

DATE	TIME	T°C	NO. OF GRASSHOPPERS
27 September 1996	1200	17	5
	1500	14	3
	1800	15	2
3 February 1997	1115	19	10
3 March 1997	0930	10	4
	1215	15	9
	1510	18	12
2 April 1997	1615	18	10

4. Conclusions and recommendations

4.1 CONCLUSIONS

Sigaus childi remains overall a Category 'A' species (Jamieson 1996), but some subcategory ratings have changed as a consequence of research. Mean population and largest population have been scaled down as a consequence of new distribution data. Habitat loss rate, predator impact, competition and reproductive or behaviour specialist have been scaled up. Table 5 lists the categories and scores according to Molloy & Davis (1994).

The distribution and abundance of *S. minutus* has not been studied since Davis (1989). Its current conservation status can not be clearly established. Large-scale habitat changes have taken place in the Mackenzie country with changes in land use (e.g. irrigation, introduction of rabbit calicivirus), and weather patterns have been erratic with both severe droughts (summer 1997/98) and summer floods (December 1994 and December 1995). Davis observed over 481 individuals in 13 days sampling with most populations located on younger river

TABLE 5. THREATENED SPECIES STATUS OF *Sigaus childi*. (SCORES ARE GIVEN OUT OF 5; 1 IS LOW THREATENED SPECIES STATUS, 5 IS HIGH. SCORED ACCORDING TO MOLLOY & DAVIS (1994).

CATEGORY	SCORE
taxonomic distinctiveness	3
status	
number of populations	2
mean populations	4
largest population	4
geographic distribution	4
condition of largest population	4
population decline rate	4
threats	
legal protection	5
habitat loss rate	4
predator/harvest impact	2
competition	5
other factors affecting survival	1
vulnerability	
extreme habitat specificity	5
reproductive or behaviour specialist	4
cultivation/captive breeding	5
value	
Maori cultural values	1
Pakeha cultural values	1
Total	58

terraces. In his unpublished report he expressed concern about the encroachment of invasive plants on to *S. minutus* territory. When I visited some of his sites besides the Edwards Stream in February 1996, I found very few (<10 in 4 km) *S. minutus* at sites where numbers had been high (252 in 7 km). The decrease in rabbit numbers may result in even more encroachment by invasive plants. Also, in November 1996, oviposition by *S. minutus* was observed following the discovery of a mating couple (Jamieson 1998b). The female did not attempt to oviposit in the ground even though there was soft soil in the vicinity, but instead, deposited her eggs on top of the ground among small pebbles. This preference for bare stony sites for reproduction may limit this species chances for population growth.

A full survey of sites discovered by Davis (1989) of the type conducted by Jamison & Manly (1997) would clarify the conservation needs of *S. minutus*, and if this was combined with some counts, a suitable monitoring programme could be established.

4.2 RECOMMENDATIONS

1. Reserves should be established for *Sigaus childi* at the important site on Galloway Station. Possible boundaries would be the at the top of the steep slopes bordering the Manor Burn. The Earnscleugh Tailings Historic Reserve should be maintained and recognition should be made of its importance to grasshoppers (Jamieson 1998a). Both reserves should be as large as possible to maintain large sparsely distributed populations. As commented on by Jamieson (1998a), it may be necessary from time to time to provide some disturbance in the reserves so that new habitat becomes locally available. Weeding may also be necessary to control invasive plants, e.g. *Thymus vulgaris* and *Sedem acre.* Chemical control of weeds is not an option as grasshoppers are particularly sensitive to fertilisers, herbicides, insecticides and other agricultural chemicals (Heliövaara & Väisänen 1993).
2. An annual monitoring programme should be conducted as described above (section 3.7). Alternative monitoring programmes, e.g. 'signs of use' (Kendall et al. 1992) survey methods, may be more suitable for monitoring the large reserves in the future, but their sensitivity to population changes needs to be established for grasshoppers. Also, it would be useful to document local population extinctions by carrying out an annual presence and absence survey of *S. childi* populations at sites identified by Jamieson & Manly (1997). All surveys should be conducted in the autumn as described above.
3. A statistically valid habitat survey and monitoring programme should be conducted for *S. minutus* in the Mackenzie Country. 'Signs of use' survey methods are probably most suitable for this species, as populations are widespread and patchy, and previous data (Davis 1989) is of this type.

5. Acknowledgements

I would like to thank the Department of Conservation for funding this project and for logistic support provided by the Dunedin and Alexandra offices of the Otago Conservancy. The following people are thanked for their assistance in identification of specimens: Brian Patrick (Lepidoptera and plants), Anthony Harris (various insects, particularly Hymenoptera), John Ward (Tricoptera) and Roy Harrison (Diptera) My thanks also to Bryan Manly for his support and encouragement, and comments on the manuscript. My daughter Dusk is thanked for her patience and support.

6. References

Bigelow, R.S. 1967. The grasshoppers (Acrididae) of New Zealand. Their taxonomy and distribution. *University of Canterbury Publications: No. 9.* 109 p.

Burnett, U.F. 1951. Observations on the life history of the Red Locust *Nomadacris septemfasciata* (Serv.) in the solitary phase. *Bulletin of Entomological Research 42*: 473–490.

Davis, C.M. 1989. A survey of *Sigaus minutus* . Report No. 252. Department of lands and Survey, Christchurch. 20 p.

De Vries, H.H.; den Boer, P.J. 1990. Survival of populations of *Agonum ericeti* Panz. (Col., Carabidae) in relation to fragmentation of habitats. *Netherlands Journal of Zoology 40*: 484–498.

Heliövaara, K.; Väisänen, R. 1993. Insects and Pollution. CRC Press, Boca Raton, FLA. 393 p.

Hudson, L. 1970. Identification of the immature stages of New Zealand alpine acridid grasshoppers (Orthoptera). *Transactions of the Royal Society of New Zealand 12*: 185–205.

Jamieson, C.D. 1996. The grasshopper *Sigaus minutus* in Central Otago: a pilot study. *Science for Conservation: 42.* Department of Conservation, Wellington. 21 p.

Jamieson, C.D. 1998a. Distribution of the endangered grasshopper *Sigaus childi* on the Earnscleugh tailings Historic Reserve. *CAS Notes 178.* Department of Conservation, Wellington.

Jamieson, C.D. 1998b. A brief description of oviposition behaviour in the grasshopper *Sigaus minutus* Bigelow (Orthoptera: Acrididae). *New Zealand Entomologist 21*: 73–74.

Jamieson, C.D. 1999. A new species of *Sigaus* from Alexandra, New Zealand (Orthoptera: Acrididae) *New Zealand Journal of Zoology 26*: 43–48.

Jamieson, C.D.; Manly, B.F.J. 1997. A statistical analysis of the habitat requirements of the grasshopper *Sigaus sp.* (Orthoptera: Acrididae). *New Zealand Entomologist 20*: 61–66.

Kendall, K.C.; Metzgar, L.H.; Patterson, D.A.; Steele, B.M. 1992. Power of sign surveys to monitor population trends. *Ecological Applications 2*: 422–430.

Molloy, J.; Davis, A. 1994. Setting priorities for the conservation of New Zealand's threatened plants and animals. (2nd ed.) Department of Conservation, Wellington. 64 p.

Patrick, B.H. 1994. Valley floor Lepidoptera of Central Otago. *Otago Conservancy Miscellaneous Series No 19*. Department of Conservation, Dunedin. 54 p.

Thomas, C.D.; Abery, J.C.G. 1995. Estimating rates of butterfly decline from distribution maps: the effect of scale. *Biological Conservation 73*: 59–65.

Uvarov, B. 1966. Grasshoppers and Locusts. A Handbook of General Acridology. vol.1. Centre for Overseas Pest Research, Cambridge University Press, London. 481 p.

Uvarov, B. 1977. Grasshoppers and Locusts. A Handbook of General Acridology. vol. 2. Centre for Overseas Pest Research, Cambridge University Press, London. 613 p.

Van Strien, A.J.; Van De Pavert, R.; Moss, D.; Yates, T.J.; Van Swaay, C.A.M.; Vos, P. 1997. The statistical power of two butterfly monitoring schemes to detect trends. *Journal of Applied Ecology 34*: 17–28.

Continue to next file: Sfc110a.pdf