The grasshopper *Sigaus minutus* in Central Otago: a pilot study

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Abstract

The distribution, abundance and ecology of the endangered grasshopper, *S. minutus*, has been studied in Central Otago. The grasshopper is restricted to remnant patches of mostly native habitat, dominated by the plant *Raoulia australis*. The populations are very isolated and gene flow is unlikely. Fewer than 100 individuals were seen during the study.

Faecal pellet analysis indicated that *S. minutus* is not dependent on *R. australis* for food. It is suggested that *S. minutus* may need *R. australis* for oviposition and/or hibernation. A one-year life cycle with long-lived individuals reproducing a second time is proposed.

An assessment of the threatened species status of *S. minutus* places it in A, the highest category.

1. Introduction

The small rugose grasshopper *Sigaus minutus* is an endangered species endemic to New Zealand. Bigelow (1967) described six species in this genus of which *Sigaus minutus* is the smallest. He suggests their closest relative is the Tasmanian genus *Russalpia*. They belong to the family Acrididae (short-horned grasshoppers) in which the antennae are of similar length to the face.

Two colour morphs of *S. minutus* are found in Central Otago. The most common form is a dull brown with varying darker patterns similar to the local schist, the other is a bright yellow-green, richly patterned morph which matches exactly with the tumbling lichen *Chondropsis viridis*. The grasshopper can easily be recognised in the field from the sinuate caudal margin of the pronotum (Fig. 1, see page 19).

S. minutus appears to be confined to the Manorburn Ecological District in Central Otago which has as its boundaries on two sides the Clutha and the Manuherikia Rivers. Topographically, the district consists of gently rolling uplands with several distinct ridges rising to 1100 metres a.s.l. It is mostly schist with a semi arid climate. Soils are of variable thickness, and show a leaching sequence with altitude and rainfall (Ecological Regions and Districts of New Zealand, Sheet 4, Department of Lands and Survey). The vegetation is a mixture of native and exotic plant species; with introduced pasture and weeds, tussock, invasive plants such as *Thymus vulgaris, Rosa rubiginosa, Sedem acre* and *Hieracium pilosella*, or rocks and cushion plants (particularly *Raoulia australis*).

The Central Otago populations of *S. minutus* have not been surveyed before. Hudson (1970) had difficulty in finding sufficient specimens for his study on the immature stages of New Zealand's alpine grasshoppers. Child collected *S. minutus* from Graveyard Gully near Alexandra in 1967 (Bigelow 1967). This site is now infested with *T. vulgaris*, which is unsuitable for *S. minutus*. Brian Patrick (pers. comm.) has collected *S. minutus* from mine tailings associated with the Manuherikia River and from pastoral lease land close to Alexandra. DoC Otago has listed it as a threatened species in Otago.

Davis (1989) surveyed the Mackenzie Country populations. He found that *S. minutus* was associated with younger river terraces which contained "a higher proportion of native plant ground cover, including lichens, mosses, cushion and mat species, herbs and grasses". Bare ground on these terraces consists of gravel and stones of varying sizes. Davis commented that in some areas this habitat type is apparently being reduced through the invasion of introduced plants. In his study, 481 specimens of *S. minutus* were positively identified; in my study, fewer than 100 specimens were seen.

The objectives of my study were:

1. To map the distribution of *S. minutus* in Central Otago and establish the presence of juveniles.
2. To determine the abundance of *S. minutus* and to establish its feeding preferences.
3. To identify the immature stages of *S. minutus*.

2. Methods

2.1 DISTRIBUTION

To study the distribution of *S. minutus* in Central Otago, I carried out foot surveys of parts of Galloway Station, Alexandra, during the summer of 1994–95. Surveys were also made of likely sites on the other side of the Clutha River, the true right, later in the season. In addition, a survey of the riverside slopes of the Clutha River from Alexandra to Roxburgh was made. Any populations of *S. minutus* found were marked on a map. However, it soon became obvious that a more direct method was necessary, as very few, very small, populations were found, and the territory covered was insignificant in relation to the size of the territory remaining. Subsequently, habitat features were recorded at 40 sites, with and without grasshoppers, and the results were analysed with a logistic regression using the programme "solo" (Jamieson and Manly, in press), as it was not immediately obvious what factors were restricting the grasshoppers' distribution.

2.2 ABUNDANCE

To study the abundance of *S. minutus* in an area where they occur, a 30 m by 30 m grid was established on top of a ridge and used for a mark-recapture study. The study site was located on DoC-managed land on Crawford Hills Rd, Alexandra, adjacent to and continuous with the property known as "The Crawfords" (Fig. 2). The site is the flat top of a north facing ridge in an exposed

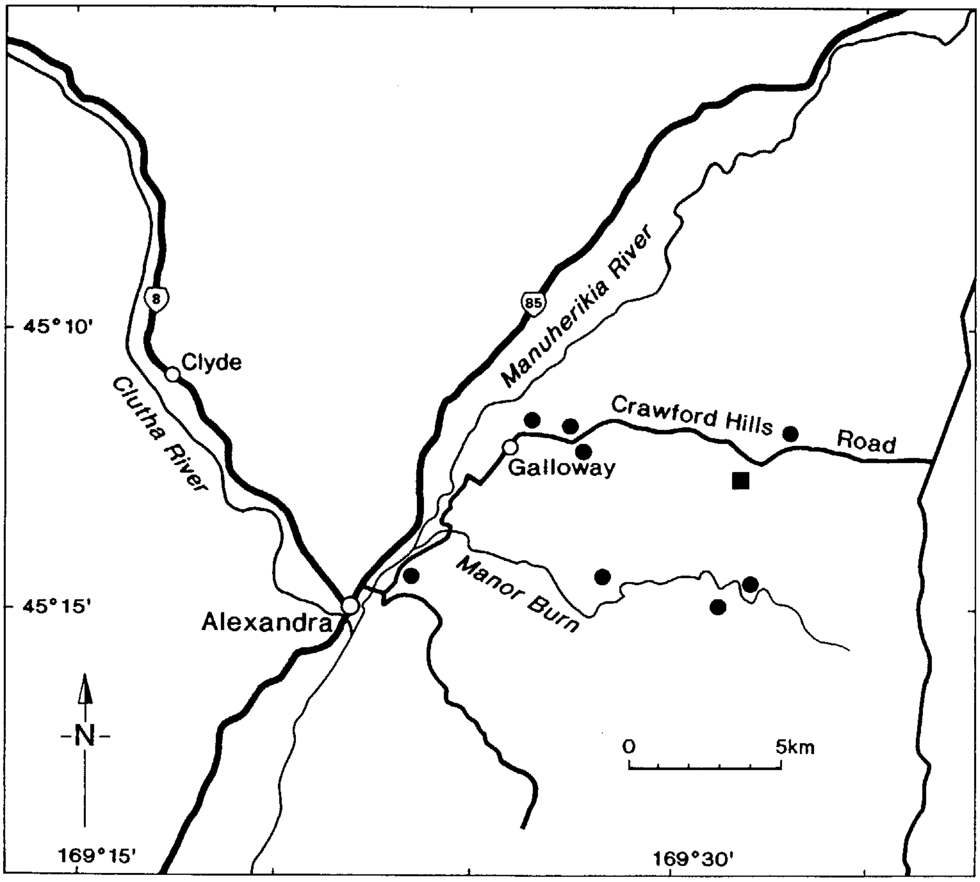

FIGURE 2. DISTRIBUTION MAP OF *S. minutus* (●) IN CENTRAL OTAGO. ■ = GRID SITE FOR MARK-RECAPTURE STUDY.

position (Fig. 3, see page 19). Currently, approximately 100 m south-east of the site, a quarrying operation is in progress where most of the Otago schist that is used for housing development in the area is obtained. The site is infrequently grazed as part of "The Crawfords" and rabbits abound in the vicinity.

The soil is thin on the ridge top and the ground is largely covered with small broken pieces of schist, larger rocks, and *R. australis.* The area has a succession of both native and exotic annuals during spring and early summer, but, by the middle of summer, there is very little green vegetation apart from *R. australis* and the small plants that colonise it.

The grid was systematically sampled by slowly walking into the sun (to avoid shadowing) at 0.75 m intervals (White 1994). Any grasshopper disturbed was caught and the grid reference noted. A small, brown, photocopied number was attached with superglue to the pronotum. The grasshopper was then placed in an aerated container for up to two hours in shaded conditions. The faecal pellets produced during this interval were collected and preserved in 80% glycerine/alcohol mixture. The grasshopper was then released at the same grid reference at which they were caught.

2.3 VEGETATION ANALYSIS

A vegetation analysis was undertaken by the author and Dr Ann Chapman on 16/1/95 at the grid site. 30 one-metre square sites were selected randomly using random number tables, and percentage ground cover was estimated by eye or individual plants were counted.

2.4 FAECAL PELLET ANALYSES

S. minutus faecal pellets were collected as described above in 2.2. The plant cuticle fragments from the pellets were teased apart with fine dissecting pins in a few drops of commercial bleach. The fragments were spread over the whole slide and scanned systematically. The pattern on the cuticle fragments from epidermal cell shape and distribution, hairs, spicules, and gland cells was compared to scanning electron micrographs made of plants found in the study area and thus were identified. Percentage composition of each plant species found in faecal pellets was recorded.

2.5 IDENTIFICATION OF IMMATURE STAGE OF *S. minutus* AND LIFE CYCLE

Observations and measurements were made of juvenile *S. minutus* in the field. They were not handled or killed for close inspection with a hand lens or microscope as populations were considered to be too vulnerable. A life cycle is proposed based on observations throughout the season.

2.6 BEHAVIOUR

Grasshopper behaviour was routinely observed in the field as they are relatively slow moving and can be followed around with ease.

3. Results and discussion

3.1 DISTRIBUTION

Populations of *S. minutus* that were found are shown on Fig. 2. The populations shown do not include every possible population of *S. minutus* in the area, as it was impossible in the time available for this study to examine every square metre of ground. However, as most of the land is in pasture, any populations missed are likely to be small and isolated.

One large site containing *S. minutus* was found at the back of Galloway Station. This site is extensive (>1 km^2) and consists of *R. australis* on steep stony hillsides. The native vegetation has been retained by the station owner because the land is too steep to establish pasture (pers. comm. Andrew Preston, Galloway Station). *S. minutus* was found to be widespread in this area, but it still needs to be fully surveyed. All other sites containing grasshoppers were small e.g., ranging from 4.5 to approximately 200 square metres in size. During the survey I found that as soon as the vegetation changed from *R. australis* to either pasture, tussock, thyme, or stonecrop, no *S. minutus* were found. If the vegetation was tussock, the grasshopper *Sigaus australis* was found. Essentially, *S minutus* grasshoppers are marooned on *R. australis* islands within pasture. Sites are kilometres apart and gene flow is unlikely. No *S. minutus* were found on the other (true right) side of the Clutha River.

Generally, the grasshoppers are sparsely distributed (about 1 to 40 square metres), with one exception: the smallest site at the intersection of Crawford Hills Rd and Galloway Rd. Ten adult and juvenile grasshoppers were crowded onto a two metre square site in autumn 1995. This was very unusual when compared to other sites, and it was probable that it resulted from recent breeding on a very small site with no migration into the surrounding pasture, even though the "island" was crowded. It is unlikely that the high number was due to immigration, as there were no other populations nearby.

Regression of presence-absence data of habitat features (Jamieson and Manly (in press)) showed that the presence of the plant *R. australis* is significant in the habitat of *S. minutus*, as are small native plants. If *R. australis* was present, the probability of finding the grasshopper was 0.44. However, if small native plants were also present, the estimated probability rose to 1. If neither of these two factors were present, the grasshopper was not found (Table 1). Two other factors were also very important in the regression: greater than 50% bare ground and an exposed site. Patrick (1994) has also found that bare ground is extremely important for Central Otago lepidopteran species. I suspect that the exposed site requirement is necessary to avoid the extremes of heat found in small Central Otago gullies where temperatures can rise to at least 40°C.

TABLE 1. PROBABILITIES OF FINDING *S. minutus* WHEN TWO SIGNIFICANT HABITAT FEATURES ARE PRESENT (+) OR ABSENT (-), (JAMIESON AND MANLY, IN PRESS).

		endemic herbs	
		-	+
R. australis	-	0.00	0.00
	+	0.44	1.00

It was also noted that at sites with a range of farming methods (irrigated and unirrigated pasture, orcharding, and remnant vegetation), no grasshoppers were found unless *R. australis* was present. An early paper by McIndoe (1932) suggests that most of the Central Otago arid regions were covered with *R. australis* which has since been ploughed in and/or over-sown with pasture species (pers. comm. Richard Stephen, Olrig Station).

The distribution of *S. minutus* is consistent with a hypothesis of remnant *S. minutus* populations surviving on remnant patches of habitat. Preliminary discussions with farmers in the area indicate that there are very few *R. australis* patches left. Thus, the possibility of finding other large populations is slim.

3.2 ABUNDANCE

In total, nineteen adult *S minutus* grasshoppers were marked during the spring period from 1/11/94 to 22/12/94. However, by 5/1/95, no *S. minutus* were found at the grid site, which was now over-run with the smaller grasshopper *Phaulacridium otagoense*. The first *P. otagoense* was seen at the grid site on 11/12/94, and their numbers then steadily increased. Positive identification of *S. minutus* juveniles was not made at the site until 1/3/95, although early in January 1995, one juvenile grasshopper was seen just off site. The high numbers of *P. otagoense*, when compared to *S. minutus* on site, made it difficult to positively identify *S. minutus*. After the adult grasshoppers disappeared from the site, I stopped handling *S. minutus* at all sites for fear of lowering their chances of survival. It should be noted that adult grasshoppers were still present at other sites throughout the season. It is possible that the brown, photocopied numbers glued to the grasshoppers at the study site made them more readily seen by predators and therefore more vulnerable to predation.

Results from the mark-recapture work are shown at Table 2. Because of the scarcity of data, it cannot be statistically analysed. Initially, the capture rate appeared to be constant, but then it decreased rapidly. However, from the basic mark-recapture calculation for each sampling date:

$$\frac{\text{total in 1st sample} \times \text{total in second sample}}{\text{number of marked animals recaptured}}$$

the population estimates are surprisingly consistent. Also, the mean estimate ($x=21\pm4$) comes close to the total number marked (n=19). The only *S. minutus* found on the last sampling day before they disappeared were previously marked individuals.

Considering the situation that developed and the behaviour of the grasshoppers (see section 3.3 for a full description), the use of a closed population model formula does not seem unrealistic. *S. minutus* is surprisingly immobile and there would be very little immigration or emigration on or off the site. Also, recruitment of juveniles to the adult population was negligible, as only adults were marked and juveniles were not present at the site at this time. The capture rate decreased with time which is consistent with their disappearance.

TABLE 2. RESULTS FROM MARK-RECAPTURE STUDY WITH POPULATION ESTIMATES.

	SAMPLING DAY				
	1/11	18/11	2/12	11/12	22/12
Total in sample	9	9	4	4	2
Number marked	9	5	1	3	0
Number recaptured		3	3	1	2
Population estimate		27	19	20	18

3.3 GRASSHOPPER MOBILITY

Consecutive records for two grasshoppers are plotted on the grid (Fig. 4). Unfortunately, good location records were not kept on the first two sampling occasions for all individuals. Better records were kept after it became obvious that the grasshoppers were remarkably immobile and usually stayed in a localised area if not disturbed. When they do move, grasshoppers usually leap about 0.5 m. The average displacement per week (from capture records) was only 2 metres. Later, I was regularly able to locate specific individuals at particular sites months apart, especially when the sites were not prone to human or large animal disturbance.

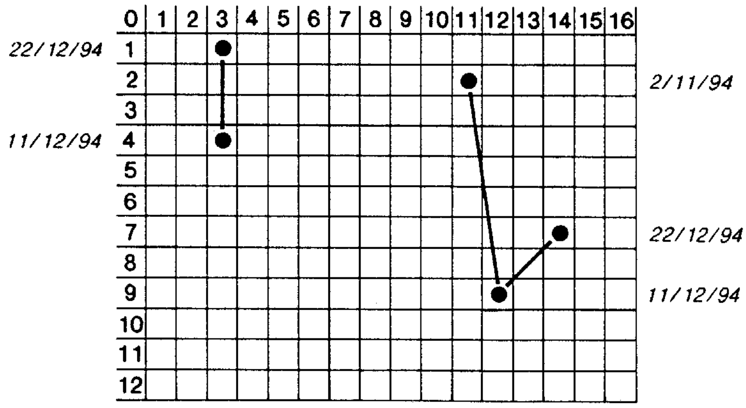

FIGURE 4. DISPLACEMENT OF TWO GRASSHOPPERS WITH TIME ON GRID SITE. CAPTURE DATES BESIDE GRID.

3.4 VEGETATION ANALYSIS

The most common category of the vegetation analysis at the grid site was bare ground (average 71%) (Table 3). This was a common feature of all sites (see section 3.1) and its importance to grasshoppers should not be under-estimated. *R. australis* covered more ground (9.3%, living and dead) than other species (Fig. 5, see page 21). A number of plants colonised the *R. australis* cushions e.g., *Poa colensoi.* The tumbling lichen *Chondropsis viridis* was a significant feature of the ground cover. In spring, *Rumex acetosella* plants were numerous, averaging 57.4 per square metre, and were found in every quadrat. *Trifolium arvense* was also found in most quadrats. *Hypochaeris radicata* and *Poa colensoi* were both found in half the quadrats. *Rytidosperma maculatum,* when present (in one third of the quadrats), covered a significant proportion of the ground (13.3%).

It is evident that this type of habitat is under threat in the Alexandra area from:

1. Lack of recognition of its importance as part of an ecosystem.
2. Conversion to pasture with or without irrigation.
3. Invasion by plant species such as *Thymus vulgaris, Sedem acre,* and *Hieraceum pilosella,* which blanket any available bare ground.

TABLE 3. COMPOSITION OF AN "AVERAGE QUADRAT" AND THE TOTAL NUMBER OF QUADRATS WHERE A PLANT SPECIES FOUND AT THE GRID SITE, CRAWFORD HILLS RD. FOR PLANT SPECIES WHICH WERE DIFFICULT TO COUNT PERCENTAGE COVER IS GIVEN, OTHERWISE, THE NUMBER OF PLANTS IN THE QUADRAT IS SHOWN. THE PERCENTAGE BARE GROUND OF AN AVERAGE QUADRAT IS INCLUDED. SEE TEXT FOR DETAILS.

PLANT SPECIES	% COVER	NO. PLANTS	NO. QUADRATS
bare ground	71.0		30
living *Raoulia australis*	6.8		14
dead *Raoulia australis*	2.5		6
Chondropsis viridis	5.1		18
Carex brevicularis	1.0		5
Rytidosperma maculatum	4.0		9
Rumex acetosella		57.4	30
Trifolium arvense		6.2	26
Poa colensoi		8.9	15
Bromus tectorum		2.2	10
Hypochaeris radicata		2.0	15
Anthoxanthum odorata		0.2	4
Echium vulgare		0.1	4
Gypsophila australis		0.2	4
Leucopogon mucosus		1.6	1
Veronica verna		0.3	3

3.5 FAECAL PELLET ANALYSIS

Fifteen different species of native and introduced plants were identified from *S. minutus* faecal pellets between 1/11/94 and 22/12/94 (Table 4). Each faecal pellet usually contained only one plant species and often all the faecal pellets produced by an individual contained the same plant species. The composition of faecal pellets collected on the same day was usually similar. The contents of the faecal pellets tended to shift with time to different plant species, presumably reflecting plant availability and/or palatability as the seasons change. Polyphagy is common among grasshopper species (White 1974a). Plants with softer leaves e.g., *Rumex acetosella, Echium vulgare*, were eaten more frequently than other species. *Carex brevicularis* and barley grass, *Hordeum murinum*, were the most common grasses eaten. Plants were not

TABLE 4. PERCENTAGE COMPOSITION OF *S. minutus* FAECAL PELLETS (N=50).

PLANT SPECIES	%
Echium vulgare	25.2
Carex brevicularis	16.1
Rumex acetosella	14.3
Hordeum murinum	14.2
Trifolium arvense	9.2
Poa colensoi	4.2
Raoulia australis	3.8
Verbascum viragatum	3.8
Airo carophylla	2.3
Veronica arvensis	1.9
Crepis capillaris	0.5
Taxicum officianale	0.4

eaten in proportion to their abundance in the habitat. Rabbits abound in all areas and no doubt compete with grasshoppers for the more palatable plant species.

3.6 IDENTIFICATION OF IMMATURE STAGES AND LIFE CYCLE

Except for their size, *S. minutus* juveniles appear the same as adult *S. minutus*, and can be differentiated from other grasshoppers by identifying the sinuate lower edge of the pronotum (Fig. 6). Field measurements of juveniles and adults, from head to abdomen, are shown in Table 5. Females are typically larger than males and there appears to be the usual 5 or 6 instars found in other New Zealand short horned grasshoppers (White 1994, Hudson 1970). Juvenile instars are postulated on the basis of field measurements of which there are very few. No attempt was made to differentiate between male and female juveniles, but it is likely that female juveniles will be larger than male juveniles at the same stage, particularly in the latter stages (Hudson 1970). More data is needed to confirm these speculations.

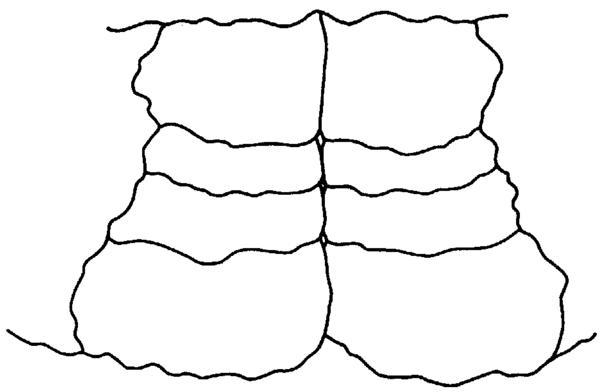

FIGURE 6. SHAPE OF PRONOTUM OF JUVENILE AND ADULT *S. minutus*.

The average body length of the Central Otago adult female *S. minutus* recorded in this survey is significantly larger than those recorded in a study of the Mackenzie Country population (18 mm this study, Mackenzie Country 14.4 mm (Bigelow 1967)). Although size is probably determined to a certain degree by food and/or temperature, this significant divergence may indicate separate species status. Bigelow (1967) comments on the likelihood of evolutionary divergence among the alpine grasshoppers in New Zealand as a result of restricted or lack of gene flow between isolated populations. Distributions of species from other genuses e.g., *Prodontia* (Emerson 1985), and among the Lepidoptera (Patrick 1994), suggest that this could be expected.

Work on the life cycle of *S. minutus is* incomplete and requires further observations over consecutive years. To date in this study, the only individuals found initially in spring were adults. Small juveniles were not found until January, 1995. However, in November 1992, 1 saw about eight very small juveniles close together on top of a *R. australis* cushion. White (1974b)

TABLE 5. FIELD MEASUREMENTS (mm) OF *S. minutus* (HEAD TO ABDOMEN). MALE AND FEMALE JUVENILE STAGES ARE NOT SEPARATED AND STAGE IDENTIFICATION IS SPECULATIVE.

STAGE	LENGTH (mm)	N
females	18	7
males	12	8
juvenile stages		
I	5	1
II	8	1
III	10	5
IV	12	3
V	15	1

suggests this type of observation is consistent with the juveniles just hatching from an egg pod. Brian Patrick (pers. comm.) found adults during September of 1992 (an early season). These observations suggest that a two month period elapses between the emergence of adults from hibernation and the hatching of juveniles from eggs. A long diapause period for eggs would help to ensure the survival of juveniles in an unpredictable climate. Central Otago often has sudden cold snaps in spring and early summer.

In autumn, with cooler temperatures, adults gradually disappeared, but not juveniles. Also, old adults (recognisable by lost limbs and a generally worn appearance) were seen among the newly matured adults at this time. On two occasions, two grasshoppers were seen leaping in different directions from a common starting point, which may indicate mating. This was not observed during the rest of the season when grasshoppers were usually solitary. Surprisingly, large juveniles were found at much lower temperatures (e.g., 10°C) than they were in the spring (usually >16°C). No old adults were seen in the spring.

From these data I postulate the following life cycle: overwintering as eggs and adults, with emergence of new adults from the previous autumn in early spring. Later in the season: hatching of both overwintering eggs and spring eggs, followed by development of juveniles throughout the summer and autumn, with obligatory adulthood before hibernation. Mating and oviposition would take place in the autumn, by both recently developed adults and those adults that survived from the beginning of the season.

3.7 GRASSHOPPER BEHAVIOUR

S. minutus grasshoppers are very immobile and if approached slowly will remain stationary. When disturbed by rapid movements, the *S. minutus* I observed always took one hop and then remained motionless, relying on their cryptic colouring for camouflage. If pursued, a grasshopper usually took a series of hops. Hops were short — 30 to 40 cm — and low to the ground (height 15 cm). *S. minutus* is a lumbering grasshopper, slow and heavy in the air, when compared to other grasshopper species.

I once observed an encounter between an individual *S. minutus* grasshopper and a skink. The quick dart of the skink was responded to very quickly by the grasshopper, which escaped. As skinks are numerous in the area, I suspect they are the grasshoppers' main predator. *S. minutus* are prone to losing legs and were often found in the field minus a back leg or two. The ability to lose legs may be an advantage when escaping skinks.

Observations made on individual grasshoppers indicated a lack of significant movement regardless of weather conditions. They spent considerable time sunning themselves from a variety of angles, scratching their heads with their back legs, crawling over stones, nibbling on vegetation, and occasionally making very short (10 cm) hops.

4. Conclusions and recommendations

4.1 CONCLUSIONS

The numbers of *Sigaus minutus* in Central Otago are extremely low. Fewer than 100 individuals (adults and juveniles) were seen during the present study. The main cause of low numbers would appear to be lack of habitat. They are restricted to remnant areas of native habitat dominated by the plant *R. australis* and with large patches of bare ground. *R. australis* did not form a significant part of the grasshoppers' diet, but may be important for hibernation and/or oviposition, as the ground is very stony. *R. australis* has an important role in the ecosystem. It can withstand very dry conditions (its roots go down approximately 2 m (McIndoe 1932) and has the ability to tolerate thin soils and stabilise eroding hillsides. Many small plants colonise old and new regions of *R. australis* cushions and provide alternative food sources for the grasshoppers. Only a few patches of this native *R. australis* habitat remain in the area, as most of it has been converted to farmland. Those sites remaining are usually small (<0.25 ha, except the large Galloway station site) and are bounded by pasture. I suspect the importance of this type of habitat has been undervalued in the past and there is definitely a need for more research to establish its importance in the lives of invertebrates in Central Otago.

The sizes of populations in this study also give cause for concern. None of the populations located appear to exceed 50 (adults and juveniles). The mark-recapture work suggests that, on an average sampling day, an observer could expect to see half of the resident population at a particular site. The maximum number seen at one site on any single sampling occasion was 10 (adults and juveniles).

A preliminary assessment of the threatened species status of *S. minutus* in Central Otago, presuming it is a separate species from the Mackenzie Country population, gives it a score of 56 (Table 6) (Department of Conservation 1994), which would place it among the highest priority threatened species — category A.

TABLE 6. THREATENED SPECIES STATUS OF *Sigaus minutus*. (SCORES ARE GIVEN OUT OF 5; 1 IS LOW THREATENED SPECIES STATUS, 5 IS HIGH. SCORED ACCORDING TO DEPARTMENT OF CONSERVATION, 1994.

CATEGORY	SCORE
Taxonomic distinctiveness	3
Status	
number of populations	2
mean population	5
largest population	5
geographic distribution	4
condition of largest population	4
population decline rate	4
Threats	
legal protection	5
habitat loss rate	3
predator/harvest impact	1
competition	4
other factors affecting survival	1
Vulnerability	
extreme habitat specificity	5
reproductive or behaviour specialist	3
cultivation/captive breeding	5
Values	
Maori cultural values	1
Pakeha cultural values	1
TOTAL	56

4.2 RECOMMENDATIONS

1. Consideration should be given to establishing a reserve for *S. minutus*. *S. minutus* is not found on Flat Top Hill, the nearest DoC reserve, which is on the other side of the Clutha River. The large site on Galloway Station, which is at present leasehold land and will come under tender review when the land is either sold to the station owner or retained for conservation purposes, looks the most promising. Management of this one large site would be a lot easier than the management of a number of small *R. australis* islands within pasture. The importance of bare ground is emphasised and, if a reserve were to be established, measures may need to be taken to prevent the spread of *T. vulgaris* and *S. acre*.
2. Further research is necessary:
    - To establish the importance of *R. australis* in the life of *S. minutus*.
    - To discover whether there are other significant *Raoulia* areas. This would involve interviews with farmers and the use of four wheel drive vehicles to get to more remote areas.
    - To make a comparison of the Mackenzie Country and Central Otago populations to determine their species status.
    - To validate the postulated life cycle. This would involve observations over consecutive years.
    - To establish a simple method for monitoring the population which can be used by field officers.

5. Acknowledgements

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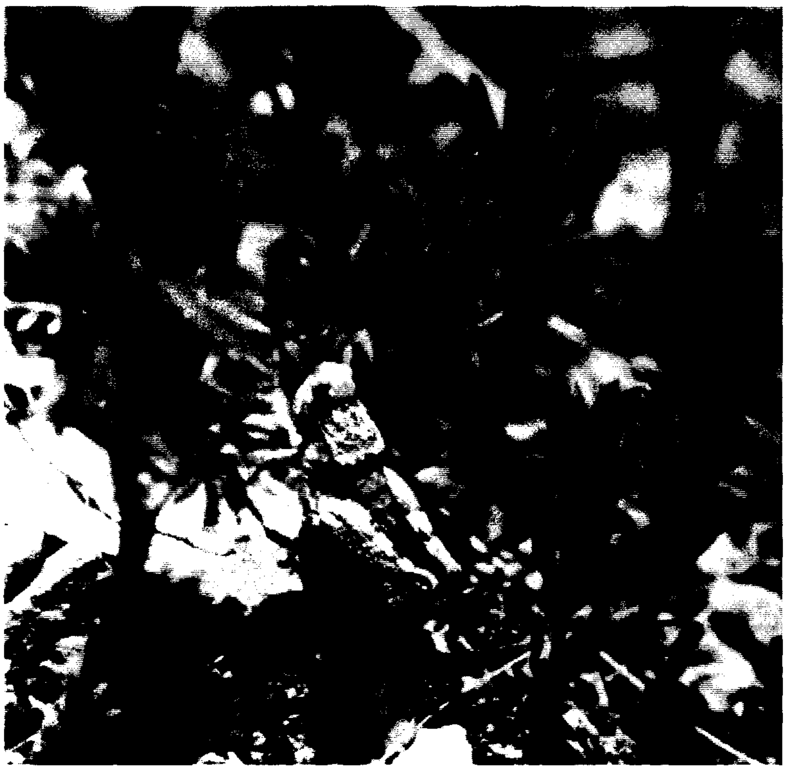

Figure 1. ***S. mlnutus*** **showing cryptic colouring.The sinuate edge to the pronotum is easily identified in the field.**

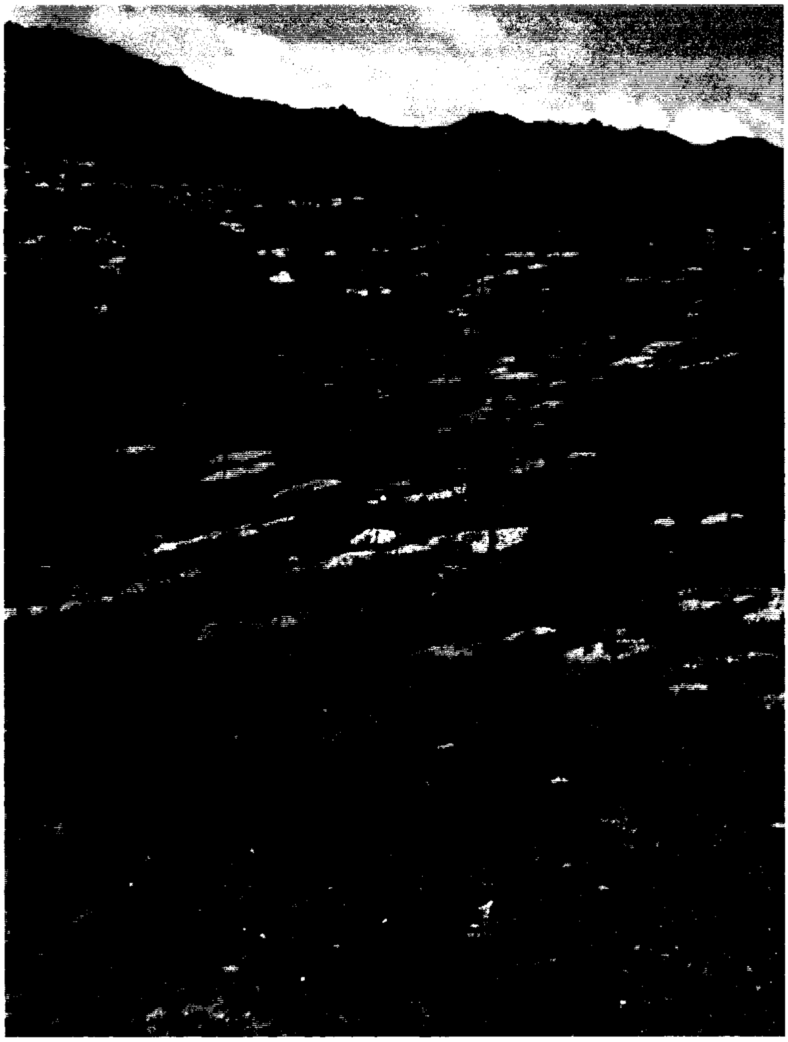

Figure 3. Grid site. The grid was marked with piles of stones which are visible in the centre of the photo.

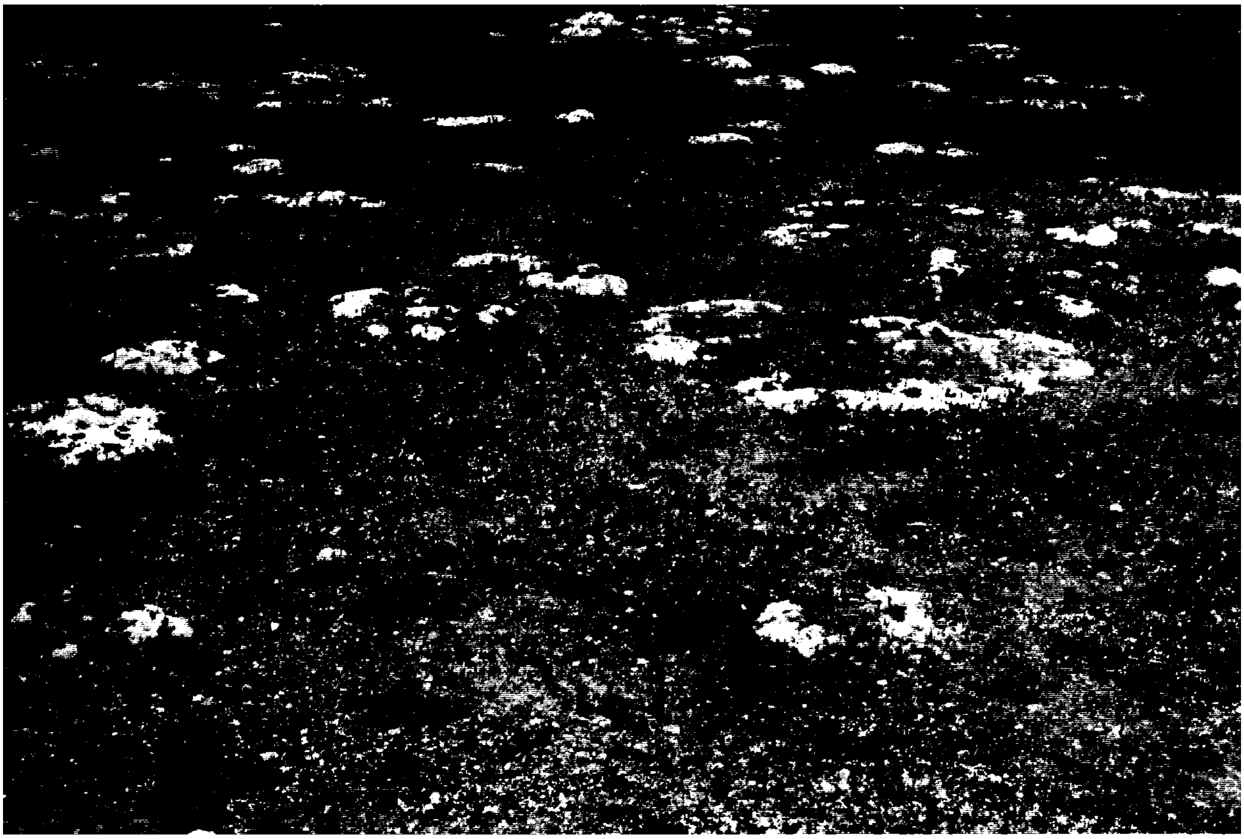

Figure 5. Typical *S. minutus* habitat showing dominance of Raoulia and bare ground.