



Figure 5 Vertical air photograph of Snow River and outwash fan showing locations of *Brachaspis robustus* observations (•) and monitoring site (outlined at centre right). The dark areas of ridge-and-channel formations support distinctive plant associations and the length of the primary vegetation band exceeds 2 km (top right to bottom left). As few sampling transects extended to the right of the diagonal track (top centre to bottom right, Haywards transmission line, ECNZ), *B. robustus* sightings are presumably under-represented in the upper areas of outwash. There was no sampling of areas to the immediate lower left of the river channel. The Haldon road is at bottom left and the old Hakataramea Pass road at top left.

**Table 3** Percent composition of *Brachaspis robustus* diets according to major plant groupings. Percentages are weighted by the approximated number of grasshoppers (N) that voided faeces in jars containing more than one individual (not all individuals voided during captivity).

Diet	Adult female N=9	Adult male N=12	Juveniles N=9	Total N=30
Grasses	8	20	12	<b>14</b>
Herbs (and shrubs?)	65	55	3	<b>63</b>
Mosses	4	3	8	<b>5</b>
Lichens	12	4	5	<b>7</b>
Unidentified (mostly herbs, unless shrubs?)	11	18	1	<b>11</b>

### 3.5 Life cycle and ecology

A range of observations and measures helped to build up a partial understanding of the species' natural history.

**3.5.1 Field recognition of *Brachaspis robustus*** The species can be distinguished from all other grasshoppers by the shape and surface of the pronotum (the body covering immediately behind the head). It has the following characters:

- The upper surface is distinctly broader than long (in *no other* New Zealand grasshopper is this area broader than long)
- The upper surface is rounded towards the sides (it does *not* meet the sides at a distinctive corner angle)
- The surface is notably irregular ('rugose'), especially in older growth stages (it is *not* smooth)
- The hind margin is more or less straight from the centre towards the sides (it is *not* wavy)

The essential character is the first one, and correct identity can be double-checked by the combination of the other three. By themselves, the three double-checking characters do *not* identify the species, as some other grasshoppers may share these.

**3.5.2 Field recognition of growth stages** To distinguish growth stages, it is necessary to observe three sets of characters:

- The two body covering segments that lie immediately behind the pronotum described above (but note that the first is often totally hidden *under* the pronotum)

- The underside egg-guides ('valves') towards the tip of the female abdomen
- The underside segments towards the tip of the male abdomen

Field examinations of these characters by hand lens provided a partial description of stages, presented as field sketches (Appendix 3). The separation of very small growth stages was problematic, especially in males, and the number of growth stages in a full life cycle remains unclear. The sketches can be related to the growth stage diagrams of Hudson 1970 for other grasshopper species, and the variation observed in some instars is shown by observation sample sizes (N) listed in Appendix 3. Occasional individuals with 'deviant' characters (not illustrated) have also been observed.

Hudson 1970 has shown that female short-horned grasshoppers pass through one more growth stage than males and characteristically grow to a much larger body size. In *B. robustus*, this sexual dichotomy is extreme by the adult stage, as shown by the following liveweight records of collected growth stages (see section 2.6):

Instar	Female:	Male:
<b>3'A'</b>	0.07 g	no record
<b>3'B'</b>	0.09 g	<b>non-existent</b>
<b>4</b>	0.11 g	0.06 g
<b>Adult</b>	1.42 g	(x2) 0.25, 0.26 g

The adult female (unexpectedly trapped in a pitfall on a Tekapo River terrace, see Appendix 1.) was not a large individual, yet demonstrates that the female reaches a body weight at least five times that of the male. It remains uncertain whether one extra growth stage in females (instar 3'B') is sufficient to account for the eventual differences in size and weight, and the variable traits listed in Appendix 3 may be of future help in clarifying the development sequences of the sexes. The uncertainties all relate to those life stages in the middle of each sequence ('3rd' and '4th' instars), and the tentative numbering assumes only one more growth stage in females than in males. There is never confusion with the final two juvenile instars ('penultimate' and 'final' instars) which are characterised by the development of vestigial wing coverings and wings from the two segments behind the pronotum.

**3.5.3 Life cycle** The sequence of the growth stages throughout the year is shown in Table 4, based on the monthly study record of monitoring site individuals identified to growth stage. The total records (806 observations) include marked and non-marked individuals, and supplementary records are from the reconnaissance data and Mark Davis, pers. comm. A double-counting of individuals in successive months is not problematic in growth stage analysis as each individual was observable only once in any month.

The spread of months shown for 4th-final instar juveniles suggests a surprising lack of synchronisation, yet also confers adaptive advantage in species survival against predation (section 3.6) and drought (section 3.7). It may even be that the spread is in

evidence *because of* such pressures. Seasonal differences between 1991-92 and 1992-93 also contributed, and in the second year it was noted that the populations of the central Mackenzie basin (Ohau River, Pukaki River and Grays Hills) were about 2-3 weeks more advanced in their life cycle progression than populations of the upper basin. Thus the months of peak occurrence in any one year and site tend to have a narrower span of months than shown by the percent N values of Table 4. It is thought likely that the higher elevation of the upper basin and the greater frequency of cool easterly winds retard the development there, particularly in the eastern populations.

The inferred over-wintering of most growth stages (Table 4) can be related to the longevities of at least four stages, as shown in Appendix 4. As these latter records apply only to re-sighted marked individuals, they **cannot indicate full longevities** because the age of an individual at marking is rarely known and the survival span beyond the (final) re-sighting is unknown. The records are sufficient, however, to indicate that *B. robustus* life stages approach longevities comparable to those known for other species (see White 1974). It is thereby determined that **unusually brief natural longevities are not evident in the adult stage and do not account for the low re-sighting successes in the present study** (see section 3.2; and note the narrow December-January span of adult female percent N values in Table 4).

**Table 4** The progression of growth stages of *Brachaspis robustus* by months of occurrence, based on monitoring site data (N observations, marked + non-marked). Percent N for peak months is shown according to sexes (F = female, M = male), and the numbering of early juvenile growth stages by instars follows Hudson 1974. Lesser occurrences include non-peak months (•), additional months from other data (o), and months of presumed occurrence (\*). Known overwintering records are shown in Appendix 4.

Instar Sex N	Month										
	Jan	Feb	Mar	Apr	WINTER	Sept	Oct	Nov	Dec		
1st	F+M	1	100								
2nd	F+M	4	100								
3rd 'A'	F+M	14	21	64	•	*	–	•			
3rd 'B'	F	35		40	49	*	–	•	•		
4th	F	73		•	•	23	–	36	22	•	
	M	15	•	20	20	20	–	•	•	o	
5th = penultimate	F	64		•	•	•	–	•	38	31	
	M	50	o	•	18	22	–	14	26	•	
6th = final	F	111		•	•	•	–	o	•	60	26
	M	61	•	•	•	•	–	•	•	48	16
Adult	F	176	26	•	•	•	–	•	•	•	40
	M	202	25	15	•	•	–	•	•	•	18

**3.5.4 Dispersal** Appendix 4 also includes dispersal data, based on straight-line (minimal) distances between marking and re-sighting. All records are from monitored sites or immediately adjacent to site margins. The only exception was an Ohau River delta sighting of an indeterminate marked female (either an adult or a final instar juvenile) observed 70 m from the study site by a River Recovery observer. Other listed data show that this is not a great distance, and thus no marked grasshopper was ever re-sighted in the wider environs of study sites. This is despite frequent searches and a total of 212 observations beyond sites (124 adults + 88 juveniles) and a further 107 observations in the Ohau River delta by River Recovery observers.

Except for the Ohau River delta (162 sightings pre-flood), the absence of dispersal evidence is not surprising in one respect because the area to be searched increases with the square of the distance from a study site, and the likelihood of a sighting decreases correspondingly. Yet because there was a total of 698 markings of *B. robustus* on the six monitoring sites plus three extended monitoring sites (Table 1 and section 3.3), it could be reasonably expected that an individual or two might have been found at greater distances if such dispersal was common. More re-sightings could certainly be expected in the vicinities of study sites if dispersal was common. A general lack of such re-sightings suggests, therefore, that **the disappearance of marked individuals from monitored populations cannot be accounted for by widespread or directed dispersal** (see section 3.2).

Further dispersal evidence is provided by the Ohau River post-flood records (section 3.8).

**3.5.5 Activity thresholds and general behaviour** *B. robustus* shares many behavioural similarities with other endemic short-horned grasshoppers. The lower temperature threshold for activity is approximately 1.4°C at 1 cm above ground surface (that is, at 'grasshopper height'). Wind and sun showers do not appear to modify behaviour greatly, but active numbers usually decline with the approach of rain. The possible role of rapidly falling barometric pressure in advance of weather changes was of interest, but barometric measures were problematic and impressions of their effects were conflicting.

Young juveniles tend to be characteristically more aggregated than older individuals, but egg sites were never recognised and no adult female was seen ovipositing. This is consistent with observations of the alpine relative *B. nivalis* which the author has not seen ovipositing in more than 20 years of observations, e.g., see White and Sedcole 1991. The sex ratio in *B. robustus* was 267 females : 268 males over the total study (but there was wide variation between local population centres), and the sexual behaviour is promiscuous (like its alpine relative). One marked adult female at Sawdon Stream was observed three times over three consecutive months, first *in copula* with one adult male (marked), then mounted by another adult male (marked, but not *in copula*), and then accompanied by a third adult male.

In one behavioural respect, *B. robustus* is also very distinctive from all other endemic short-horned species. Its escape behaviour is heavily dependent on its cryptic colouring and it often relies on motionless behaviour rather than active escape. Even when it



jumps to escape, the action is almost always less vigorous than in other species, the distances jumped are noticeably shorter, and when pursued, the number of jumps is fewer. These behaviours are highly relevant to the role of predation (see section 4.2).

**3.5.6 Habitat preference** Macrohabitat preference is very difficult to characterise, given the diverse nature of sites where the species is found. The only feature obviously in common is stoniness. Variation in the character of known sites is as follows:

- Diverse loose-stone aggregates, as in braided river beds, e.g., Ohau River delta (Figure 6), Pukaki River, Snow River, Sawdon Stream
- Lichen-covered embedded stone pavements, as in stable terraces and fans, e.g., Sawdon Stream young flood terraces (Figure 7), Grays Hills old river terraces, Snow River fan old outwash (vegetation band, see Figure 5)
- Fractured non-fluvial stones of recent downcutting flood disturbances, e.g., Mackenzie River (Figure 8) and Snow River monitoring sites
- Degrading embankments of loose stone, as in gullies on high terrace risers, e.g., Tekapo Canal monitoring site (Figure 9)

Perhaps the only feature in common to population centres is the usual presence of fine stone pavements—either widespread or in localised patches. A September observation at the Sawdon Stream monitoring site suggests that frost-heave may demarcate the primary population areas as those areas in which there is minimal physical disturbance under frozen conditions. This inference appears to be consistent with the presumed frost response of areas where the Robust Grasshopper was found during extended monitoring (section 3.3).

It is suggested that a preference for areas with fine stones may be related to times of limiting temperature conditions, when radiant energy heats smaller stones more quickly. Basking behaviour is characteristic of all grasshopper species and warmer substrates are attractive both in the daily temperature cycle and over the seasonal cycle.

In other respects, microhabitat preference was not readily determined within the relatively uniform topographies of most population centres. However, the gully formation of the Tekapo Canal site afforded two discriminating observations that may explain why juvenile records (in particular) were observed primarily near the rim of the gully:

1. Juveniles were more prominent on the north-facing (south) rim where sunshine hours were maximised in early and late season (at left in Figure 9).
2. The same north-facing rim is exposed to the prevailing northwesterly winds and was conspicuously stonier than the more wind-protected south-facing gully rim (at right in Figure 9).



**Figure 6** Ohau River delta (post-flooding, February 1993) showing the braided river formations of loose stone.



**Figure 7** Sawdon Stream, young flood terrace of embedded stones encrusted by lichen (jump-net in foreground).