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**ECOLOGICAL RESEARCH  
AND MONITORING OF  
THE PROTECTED GRASSHOPPER  
*Brachaspis robustus*  
IN THE MACKENZIE BASIN**

by

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# **ECOLOGICAL RESEARCH AND MONITORING OF THE PROTECTED GRASSHOPPER *BRACHASPIS ROBUSTUS* IN THE MACKENZIE BASIN**

by

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## **ABSTRACT**

The distribution, abundance and natural history of the rare Robust Grasshopper has been assessed throughout its present range in the central and upper Mackenzie Basin, Canterbury. Reconnaissance suggests that it has recently disappeared from the southern basin, but it survives further north in some river channels and their outwash areas as small and often isolated populations. Regular monitoring of selected populations has clarified aspects of species biology and ecology, including growth stage longevities, dispersal, diet and habitat preferences.

Only one moderately large population centre is known (estimate: 250-300 adult recruits per year), and all populations appear to face periodically heavy predation from a suite of predators, indigenous and introduced. Annual losses of adult females before breeding appear to be the most critical survivorship factor. Populations in river channels in addition face periodic losses from natural flood events or large hydroelectric river releases. The risks of natural and induced disasters are assessed in evaluating the current status of the species, and a suggested long-term scenario is presented to explain the virtual lack of species records before the 1980's. It draws together five key elements: rabbits, pest control, predation, vegetation change and hydroelectric development. Four recommendations are proposed to improve species and habitat protection.

## **1. INTRODUCTION**

The Robust Grasshopper, *Brachaspis robustus* Bigelow, is a protected species endemic to New Zealand. It is a montane grasshopper belonging to the family Acrididae (short-horned grasshoppers) in which the antennae are of similar length to the face (Figure 1). The usual colour is slate-grey but varies between individuals, and especially between habitats of different background colours. Hence, earthen browns are more prominent in some areas, and richly patterned black and grey individuals may be found in prominent lichen areas. Light yellowish patterns on the thorax (and occasionally orange) add to the cryptic colouring of a few individuals, and the species' flash-display colourings on the inner side of the hind-legs provide an intense combination of red and indigo-violet. This latter combination is more dramatic than in any other New Zealand grasshopper.

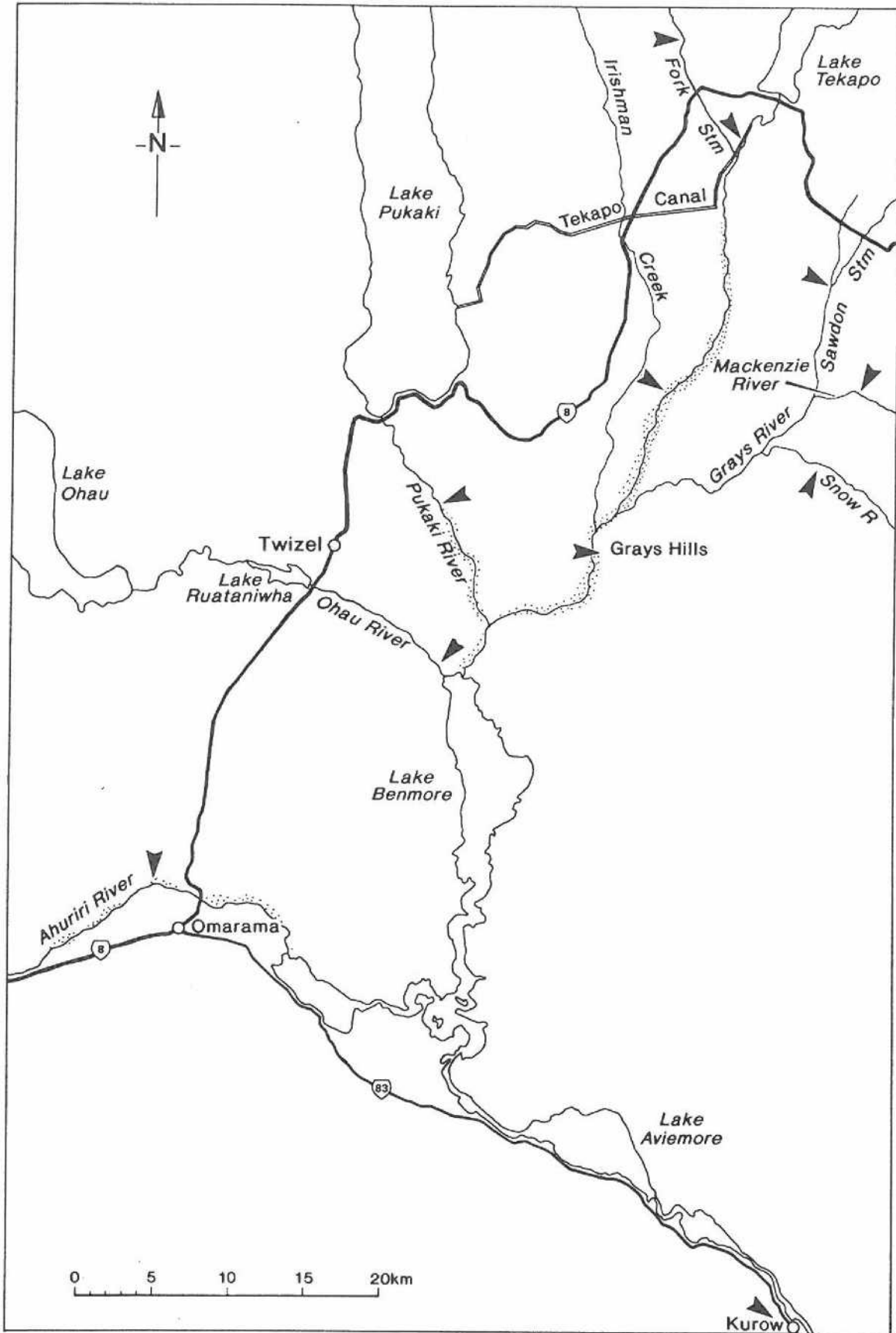


Photo: Robin Smith

**Figure 1** *Brachaspis robustus* adult female.

The grasshopper is known from stony floodplain terraces, fluvio-glacial outwash localities, recent fluvial outwash and rocky braided river systems of the Mackenzie Basin, Canterbury (Figure 2). Until 1984, only three specimens deposited in the Canterbury Museum, Christchurch, were known to science: two undated individuals labelled simply 'Kurow' (located on the Waitaki River that drains the Mackenzie Basin) and a 1963 adult labelled 'Ahuriri River, North Otago' (located at the southern limits of the basin) (see Bigelow 1967 for details and a species description). In 1954, several specimens were observed in Fork Stream at Balmoral Station, towards the northern limits of the basin (John Dugdale, pers. comm. 1993), and in 1971-72, the species was common by the Tekapo A Powerhouse (Pat Quinn, pers. comm. 1993). New discoveries of the species followed from 1984 onwards in the upper Mackenzie Basin (recorded in part by Davis 1986) and one further specimen was added to the Canterbury Museum collection. Despite any earlier 'common knowledge', a meagre 10 observations had been scientifically recorded by 1984, but by 1990, Davis had added 80 further sightings to Canterbury Conservancy records.

The current investigation spanned November 1991 to May 1993, and its observations have been complemented by further new records supplied by Canterbury Conservancy staff (Mark Davis, Ken Hughey, Richard Maloney, Ron Nilsson, Bert Rebergen and Lynn Adams). The contributions of these observers is gratefully acknowledged.



**Figure 2** River and outwash systems of the Mackenzie basin. Arrows indicate known records of *Brachaspis robustus*.

The objectives of the present study were to explore locations and monitor the abundance of *Brachaspis robustus* in the Mackenzie Basin, spring-autumn 1991-92, 1992-93 as follows:

- To progressively mark and record grasshoppers on first capture and re-record at subsequent sightings
- To piece together a biology and life-history from completed marking/re-sighting records
- To estimate minimum population sizes and survival prospects, using formal analyses if data permit
- To relate observed grasshopper behaviour to habitat requirements including, if possible, identification of food plants by faecal analysis
- To define known site locations
- To prioritise sites for recommended conservation effort, assuming the case for special effort is upheld.

The study was carried out subject to the conditions of an authority to catch, handle, transfer and release absolutely protected wildlife (DoC Permit 12/23). The conditions stipulated minimised disturbance of *B. robustus* populations; minimised stress of captured, handled and marked individuals; and the most humane holding conditions for individuals temporarily held in the field for the collection of voided faeces. The authority did not allow the removal of animals from the field.

Species protection is established in the Seventh Schedule of the Wildlife Amendment Act 1980. Ramsay *et al* 1988 considered the species as possibly at risk from habitat modification and perhaps vertebrate predation. Sherley 1989 assigned it tentatively to 'Research Rank 1', that is, immediate research is essential.



## 2. METHODS

Monthly field visits were made November 1991 - May 1992, and September 1992 - May 1993. Reconnaissance sought to identify as many *Brachaspis robustus* sites as possible while monitoring sought to assess population ecology at selected sites.

### 2.1 Reconnaissance

Rocky braided river systems were not a known habitat type until 1991, and this discovery by Canterbury Conservancy staff greatly enlarged the potential species area to be searched. So also did the author's early discovery of *B. robustus* at a distance of 1 km from a current river channel. All 1984-90 sightings in the upper Mackenzie Basin had been adjacent to rivers and streams or within their immediate outwash systems or terraces. The new discoveries made comprehensive reconnaissance by the author an impracticable achievement within the terms of the contract, and the following strategy objectives were therefore developed:

- To facilitate recognition of *B. robustus* by conservancy staff of the River Recovery Programme, so leaving reconnaissance of the Tekapo River and the Ohau River (above the delta) almost totally to their efforts during the course of concurrent bird surveys
- To search likely habitat areas in as many other Mackenzie Basin river beds and stream beds as possible
- To search widely in the vicinity of selected monitoring sites (see 2.2 below) to establish the extent of species distributions beyond the immediate environs of current river channels.

The study's concept of reconnaissance was to locate as many *B. robustus* grid references as possible over the widest achievable area without taking time to investigate the numbers of observable individuals within any grid. Topographic map grids (NZMS I series and Infomap 260 series) were not systematically searched but potential habitats were extensively sampled by random walk, and sightings of the grasshopper were then identified by grid reference.

Reconnaissance did contain a monitoring component in the sense of recording grasshopper counts per unit searching time, and these measures included time taken to assess and record the life-stage and sex observed. Most grasshoppers were captured by jump-net (White 1975) and immediately released after assessment, commonly within 1 minute. Only weather conditions favourable to grasshopper activity were used for reconnaissance.

### 2.2 Monitoring

Six local sites ranging in size from 0.4-2.3 hectares were selected for monitoring over the two years, with centre-point grid references (NZMS 1) as follows:

S100 077959 Tekapo Canal	- high terrace lateral gully
S101 144849 Sawdon Stream	- young flood terrace
5101 143770 Mackenzie River	- river outwash stream bed
S101 129722 Snow River	- river outwash stream bed
S109 974661 Grays Hills	- old flood terrace
S109 857575 Ohau River	- river delta

As far as practical, site boundaries were established by natural topographic features and vegetation features at the periphery of observed population centres. Thus, arbitrary definitions of monitoring boundaries were minimised, and where feasible, buffer areas were included beyond the initial area of monitored presence.

Grasshoppers within the boundaries were sampled monthly in a slow walk to-and-fro across the entire area of a site using a succession of transect bands of approximately 1.0 -1.5 m width. The transects were not fixed and, when necessary in months of low sun elevation, their axes were varied when necessary to avoid walking into one's own shadow. The actual time spent per site under conditions favourable to both grasshopper activity and efficient observation varied from 1-6 hours, depending on site area, but elapsed time was often greater because of unfavourable conditions e.g., high winds, low temperatures, rain. On occasions, a site needed to be re-sampled over two or three days to meet acceptable sampling standards.

Any variability between monthly sampling efficiency due to variations in the prevailing conditions did not interfere with methodology *per se*. A capture-recapture objective requires only that marked and non-marked grasshoppers have an equal probability of capture, regardless of variations in sampling intensity. Captured individuals were each marked on the prothorax with a unique coding mark using oil paint and a tubular nib pen with plunger removed (see White 1970 for methodology) and released at the same point where captured, usually within 2 minutes. White paint was used until 12 February 1992 when evidence of significant predation by vertebrates began to mount, and new marking was immediately suspended except for small marks applied to adults in inconspicuous positions. Beginning March 1992, grey paint was substituted to minimise visual cues to a predator, and unique coding of both juveniles and adults resumed.

The following sampling conditions were recorded during monitoring:

air temperature range (minimum-maximum, °C) immediately above the exposed ground surface; wind speed range (minimum-maximum, km/hr) at 2 m above ground; cloud cover (start-finish); barometric pressure (start-finish, mg Mercury) 1992-93 only; vegetation and substrate condition (wetness, disturbance); vertebrates and/or their sign in or near monitoring areas; other grasshopper species observed.

### **2.3 Extended monitoring**

In addition to the regular monthly monitoring above, the extended environs of three sites (Mackenzie River, Sawdon Stream and Snow or 'Snowy' River) were also periodically monitored. In 1991-92 only, two downstream sites at Sawdon Stream plus a Snow River site 1 km from the river channel were monitored as above. In addition,

two methods of extended monitoring were also developed in the environs of Mackenzie River and Snow River sites over the two study years:

- At Mackenzie River, *B. robustus* counts per unit time were recorded for five months in 1992 and 1993 during random walks within 500 m of the primary study site
- At Snow River, counts per unit distance were recorded over eight months using a progression of 26 line transects paced along variously aligned axes on the extensive outwash fan

In the second method, nearly all transects were 1.5-1.7 km in length, and *B. robustus* locations on each transect were mapped on a vertical air photograph. Because location recognition in this extensive landscape was decidedly difficult except by repeated measuring, a hand-held counter and controlled pacing was used to monitor both grasshoppers and landscape mapping features. Most transects were positioned to sample both a very old outwash formation (characterised by a distinctive vegetation composition) and the surrounding outwash areas (with a vegetation more typical of the region).

#### **2.4 Vegetation analyses and diet**

Vegetation analyses were carried out by Dr Peter Espie at two sites in January 1992 (Mackenzie River and Sawdon Stream) and in December 1992 at Snow River and two randomly selected areas of the distinctive outwash band in 2.3 above. At each site, species composition and percent ground cover were determined subjectively by eye using 30 m radius reconnaissance plots (see Espie *et al* 1984; Allen 1992).

Dietary evaluations were carried out by faecal cuticular analysis using the faeces obtained from a range of captive individuals on four monitoring sites. Grasshoppers were held for up to four hours in aerated jars placed in shaded conditions and containing a few plant tissues on offer for current feeding. Hot weather conditions were avoided. The faeces produced during this interval originate from earlier field ingestion (see White and Watson 1972; White 1978). Cuticle examinations were subsequently carried out by Joy Talbot. Faeces were first soaked in warm water to which faecal bacteria were added by pre-soaking rabbit pellets. Containers were incubated for 7 days at 30°C (approx.) and then the contents were washed over fine gauze and mounted in water for analysis using an interference contrast microscope.

#### **2.5 Life cycle and ecology**

Examination of individuals by hand lens in the field was the only available means of identifying successions of juvenile stages in relation to body characters already recognised for other grasshopper species (see Hudson 1970). Selected characters that showed variation and posed some uncertainties in 1991-92 were therefore systematically observed in 1992-93.

The locations of marked individuals were documented by specifying site boundary coordinates, and thereby permitted straight-line (minimal) dispersal distances to be paced out when a marked individual was subsequently re-sighted. Behavioural ecology was also recorded, for example, mating behaviour, escape behaviour, and microhabitat preference; and limiting activity thresholds were of interest whenever conditions permitted an observation. As the study progressed, increasing attention was paid to possible predation by vertebrates, recording animal presence and collecting faecal material. Elaine Murphy (then of Canterbury Conservancy) identified mammalian faeces before they were soaked in water and examined by the author for the presence of grasshopper fragments.

## **2.6 Hydroelectric river releases**

The effects of 'flood events' on river populations of *B. robustus* were observed during two notable water releases by Electricity Corporation of New Zealand Limited (ECNZ):

1. Robust Grasshoppers at the Ohau River delta monitoring site and its environs (see 2.2 above) were monitored immediately before and after the ECNZ Gate 22 spill tests of 11-13 February 1993 (peak flow at gate: 401 cumecs, 12 February, 1330-1445 h; normal annual flow: 0 cumecs). In the expectation of the first total delta flooding in 7-10 years, an authority was obtained to catch, handle, kill and transfer from the delta six *B. robustus* grasshoppers to be deposited in the National Arthropod Collection (5 specimens) and the Lincoln University collection (1 specimen) (DoC Permit 12/38). The six specimens were selected 10-11 February to represent a range of life-stages, and the liveweights were recorded within 1 h of death.
2. Robust Grasshopper grid references recorded for the Pukaki River during reconnaissance (see 2.1 above) were observed from the high south terraces during the ECNZ statutory annual release (peak flow 20-21 March 1993: 140-143 cumecs; normal flow 363 days per year: 0 cumecs). All observable reconnaissance grid locations were inventoried as 'flooded' or 'non-flooded'.

### 3. RESULTS AND DISCUSSION

#### 3.1 Reconnaissance

Reconnaissance grid references are listed in Appendix 1 for those areas searched on foot for *B. robustus*. These were select areas in which habitat type was broadly characterised by stoniness and a minimum presence of native herbs and shrubs, principally willow-weed (*Epilobium* spp.) and associated Raoulia cushion plants and prostrate *Muehlenbeckia* spp. In the selection of such sites, broader landscapes were evaluated from vantage points throughout the Mackenzie Basin and its drainage area, but grid references are not listed for any such generalised assessments. It is believed that the most likely habitat prospects have been searched on foot.

**3.1.1 Lower (southern) Basin** The southern drainage of the Mackenzie Basin has been heavily modified in the last 30 years by the creation of Lake Benmore and the spread of willow trees and lupins along braided river beds. In 1993, no likely habitats could be located in the delta of the Ahuriri River, nor along Lake Benmore margins nor in the Waitaki River above and below Kurow. Nor does promising habitat now exist in the heavy lupin areas of the lower Ahuriri River or in Quailburn Stream.

Upstream of the lupin stands, extensive river stretches of apparently suitable habitat are present and were searched (Appendix 1), including the lower reaches of Ribbonwood Creek and the Avon Burn. In none of these areas were there sightings of *B. robustus*, and nor have there been any upstream sightings by the River Recovery programme team during extensive bird monitoring of the next 1 km of river channel (Richard Maloney pers. comm.). Further westwards, the steep rainfall gradient towards the southern alps is thought to almost certainly preclude the possibility of species presence and survival.

There is therefore no evidence in support of the current survival of the Kurow and Ahuriri River populations of *B. robustus* from which the three original specimens of the Canterbury Museum were obtained by 1963. No current habitat in the vicinity of Kurow is remotely similar to other known habitat types, and the lower reaches of the Ahuriri River (thought to be the most likely source of the 1963 specimen) are now modified towards exclusion of stable open-space habitats that rarely flood. The Ahuriri record remains the most westerly known limit of the species' former distribution, and the Kurow record is the most southerly.

**3.1.2 Central and Upper Basin** The three primary natural waterways of the upper Mackenzie Basin are the Ohau, Pukaki and Tekapo Rivers. Comprehensive reconnaissance data are now available for all three.

1. The Ohau River delta was the southernmost location of *B. robustus* confirmed by the present study. A cursory reconnaissance above the delta in November 1991 failed to locate any individuals, and the River Recovery programme team has not yet located the species above the confluence of the Twizel and Ohau Rivers, 2 km from Lake Benmore (Richard Maloney pers. comm.). Hence, although the lower reaches of the Twizel River were not searched in the present study, it would appear that the Robust

Grasshopper may occur in only a 2 km stretch of Ohau River delta. Further see sections 3.2 and 3.8 below.

2. The Pukaki River was intensively searched along the greater part of its length September-December 1992 (Appendix 1; Fig. 3), and all remaining upper reaches to the Lake Pukaki spillway were also assessed. A total of 74 *B. robustus* was sighted and the data show that populations extend for one half of the river's length from the confluence with the Tekapo River. The mean counts of individuals sighted per hour of searching over 2-hour spells provide a possible indicator of relative abundance from the upper reaches to just above the confluence (refer also to Fig. 3):

0.0; 0.0; 2.0; 8.0; 6.0; 4.5; 3.5; 2.5; 1.0; 2.5

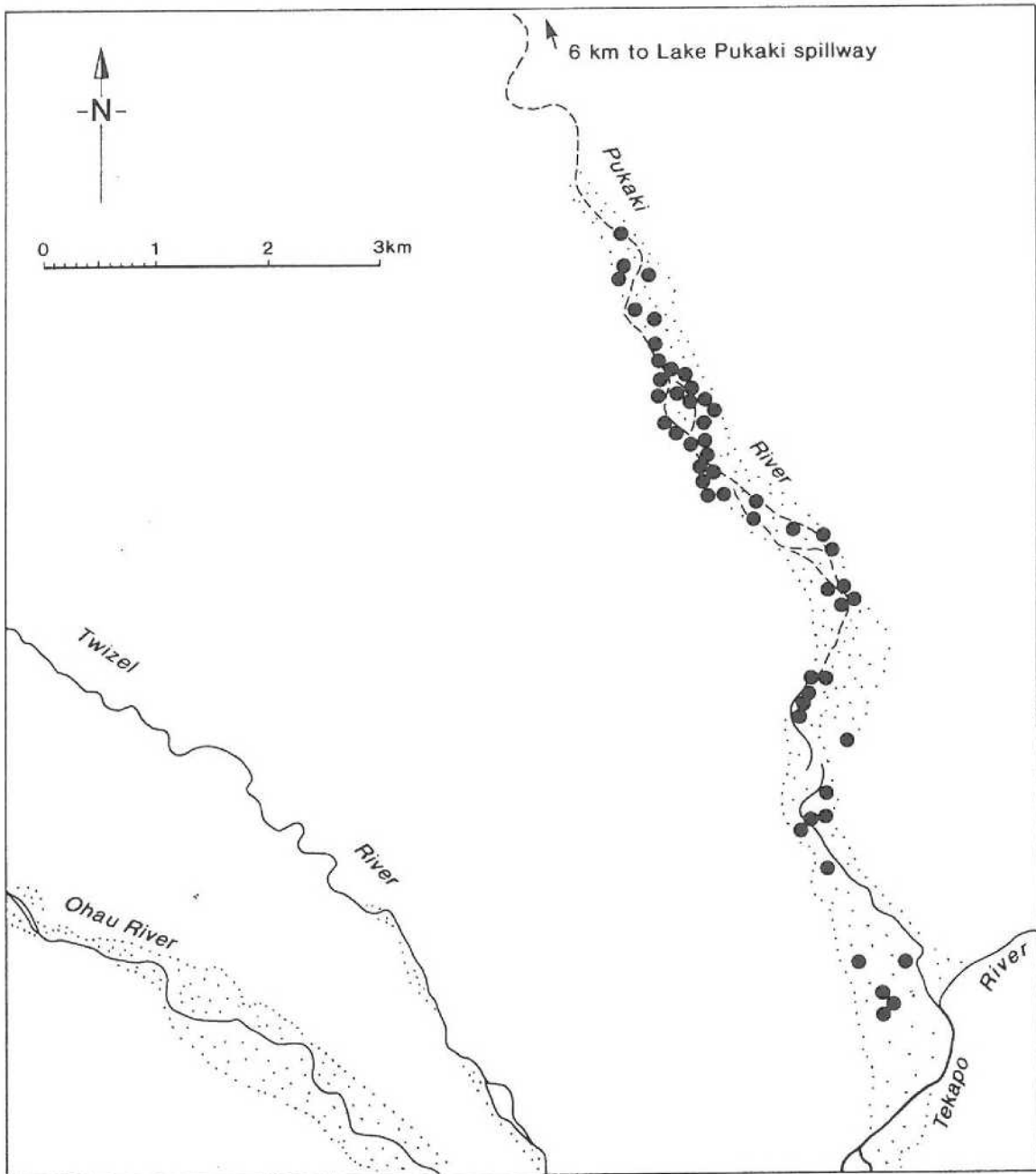
While middle segments clearly have higher abundances than the upstream segments, it cannot be ruled out that the smaller counts in downstream segments might in part reflect a seasonal reduction in abundance from November to December. Downstream reconnaissance was not completed until December.

3. Reconnaissance of the Tekapo River channel was left to the River Recovery programme staff (see section 2.1) and the locations of 114 observations are reported by Richard Maloney (pers. comm.) On terraces beyond the channel there are also a number of records. Reconnaissance in the vicinity of the Grays Hills monitoring site failed to locate terrace populations in the lower reaches of the river (Appendix 1), but some exist on upstream terraces. In addition to the upstream population at the Tekapo Canal monitoring site on a true right terrace 2 km below the Tekapo A Powerhouse, an adult female was recorded on a true left terrace only 1.3 km below the powerhouse (Appendix 1). On two high terrace risers 6 km further downstream, Davis 1986 has also recorded populations. Reconnaissance of Fork Stream and an unnamed stream yielded no additional sightings (Appendix 1), but Davis (pers. comm.) reports a 1992 sighting of four Robust Grasshoppers in Fork Stream at Balmoral Station (Grid reference NZMS 1 S89: 032037). This is upstream of current reconnaissance and appears to correspond to 1954 sightings (see Introduction). The location represents the most northerly observation of the species.

### 3.2 Monitoring

Table 1 presents a summary of marked grasshopper records. It should be noted that because paint marks are in effect 'lost' when juvenile grasshoppers shed their skins between growth stages (known as 'instars'), adult and juvenile records **cannot be summated**. Allowing that any marked adult could formerly have been a marked juvenile, summation almost certainly leads to some double-counting in these small populations. For this same reason, the listed juvenile records are themselves expected to be inflated, for single individuals can be marked in successive instars.

In addition to the marked individuals of Table 1, a minimum of 153 non-marked sightings (17 adults + 136 juveniles) was made at the six study sites over the two years. Marked and non-marked records from sites **cannot be summated** for reasons similar



**Figure 3** The lower Pukaki River showing locations of *Brachaspis robustus* observations (dots). The river is 17 km long. No evidence of *B. robustus* has been found in the upper reaches of either the Pukaki River or the Ohau River (bottom left). Twizel River is also shown.

to those above: a non-marked individual might have been marked subsequently and/or have been previously marked (as a juvenile).

Three things are immediately clear from Table 1:

1. The populations of monitored areas are variable in size (both as adults and juveniles) and in density (based on mean counts per hour of search).
2. There is a very high rate of disappearance of marked individuals without re-sighting (note the very small numbers in parentheses).
3. There are too few re-sightings to permit formal capture-recapture estimation of population sizes for any site, including Sawdon Stream where a higher success rate is evident.

A somewhat low re-sighting success for juveniles could be anticipated with the monthly monitoring intervals, for juvenile grasshoppers generally shed their skins every few weeks over the warmer months of the year (see White 1974). It is therefore the low re-sighting success for adults that is of critical interest in *B. robustus*, and from early 1992, the study was increasingly focussed on finding the explanation. Four possibilities were evident by autumn 1992, and monitoring effort in the 1992-93 year sought evidence to discriminate between the following:

- Adult dispersal away from monitoring sites
- Predation mortalities (and the possible increase in prey detection due to paint markings)
- Drought mortalities
- A possibility of unusually brief natural longevities in adults of this species

**Table 1** Total numbers of *Brachaspis robustus* adults and juveniles marked over two years at the six monitoring sites. Parentheses show the numbers re-sighted, and the mean counts per 1 hour of search time are based on total marking successes + re-sightings. The sites are ordered north to south.

Site	Adult	Juvenile	Counts per hour
Tekapo Canal	9 (1)	19 (0)	1.5
Sawdon Stream	103 (15)	86 (9)	3.0
Mackenzie River	105 (2)	144 (2)	4.2
Snow River	48 (1)	34 (0)	4.8
Grays Hills	27 (3)	16 (0)	2.0
Ohau River delta	51 (1)	42 (1)	5.4
	<b>343 (23)</b>	<b>341 (12)</b>	



The cumulative evidence is reported in sections 3.3-3.8 and evaluated in section 4. It will be shown that monitoring data are also relevant by directly comparing the two sampling years over the calendar months in common to each, site by site (Table 2). Four sites had six months in common (November-April), Snow River had five in common (weather precluded sampling in January 1992), and Ohau River delta had only four in common up to the 1993 flood event (section 2.6).

The 1992-93 decline of adults and juveniles at Sawdon Stream and Grays Hills is of note (see section 3.5).

### 3.3 Extended monitoring

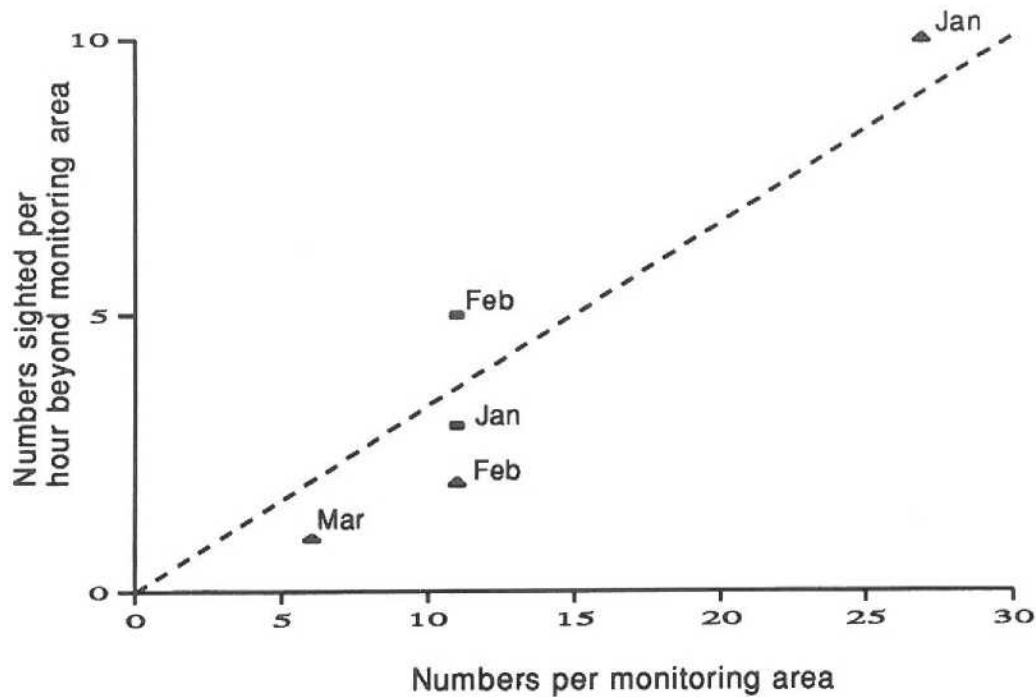
The extended environs of the three most easterly sites were periodically monitored but each in a different manner.

**3.3.1 Sawdon Stream** Two small downstream sites were monitored in 1991-92 (centre-point grid references, NZMS 1, 5101: 142843, 141838). In a total of 17 *B. robustus* seen (11 adults + 6 juveniles), 12 were marked and there were no re-sightings. An additional 8 individuals were observed in adjacent stream channel or outwash areas extending up to 300 m to the east (5 adults + 3 juveniles). Across more extended areas towards the main monitoring site, 13 adults + 11 juveniles were similarly observed over two years from stream channel to the sparse network of fine gravels across the eastern outwashes. It is therefore evident that Sawdon Stream has a widely dispersed population centred on the stream channel and adjacent flood terraces; and also a thinly spread and isolated(?) population amongst eastern outwash areas. The most extreme record was 0.7 km from the channel.

**3.3.2 Mackenzie River** A dispersed population was similarly present in grassland and river channel adjacent to the monitoring site, and there was a notable presence

**Table 2** Total numbers of *Brachaspis robustus* adults and juveniles marked over the calendar months in common to each sampling year (see text).

Site	Adult		juvenile	
	1991-92	1992-93	1991-92	1992-93
Tekapo Canal	3	5	5	8
Sawdon Stream	60	27	51	8
Mackenzie River	48	50	56	36
Snow River	19	26	10	14
Grays Hills	19	8	9	4
Ohau River delta	20	13	2	1
	<b>169</b>	<b>129</b>	<b>133</b>	<b>71</b>



**Figure 4.** Observed *Brachaspis robustus* numbers (adults + juveniles) in monitoring area and the extended environs of monitoring area on five occasions (■ = 1992; ▲ = 1993; months = January-March). The diagonal line represents one-to-one equivalence per unit time (see text).

along the gravelled tracks of the old roadway. A total of 44 *B. robustus* (16 on the roadway) was recorded during random searches of the area (25 adults + 19 juveniles). Figure 4 relates the numbers of observations in timed walks (1 hr and 2 hrs) to contemporaneous monthly counts from the monitoring site. The diagonal line represents one-to-one equivalence between counts per unit time based on mean duration per monitoring occasion (less the time spent handling and marking) and the extended grassland monitoring durations. The closer the count co-ordinates lie to this line, the more similar are the trends in *B. robustus* numbers within site and environs.

The reasonable approximation shown between line and co-ordinates provides evidence that the trends in abundance within the site were matched (over time) by trends in abundance beyond the site to at least 500 m. It follows that:

- The addition of paint marks to monitored grasshoppers was not a primary factor in the observed declines in site abundances, and hence paint marks did not greatly increase prey detection by predators; and
- When site counts reduced, disappearing marked grasshoppers did not disperse from monitored sites to adjacent grassland and river channel.

In support of the evidence against extensive dispersal, no marked grasshoppers were sighted in the grassland apart from one within 30 m of the study site two days after marking. Nor were marked grasshoppers found in the main river channel to the south of the site.

**3.3.3 Snow River** One small outwash fan site 0.7 km from the river was monitored in 1991-92 (only two *B. robustus* adults were marked) but in due course the site was proven to be an incidental location within a 2 km band widely occupied by *B. robustus*. The band is a very old outwash formation shown in Figure 5. The mapped sightings of the Robust Grasshopper show a clear preference for this habitat type (including secondary ridge systems to the right, towards the river) and non-preference for adjacent habitat.

A total of 68 sightings over two years (45 adults + 23 juveniles) was recorded in the extended monitoring at Snow River, and the mean count per unit distance along the 1992-93 line transects was 1 individual per 655 m of the primary outwash band. About 150 transects of 2 m width could be fitted into this band, and an estimate of adult population size for the one band is 250-300 individuals. It is likely that this is the largest contiguous population of *B. robustus* in existence. It is furthermore flanked towards the river channel by secondary ridge systems (see Fig. 5) with a smaller and less cohesive population.

### 3.4 Vegetation analyses and diet

Appendix 2 presents vegetation analyses for the eastern Basin sites and indicates species (or genera) identified in *B. robustus* faeces collected at four monitoring sites, including Ohau River delta. Other plant species (primarily herbs?) were also present in faeces but were not identifiable, and food preferences appear to include the grasses *Elymus rectisetus* and *Poa pratensis*, the herb *Achillea millifolium*, and unidentified mosses and lichens. The frequencies of these foods in the diet are greater than their apparent frequency in the vegetation, and the presence of *A. millifolium* at Mackenzie River was identified from diet rather than from vegetation analysis.

Note in Appendix 2 the paucity of vegetation species and ground cover in the favoured Mackenzie stream bed habitat where *B. robustus* occurs in highest numbers (fewer grasshoppers occur in the adjacent outwash terrace). Vegetation paucity at two non-analysed sites was even more marked: Ohau River delta offered little more than *Epilobium*, *Raoulia* and *Muehlenbeckia* species (but a *B. robustus* nymph also found some *Achillea millifolium*, identified from faeces); and the Grays Hills site was principally *Agrostis*, *Anthoxanthum*, *Epilobium*, *Hieracium*, *Raoulia*, *Rumex* and *Rosa* (based on Davis 1986).

Table 3 summarises the diet of *B. robustus*, based on faeces collected in the months of September and December-April. It is suggested that the relatively high moss and lichen content (contrast vegetation composition, Appendix 2) might reflect the dietary importance of moisture absorption by these plants at night. Food succulence is important in grasshopper diets (White 1978), and mosses and lichens may provide a means of withstanding Mackenzie Basin aridity and drought (section 3.7). Although such foods do not generally occur in the main river channels, it is suggested that the loose rock formations of river channels may compensate in terms of grasshopper water-balance, for rock interstices permit avoidance of stressful daytime heat, and condensation of free water may occur at night.