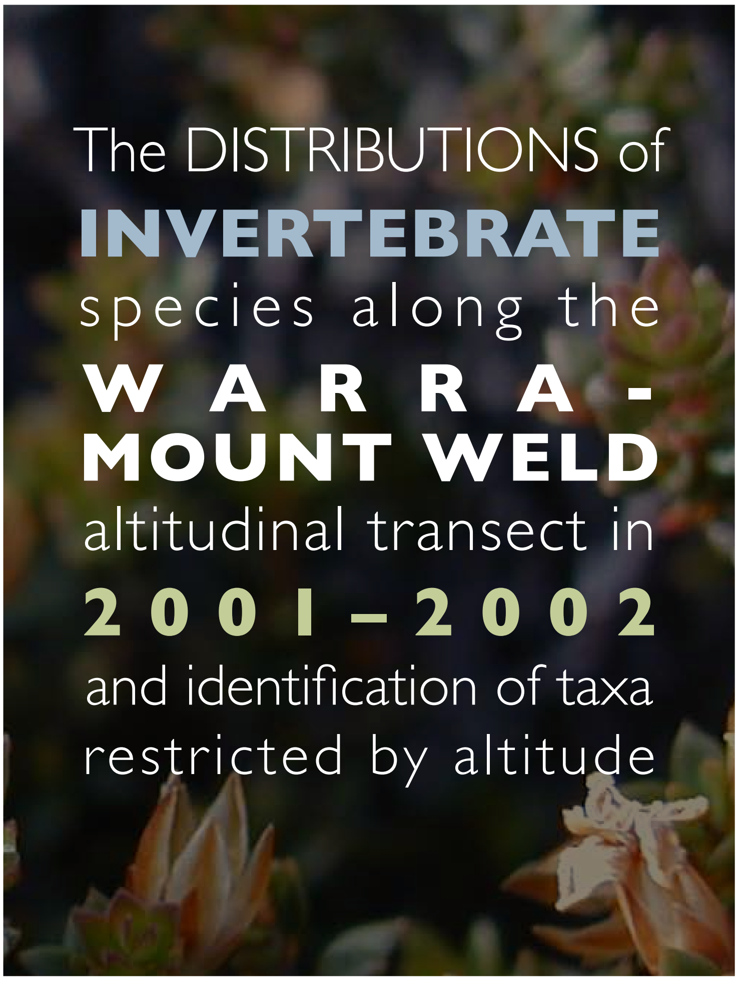

The DISTRIBUTIONS of INVERTEBRATE species along the WARRA-MOUNT WELD altitudinal transect in 2001–2002 and identification of taxa restricted by altitude

MICHAEL DRIESSEN and
STEPHEN MALLICK (editors)

NATURE CONSERVATION REPORT 13/4

Department of
Primary Industries, Parks, Water and Environment

Tasmanian
Government

The distributions of invertebrate species along the Warra-Mount Weld Altitudinal Transect in 2001–2002 and identification of taxa restricted by altitude

Reports on invertebrate groups by:

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Michael Driessen and Stephen Mallick

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Nature Conservation Report 13/4

This report was prepared under the direction of the Department of Primary Industries, Parks, Water and Environment (World Heritage Area fauna program). Commonwealth Government funds were provided for this project through the World Heritage Area program. The views and opinions and analyses expressed in this report are those of the authors and do not necessarily reflect those of the Department of Primary Industries, Parks, Water and Environment.

ISSN 1441-0680 (print)
ISSN 1838-7403 (electronic)

Published by the Biodiversity Conservation Branch, Resource Management and Conservation Division, Department of Primary Industries, Parks, Water and Environment, PO Box 44, Hobart, Tasmanian 7001, Australia

Cover design by Brett Littleton, Information and Land Services, Department of Primary Industries, Parks, Water and Environment.

Front cover images: *Pterolocera* sp., *Tasmaniacris tasmaniensis*. Back cover images: from top right *Pseudolycus haemorrhoidalis*, malaise trap, *Tasmaniacris tasmaniensis*, vegetation at 800 m on Mount Weld. All images by Michael Driessen.

Suggested citation:
Cite individually authored reports as per standard conventions in:

Driessen, M.M. and Mallick S.A., editors (2013). The distributions of invertebrate species along the Warra-Mount Weld Altitudinal Transect in 2001–2002 and identification of taxa restricted by altitude. Nature Conservation Report 13/4, Department of Primary Industries, Parks, Water and Environment, Hobart.

SUMMARY

The Warra-Mount Weld Altitudinal Transect survey is a long-term study originally established to record inventory and distributional data for plants and animals along an altitudinal gradient (100–1300 m) to provide a baseline to document changes in their distribution and abundance due to climate change or other environmental events such as fire.

The Warra-Mount Weld Altitudinal Transect was sampled for invertebrates in 2001 (February, March, April, November, December) and 2002 (January, February, March, April), and again ten years later in 2011 and 2012 (December, January, February, March). The invertebrate data from 2001 (all months), and 2002 (January and February) were identified to Order level and analysed by Doran *et al.* (2003). The present report analyses the same data as Doran *et al.* (2003) but also includes the additional months of March and April 2002 and focuses on species-level analysis for selected groups. The samples from the 2011 and 2012 sampling have yet to be identified and analysed.

The aims of the present report are: to describe changes in species distribution with altitude for selected taxa and to identify taxa restricted by altitude; to compare invertebrate assemblages at the ordinal level for the February–March 2001 and February–March 2002 samples; and to identify advantages and limitations of the monitoring program and options for future survey.

The following taxa were sorted to species or morphospecies level: Amphipoda, Coleoptera, Collembola, Formicidae, Gastropoda, Orthoptera, Chilopoda and Diplopoda. There were marked altitudinal patterns in species composition and abundance for all these taxa, and all taxa with the exception of Chilopoda and Diplopoda had examples of species either restricted to high altitude and or with a narrow altitudinal range. These altitude-restricted species provide possible indicator species which may be useful in demonstrating altitudinal shifts due to climate change through subsequent sampling.

We compared invertebrate assemblages at the ordinal level for the February–March 2001 and February–March 2002 samples to explore background levels of variation in the data. We also compared captures of species between 2001 and 2002 for several groups which were identified to species level where there were sufficient number of captures to warrant a comparison between years (Orthoptera, Collembola, and Coleopteran families Carabidae, Curculionidae, Leiodidae and Staphylinidae).There was significant variation in invertebrate abundance between the two years across a broad range of taxa. This variation may limit the ability of the Warra-Mount Weld Altitudinal Transect to detect long-term, climate-induced shifts in the invertebrate assemblages using abundance at least at the ordinal level.

The limitations of the study to explore long-term shifts in invertebrates due to climate or other long-term environmental change are discussed, together with a number of possible options for future directions for the project.

CONTENTS

1 INTRODUCTION

The influence of latitude and altitude on species diversity has long fascinated ecologists, and has led to a diverse array of hypotheses to explain the observed trends (McCoy 1990, Gaston *et al.* 2000). However, in addition to its intrinsic ecological interest, the relationship between species diversity and abundance along latitudinal or altitudinal transects has a current pertinence in relation to predicted impacts of climate change. The effects of climate change are predicted to include significant changes in rainfall patterns, temperature, fire risk, the incidence of severe weather events, and a rise in sea level. While the projected climate changes for Tasmania are somewhat less extreme than for other parts of Australia, they are still significant and include a year-round rise in temperature of up to 3°C, declines in rainfall (particularly over summer), and increased severe weather events such as frosts, heat waves and flooding (Bennett *et al.* 2010, Grose *et al.* 2010).

There is an increasing emphasis on establishing baseline monitoring programs to document change as it occurs, because the flow-on effects of climate change may now be difficult or impossible to prevent, both in the climatic variables themselves and in the plants and animals that respond to them. Studying established patterns of species diversity along latitudinal or altitudinal gradients provides a useful way to investigate the influence of climatic and biological variables on species diversity (Lawton *et al.* 1987). Such studies also have the potential to provide a baseline data set from which to investigate potential flora and fauna shifts with changes in climate. Of the two, latitude suffers from a number of drawbacks, in particular the need for a very long transect to cover a reasonable range of temperatures, which then involves additional variables such as vegetation, natural enemies, photo-period, etc., which can confound any effects of temperature *per se* (Whittaker & Tribe 1996). In this respect, an altitudinal gradient can provide a natural 'experiment' in which a significant range of temperature (in the order of 5–15°C) can be studied in the one geographical location and with a minimum of confounding biological and geographical variables (Whittaker & Tribe 1996, Sirin *et al.* 2010).

The primary original objective of the Warra-Mount Weld Altitudinal Transect invertebrate project was to record baseline inventory and distributional data for plants and animals along an altitudinal gradient which can then be used to document altitudinal shifts in invertebrate assemblages over time which may result from climate change or other processes such as wildfire (Bashford *et al.* 2001, Doran *et al.* 2003, Grove 2004). An establishment report for the project has been completed (Grove 2004). To date, the Warra-Mount Weld Altitudinal Transect has been sampled for invertebrates in 2001 (February, March, April, November, December) and 2002 (January, February, March, April), and again ten years later in 2011–2012 (December, January, February and March). The data from the February–April 2001, November, December 2001 and January, February 2002 sampling were analysed using an ordinal level analysis by Doran *et al.* (2003). The present report analyses the same data as Doran *et al.* (2003) plus the additional months of March and April 2002 and focuses on species-level analysis for selected groups. The samples from the 2011 and 2012 sampling have yet to be identified and analysed.

This report has the following aims:

1. To describe changes in invertebrate species distribution with altitude for selected taxa (Amphipoda, Chilopoda, Coleoptera, Collembola, Diplopoda, Formicidae, Gastropoda and Orthoptera) and to identify species restricted by altitude;
2. To compare invertebrate assemblages at the ordinal level for the February–March 2001 and February–March 2002 samples to explore background levels of variation in the data;
3. To identify advantages and limitations of the monitoring program and options for future survey.

2 METHODS

Warra site description

The Warra Long Term Ecological Research (LTER) Site is a 15 900 ha area lying between the Huon and Weld Rivers, approximately 60 km south-west of Hobart. The site includes Mount Weld (lower-mid slopes but excluding the summit) and Mount Frederick, and has an altitude range of 37–1260 m. The area is geologically diverse but is dominated by Jurassic dolerite. Most of the area is forested, the most common forest type being wet *Eucalyptus obliqua* forest. There are also areas of climax cool temperate rainforest, buttongrass moorland, subalpine woodland, and alpine heathland and scrub. The western portion of the site is part of the Tasmanian Wilderness World Heritage Area which is managed for conservation values by the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE). The eastern portion is State Forest managed by Forestry Tasmania for multiple uses including timber harvesting. A detailed description of the Warra site can be found in Brown *et al.* (2001).

Transects

Two altitudinal transects were established to sample invertebrates. Transect A (referred to here as the Warra transect) was located within the Warra site and bisected by the South Weld Rd, covering an altitudinal range of 100–600 m and supporting *Eucalyptus obliqua* and *E. delegatensis* wet forests. Transect D (referred to here as the Mount Weld transect) was located immediately outside the Warra area on the north-eastern side of Mount Weld, covering an altitudinal range of 500–1300 m (note that the 500 m site was not used in invertebrate sampling). The vegetation changes with altitude from *Eucalyptus obliqua* and *E. delegatensis* wet forests through subalpine woodland to alpine heaths. The treeline on transect D occurs between the 1000 and 1100 m contour (Doran *et al.* 2003). The exact altitude of each sampling location is given in Table 2.1. A detailed description of each transect are given in *Doran et al.* (2003) and Grove (2004)

Pitfall sampling

The method of sampling invertebrates is described in detail in Bashford *et al.* (2001) and Doran *et al.* (2003). For each 100 m contour on transects A and D between 100 and 1300 m (excluding 500 m on transect D, and including two 600 m sites—one on each transect) an invertebrate sampling plot was established within the 50 by 20 m floristic plots established for each altitude surveyed. Ground dwelling invertebrates were sampled using pitfall traps arranged in a 2 by 3 grid within the 50 by 20 m plots, with the exact location of pitfalls depending on availability of sufficient soil and substrate to set the trap (Doran *et al.* 2003). As described in Bashford *et al.* (2001), pitfall traps consisted of a 15 cm length sleeve of 9 mm diameter PVC stormwater pipe sunk vertically into augured holes in the soil. A 425 ml plastic cup of matching diameter was fitted within each sleeve. To prevent rain and debris entering the cups directly, plastic food container lids were supported 3 cm above the cups on bamboo skewers. Each cup was filled 100 mm of either 33% (35.3 g/L) ethylene glycol for sheltered sites (below the treeline: 100–1000 m) or undiluted (1075 g/L) ethylene glycol for exposed sites (above the treeline: 1100–1300 m). In the last two months of the study, 5% glycerine/glycerol was added to the pitfall to improve the condition of specimens recovered for identification. The number of pitfall traps successfully set and retrieved is given in Table 2.1.

Table 2.1 Exact altitude of each sampling location on the Warra and Mount Weld transects, and the number of pitfall traps (maximum = 6) successfully set and retrieved for each altitude and month.

100-m contour	Exact altitude (m)	Feb 2001	Mar 2001	Apr 2001	Nov 2001	Dec 2001	Jan 2002	Feb 2002	Mar 2002	Apr 2002	Total
Warra											
100	105	6	6	6	6	6	6	6	6	6	54
200	190	6	6	6	6	6	6	6	6	6	54
300	315	6	6	6	5	6	6	5	4	6	50
400	360	6	6	6	6	6	6	6	6	6	54
500	536	6	6	5	6	6	6	6	6	6	53
600	585	6	6	4	6	6	6	6	6	6	52
Mount Weld											
600	620	2	5	5	6	6	6	6	6	5	47
700	739	6	6	5	6	6	6	6	6	5	52
800	840	6	4	5	6	6	6	6	6	6	51
900	920	6	6	6	6	6	6	6	6	6	54
1000	1010	6	6	6	6	6	6	6	6	6	54
1100	1105	5	6	5	6	6	6	6	6	6	52
1200	1188	6	6	6	6	6	6	6	6	6	54
1300	1300	6	6	6	6	6	6	6	6	6	54

Malaise trap sampling

Malaise traps were established at every second sampled altitude below the treeline, with an additional trap set at the lowest altitude (100, 200, and 400 m on the Warra transect; 600, 800, and 1000 m on the Mount Weld transect). The fragile nature of malaise traps made them unsuitable for the exposed conditions above the treeline (Bashford *et al.* 2001). Malaise traps were placed within each site at a location where suitable trees were available to hang them in the path of flying insects. Malaise traps consisted of a 28 gauge Terylene mesh tent with dark central panels and a light-coloured sloping roof, leading to a collection bottle containing 70% alcohol.

Sampling schedule and sorting

The sampling schedule is described in detail in Doran *et al.* (2003). Pitfall and malaise traps were set for a nominally four week period, although precise timing depended on weather conditions for helicopter access to the high altitude sites. Pitfalls on the Warra transect were established and allowed to settle in late December 2000. Access issues prevented this from occurring on the Mount Weld transect; on this transect pitfalls and malaise traps were established and opened over a three day period in late January 2001. Pitfalls were opened and malaise traps were established on the Warra transect the day after the traps on the Mount Weld transect were completed. Samples were collected at the end of February, March and April 2001, before traps were closed over winter and reset at the end of October 2001. Second season samples were taken at the end of November and December 2001, and January, February, March and April 2002. Pitfall traps were cleared by filtering the ethylene glycol through a 0.9 by 0.3 mm mesh and preserving the material in 70% alcohol. Malaise traps were cleared and reset by simply replacing the collection bottle with a new one.

All pitfall and malaise-trap material was sorted to major taxonomic groups under a stereo dissecting microscope in the laboratory. Most invertebrates were identified to the level of Order, however some were identified only to Phylum (Nemata) and Class (Gastropoda, Chilopoda, Diplopoda, Oligochaeta), and one group, the Formicidae, were identified to Family. For convenience we refer to the level of identification as Order. In addition, some of the material was sent to specialists for sorting and identification to species or morphospecies level (Amphipoda, Coleoptera, Collembola, Formicidae, Gastropoda, Orthoptera, Chilopoda and Diplopoda). The taxa chosen for species level identification was restricted by funding and availability of specialists. For the Coleoptera and Orthoptera, all sample material from all months was sorted to species or morphospecies level. For the remaining taxa, only a subset of months was sorted to species or morphospecies level (Table 2.2).

Table 2.2 Number of monthly samples of selected taxa sorted to species or morphospecies level.

Taxa	Sample months	No.
Amphipoda	February–April 2001, November–December 2001, January 2002	6
Chilopoda	February–April 2001, November–December 2001, January–February 2002	7
Coleoptera	February–April 2001, November–December 2001, January–April 2002	9
Collembola	February–April 2001, November–December 2001, January–February 2002	7
Diplopoda	February–April 2001, November–December 2001, January–February 2002	7
Formicidae	February–April 2001	3
Gastropoda	February–April 2001, November–December 2001, January–February 2002	7
Orthoptera	February–April 2001, November–December 2001, January–April 2002	9

3 AMPHIPODA (landhoppers)

by Alastair M. M. Richardson

Summary

1. The distributions of Amphipoda on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001, November–December 2001 and January 2002.
2. Seven species of amphipod were collected on the Warra-Mount Weld Altitudinal Transect, with four species dominating the catch: *Keratroides vulgaris, Mysticotalitrus cryptus, M. tasmaniae* and *Neorchestia plicibrancha*.
3. *Neorchestia plicibrancha* was the dominant amphipod at altitudes above about 900 m, and there was a sharp increase in *N. plicibrancha* between 1100 and 1200 m.
4. Although there is no absolute altitudinal cut-off, the point at which *N. plicibrancha* numbers sharply increase could serve as a climate change marker.
5. Since landhoppers are active dispersers their distributions are likely to respond quite quickly to climate change. They also have the advantages of being readily trappable, present all year and are reasonably easy to identify.

Tasmania's terrestrial amphipod fauna

Tasmania supports a diverse and interesting fauna of terrestrial amphipod crustaceans in the family Talitridae, generally known as landhoppers. The fully terrestrial species form the most evolutionarily advanced section of a larger assemblage that includes the supralittoral and intertidal talitrids and members of their sister family, the Hyalidae, which together represent a globally unique fauna that illustrates the terrestrial colonisation by this crustacean group (Richardson & Swain 2000, Richardson & Araujo in press).

Fifteen species of landhoppers in seven genera have been described from the mainland of Tasmania (Friend 1987) and two or three undescribed forms have been identified (see below). Three of the genera and all but one of the species are endemic to the Tasmanian mainland. None of the species show restricted geographical distributions and none are known to be threatened, however one undescribed *Mysticotalitrus* species may be restricted to high altitudes. Several species, although fully terrestrial, are known to be strongly restricted to coastal regions (Friend 1987, Richardson *et al.* 2003).

Strong niche partitioning and fine scale habitat preferences (Friend & Richardson 1977, Richardson & Devitt 1984) between landhoppers mean that it is common to find two or more species coexisting in samples.

Landhoppers may reach very high densities in forest litter, where they play an important role in decomposition and nutrient cycling (Friend & Richardson 1986, Richardson & Morton 1986). They feed selectively on decaying leaf material (Richardson & Morton 1986) and probably form an important item of diet for several other species, including antechinuses, lyrebirds and other invertebrate predators on the forest floor (Friend & Richardson 1986).

Taxonomic notes

The alpha-taxonomy of Tasmanian landhoppers was well-established by Friend (1987), and although two or three undescribed forms have been identified in the genera *Tasmanorchestia* and *Mysticotalitrus,* it is unlikely that a significant number of species remain to be found, thanks to the animals' good powers of dispersal and the resulting absence of geographically restricted species. Having said that, no molecular analysis has been carried out on the group, and this may well reveal smaller scale structuring. The very widely distributed *Keratroides vulgaris* shows a good deal of morphological variation and would be a prime candidate for a detailed molecular study.

Higher level classification within the Talitridae is much less certain. The family is globally distributed and includes a wide range of forms from intertidal, supralittoral, terrestrial and freshwater aquatic habitats. Bousfield (1982, 1984) has proposed some eco-morphological subdivisions within the family, of which one is relevant here. He proposed that the presence of an obscure character (the presence or absence of cusps at the base of the dactyls of the walking legs) marks a deep division within the landhoppers, separating an ancient lineage of Gondwanan origin (the simplidactylate species, lacking dactylar cusps) from a more recent group (the cuspidactylate species) with a likely origin from the supralittoral beachfleas.

The Tasmanian landhoppers largely fall in the simplidactylate group (*Austrotroides, Arcitalitrus, Keratroides, Mysticotalitrus, Neorchestia*), and interestingly the cuspidactylate genera are largely restricted to the wet west (*Tasmanorchestia, Orchestiella*).

Mount Weld amphipods: description of fauna and changes with altitude and habitat

Seven species of amphipod were collected on the Warra-Mount Weld Altitudinal Transect, with four species dominating the catch: *Keratroides vulgaris, Mysticotalitrus cryptus, M. tasmaniae* and *Neorchestia plicibrancha*. Overall, there is a clear altitudinal turnover of amphipod species as *N. plicibrancha* becomes the dominant species at higher altitudes (Table 3.1).

Of the minor species, the two species of *Austrotroides* occur very rarely in the November and December samples (Table 3.1). *Austrotroides leptomerus* appears to have a specialised habitat (axils of *Richea pandanifolia*, or other above ground litter accumulations) (Friend 1987, Richardson 1993). Friend (1987) notes that *A. longicornis* is rare, but gives no indication of a specialised habitat. *Orchestiella quasimodo* occurs consistently in low numbers below around 800 m; Friend (1987) notes that it commonly found in tea tree swamps and *Orchestiella* spp. have been collected elsewhere in saturated litter at the edge of rainforest seepages (AMMR, unpublished data). It would be of interest to examine the habitat immediately around the traps in which this species was caught to see whether the substrate was likely to be water-saturated.

Keratroides vulgaris generally dominates collections over the two *Mysticotalitrus* spp. on the lower parts of the transect (Table 3.1). Correlation analysis shows no evidence of a negative relationship between *K. vulgaris* and the other two species combined, either at the sampling station or individual trap level. These three species are members of the eastern forest group (Friend 1987) and are widespread in south-eastern Tasmania. On Mount Wellington, Richardson and Devitt (1984) showed that *K. vulgaris* only dominated this assemblage in gullies at lower altitudes, but also became codominant with *M. cryptus* at altitudes above about 900 m. *M. tasmaniae* was dominant in *Eucalyptus obliqua* forest litter away from gullies at lower and intermediate altitudes.

Neorchestia plicibrancha is clearly the dominant amphipod at altitudes above about 900 m (Table 3.1). It occurs in smaller numbers at lower altitudes and low numbers of *Keratroides vulgaris* are present in some collections at the higher sites (though never at 1300 m), however the increase in *N. plicibrancha* numbers above 1000 m is striking. Table 3.1 shows that for the 2001 sampling the sharp increase in *N. plicibrancha* occurs between 1100 and 1200 m. Mount Weld does not seem to show the same distributional patterns of landhoppers as those on Mount Wellington (Richardson & Devitt 1984), ie a re-appearance of *K. vulgaris* and *M. cryptus* above 900m. This may reflect Mount Weld's greater height and less maritime climate.

Possible indicator species

Although the landhoppers do not provide a single species or suite of species with an absolute altitudinal cut-off, the point at which *N. plicibrancha* numbers sharply increase could serve as a climate change marker. Since landhoppers are active dispersers their distributions are likely to respond quite quickly to climate change. They also have the advantages of being readily trappable, present all year and are reasonably easy to identify.

Table 3.1 Amphipods captured in pitfall traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Austrotroides longicornis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Austrotroides leptomerus	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2
Neorchestia plicibrancha	0	0	9	1	7	7	3	9	15	23	44	66	249	188	621
Mysticotalitrus cryptus	2	18	10	17	13	2	1	1	2	1	5	0	0	0	72
Mysticotalitrus tasmaniae	4	21	2	6	8	2	0	0	0	5	3	0	0	0	51
*Keratroides vulgaris**	32	138	57	80	12	20	48	11	9	11	5	0	14	0	442
Orchestiella quasimodo	0	0	1	25	6	2	0	6	3	0	0	0	0	0	43
Talitridae unidentifiable	2	15	0	6	4	0	2	0	0	3	1	0	0	0	33

*An additional five specimens of *Keratroides vulgaris* captured in the 1000 m malaise trap

4 CHILOPODA AND DIPLOPODA (centipedes and millipedes)

by Robert Mesibov

Summary

1. The distributions of Chilopoda and Diplopoda on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001, November–December 2001 and January–February 2002.
2. Pitfall trapping did not yield a large sample of Chilopoda and Diplopoda as these groups are more efficiently collected by hand.
3. Five centipede taxa, eight taxa of non-Polydesmida millipedes and ten species identifiable among the 39 specimens of Polydesmida millipedes were captured in pitfall traps.
4. With one exception, none of the Chilopoda or Diplopoda identified to species is potentially worth monitoring as a mountaintop species which might be disadvantaged by global warming. The exception, *Noteremus summus*, is inadequately known. *N. summus* is so far only known from the 11 specimens collected between 1100 and 1300 m on Mount Weld.
5. Use of pitfall traps using ethylene glycol limits the usefulness of Chilopoda or Diplopoda material for climate change monitoring and for general taxonomic and biogeographic purposes.

Tasmania's myriapod fauna

The Myriapoda include centipedes (Class Chilopoda), millipedes (Class Diplopoda), Pauropoda (Class Pauropoda) and Symphyla (Class Symphyla). There are about 300 species of myriapod (native plus introduced) in Tasmania. Nearly all of Tasmania's native myriapods are endemic to the state. There are also whole groups of myriapods found elsewhere in the world (including mainland Australia) which are not found in Tasmania (Mesibov 2012).

Notes on methodology

Chilopoda and Diplopoda were sorted to Order and counted at Forestry Tasmania (Grove 2004). They were among the invertebrate groups '*due to be sent to the Queen Victoria Museum (QVMAG) in Launceston in late 2004 for long-term storage*' (Grove 2004). Unfortunately the samples had not been curated 'for long-term storage'. They were in plastic blood-sample vials within plastic bags, and most of the alcohol in the vials had evaporated. The pitfall trapping had been done with ethylene glycol, in which myriapod specimens rapidly degrade. Only a few of the specimens were of enough interest and in good enough condition to be kept at QVMAG. Specimens were transferred to glass vials, with the original FT labels, for taxon-level storage. Trap-by-trap results were analysed only for Polydesmida millipedes.

Mount Weld Chilopoda and Diplopoda: description of fauna and changes with altitude and habitat

Pitfall trapping on Mount Weld in summer did not yield a large sample, which is not surprising. Chilopoda and Diplopoda, in particular, are more efficiently collected by hand (Mesibov *et al.* 1995, Snyder *et al.* 2006), and are more surface-active outside the summer months.

Chilopoda

Five centipede taxa were in the samples: *Craterostigmus tasmanianus*, *Cryptops* sp., *Henicops maculatus*, *Steneurytion* sp. and *Tasmanophilus* sp. The two identified species are widespread in

Tasmania from sea level to mountaintops. The same is true for the three genera not identified to species.

Diplopoda

The eight taxa of non-Polydesmida millipedes identified in the samples were two species of Spirostreptida, the pill millipede *Procyliosoma* sp., the polyzoniidans 'AcuMes' and 'SipTas', and three chordeumatidan species: *Australeuma jeekeli*, *A. simile* or *A. golovatchi* (not identifiable due to specimen degrade) and *Neocambrisoma*? sp. While Spirostreptida can be found from sea level to the highest elevations in Tasmania, the other taxa are only occasionally found on mountaintops.

Ten species were identifiable among the 39 Polydesmida specimens recovered from the samples: *Asphalidesmus parvus*, *Atalopharetra bashfordi*, *Atalopharetra johnsi*, *Atrophotergum montanum*, *Gasterogramma austrinum*, *Noteremus summus*, *Paredrodesmus bicalcar*, *P. purpureus*, *Tasmaniosoma australe* and 'M68' (Table 4.1). All except *N. summus* and 'M68' are known to occur at a range of elevations within their respective distributions. *N. summus* is so far only known from the 11 specimens collected between 1100 and 1300 m on Mount Weld. 'M68' was collected at 600 and 700 m on Mount Weld and has been found at a lower elevation near Scotts Peak. A faint indication of altitudinal preference within a polydesmidan genus on Mount Weld was found with *Atalopharetra*: eight males of *A. johnsi* were recorded between 400 and 1100 m compared with six males of *A. bashfordi* between 100 and 1300 m (Table 4.1). The previously known elevation ranges for *A. johnsi* was 120–790 m and for *A. bashfordi* was 40–450 m.

Possible indicator species

With one exception, none of the Chilopoda and Diplopoda identified to species from the 2001–2002 sampling is potentially worth monitoring as a mountaintop species which might be disadvantaged by global warming. The exception, *N. summus*, is inadequately known. It may occur at lower elevations on Mount Weld, and it may also occur at other locations in far southern Tasmania, which has not yet been adequately sampled for multipedes (Mesibov 2009). Repeated pitfall trapping on Mount Weld is unlikely to change this picture, and if ethylene glycol is used in the traps, the usefulness of Chilopoda and Diplopoda material for monitoring and for general taxonomic and biogeographic purposes will again be greatly reduced.

Table 4.1 Polydesmida millipedes captured in pitfall traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Paredrodesmus bicalcar	0	0	0	0	0	1	0	0	0	0	1	0	1	0	3
Atalopharetra bashfordi	0	0	0	0	0	0	0	0	0	0	0	1	2	3	6
Noteremus summus	0	0	0	0	0	0	0	0	0	0	0	6	1	4	11
Tasmaniosoma australe	0	0	1	1	1	0	0	0	0	0	0	1	2	0	6
Atalopharetra johnsi	0	0	0	5	0	0	1	1	0	0	0	1	0	0	8
Paredrodesmus purpureus	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
‘M68’	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
Atrophotergum montanum	0	0	0	0	0	0	1	0	0	0	0	0	0	1	2
Asphalidesmus parvus	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
Gasterogramma austrinum	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2

5 COLEOPTERA (beetles)

by Lynne Forster and Simon Grove

Summary

1. The distributions of Coleoptera on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001, November–December 2001 and January–April 2002.
2. The Warra-Mount Weld Altitudinal Transect is a significant contribution to knowledge about Tasmanian beetles because it provides the first methodological study of Tasmanian beetles associated with altitude.
3. Beetles from 56 families were collected along the Warra-Mount Weld Altitudinal Transect. The dominant four families were Carabidae, Curculionidae, Leiodidae and Staphylinidae.
4. Carabidae numerically dominated assemblages above 1000 m, while Curculionidae, Leiodidae and Staphylinidae were in relatively lower numbers at higher altitudes.
5. Most species occurring at high altitudes were widespread, euryaltitudinal species.
6. A small number of apparently stenotypic specialists were present, albeit in low numbers: *Calytogonia atra occidentalis* (Carabidae), *Nat vandenbergae* (Coccinellidae), *Notolioon gemmatus* (Byrrhidae), *Coripera adamsi* (Tenebrionidae), *Semelvillea tasmaniae* and *Microdonacia truganina* (Chrysomelidae).
7. Beetles are relatively cost-effective to sample, occupy a diversity of habitats and comprise a variety of feeding guilds which provide multiple strata within which change might be observed. More mobile winged species not dependent on particular plant species are likely to be a component of the beetle fauna that will adjust their distributions more quickly in response to climate change. Flightless and ground-active beetles inhabit environments with more stable microclimates and may therefore adjust their distributions more slowly.

Tasmania's beetle fauna

Tasmania's beetle fauna has been documented based on a variety of sampling techniques, particularly pitfall trapping, which targets the ground-active litter fauna (Mesibov 1998, Michaels & Bornemissza 1999, Grove & Yaxley 2005, Baker 2006, Baker *et al.* 2009); direct sampling from log sections (Yee *et al.* 2001), and log emergence enclosures (Grove & Bashford 2003, Hopkins *et al.* 2005), which target saproxylic species; flight intercept traps and fogging of rainforest canopy, which target aerially active species (Bashford *et al.* 2001); and direct sampling of tree-ferns, which samples species belonging to various trophic levels on these plants (Fountain-Jones *et al.* 2012). The fauna from wet sclerophyll and mixed forests is better known than for other vegetation types, since these habitats have been the major focus of research conducted to date.

Over 1700 genera in 102 families of beetles have been recorded from Tasmania, of which only perhaps a third of the component species have been described. Several features characterise the importance of the fauna.

Ecologically important function

Beetles are important recyclers of nutrients in litter, wood, foliage, fungi and dung. Some, such as the eucalypt flower-feeding *Boganium armstrongi* (Boganiidae), are plant pollinators (Lawrence & Britton 1994); many are a food source for birds, reptiles and birds. Predatory species such as

Chauliognathus (Cantharidae), *Cleobora mellyi* and *Harmonia conformis* (Coccinelidae) control populations of potential insect pests.

It is thought that over half of Tasmania's beetle species are obligatory or facultatively saproxylic and include genera which are threatened in Europe due to loss of dead-wood habitat. Examples include *Prostomis* (Prostomidae), *Corticaria* (Latridiidae), *Litargus* (Mycetophagidae), *Quedius* (Staphylinidae) and *Dromaeolus* (Eucnemidae).

Endemic species of Gondwanan origin

Tasmania has a diversity of wet forest species which reflect their origin in the cool, wet, temperate forests of Gondwana. Many have retained their association with *Nothofagus (*e.g. *Nascioides quadrinotatus*; Buprestidae) whose larvae feed on the cambium of *Nothofagus* (Williams 1987), the corticolous *Egolia variegata* (Trogossitidae), *Pseudometyrus cylindricus* (Curculionidae) and *Teredolaemus laei* (Bothrideridae) which feeds on yeasts in tunnels of Patypodinae weevils (Lawrence & Britton 1994).

Tasmanian genera also found in both South America and New Zealand pre-date the late Cretaceous Period and include the corticolous, mould-feeding *Nothoderodontus* (Derodontidae), fungus-feeding *Aridius, Enicmus* and *Latridius* (Latridiidae), and predatory *Metacorneolabium* (Staphylinidae). In common with South America, Tasmania shares the genera *Syllitus* (Cerambycidae), *Neopelatops* (Leiodidae), *Chauliognathus* (Cantharidae), *Cryptamorpha* (Silvanidae), and *Mordella* (Mordellidae) and has many closely related genera including *Syndesus* (Lucanidae). New Zealand shares Tasmanian genera such as *Microbrontes* (Laemophloeidae), *Brachypeplus* and *Soronia* (Nitidulidae), *Lemidia* (Cleridae) and *Dryocora* (Prostomidae) and has genera which are closely related to, for example, *Lissotes* (Lucanidae) and *Semelvillea* (Chrysomelidae).

A climatic refugium for basal representatives of Gondwanan wet-forest taxa

Tasmania has provided a significant refugium for plesiomorphic members of a number of tribes, genera and species of Australian beetles. It is thought that Pleistocene conditions in Tasmania were not as extreme as in other parts of Australia, so plesiotypic species survived with little need for the rapid evolution and speciation that occurred in mainland Australia (Erwin 1972, Baehr 1997). Thus, Tasmanian wet forests often have fewer species within a genus and these are frequently endemic, widespread and accompanied by perhaps one or two locally restricted members of the same genus. Examples in the Carabidae include Tasmania's endemic and widespread *Notonomus politulus* and rare *N. tubericauda* (Carabidae: Pterostichinae), yet 107 species in this genus occur Australia-wide; and *Tasmanitachoides hobarti* (Carabidae: Trechinae) which is basal to 22 mainland species (Erwin 1972).

Further endemism at the genus level is also prevalent, e.g. *Mamillanus*, *Pogonoschema*, *Sloanella* , *Tasmanorites*, and the cavernicolous *Geodetrechus* in the Trechini (Carabidae), a tribe restricted to cool wet temperate forests (Moore 1972).

Australian sclerophyll endemics

The breakup of Gondwana was followed by a drying and spread of sclerophyllous vegetation as Australia drifted north. Tasmania has a number of plesiotypic species of xerophilic taxa which evolved with the spread of sclerophyll vegetation e.g. *Pterohelaeus*, *Saragus* and *Celibe* (Tenebrionidae: Heleini: Heleina) (Matthews 2000) and *Adelotopus* (Carabidae: Pseudomorhinae) Baehr (1997) which all evolved flattened body shapes with flanges for living under bark. It also has species in the endemic Australian families Lamingtoniidae and Myraboliidae.

The Warra-Mount Weld Altitudinal Transect is a significant contribution to knowledge about Tasmanian beetles because it provides the first methodological study of Tasmanian beetles associated with altitude. Previous knowledge about such associations has been gleaned from opportunistic collecting, particularly in the Central Highlands, Hartz Mountain and Mount Wellington.

Mount Weld beetles: description of fauna and changes with altitude and habitat

A total of 8985 beetles, belonging to 510 species in 56 families, were collected from the Warra-Mount Weld Altitudinal Transect. Three-quarters of these were from pitfall traps (6794 beetles representing 300 species), and one-quarter from malaise traps (2191 beetles representing 319 species). Altogether, 211 species were caught only in malaise traps, 192 species were caught only in pitfalls traps, and 108 species were caught by both methods.

Four families of beetles were represented by sufficient species to examine their overall patterns of distribution in relation to altitude (Table 5.1). In Carabidae, species richness was highest above 1000 m (Fig. 5.1a). However, for Curculionidae, Leiodidae and Staphylinidae, species richness was lower at the higher altitudes (Fig. 5.1b, c, d).

Taxonomic notes

Calyptogonia atra occidentalis is a subspecies of flightless carabid that has been recently formally described from material collected during this study on Mount Weld (Baehr 2013). The genus *Calptogonia* (Carabidae: Migadopinae) is endemic to Tasmania and the type subspecies, *C. a. atra,* is only known from its original collections in the early 1900s in the western Central highlands. The new subspecies, which is only known from above about 840 m on Mount Weld, raises the possibility that the isolated tops of Tasmanian mountains may host further cryptic species or subspecies.

All known stenoaltitudinal, high-altitude Carabidae species in Tasmania are members of Migadopinae which is a Gondwanan subfamily shared with South America and New Zealand. Other Tasmanian high-altitude specialists from this subfamily, *Migadopiella octoguttata* and *M. convexipennis*, were not found at Mount Weld; they may be restricted to the Central Plateau (Baehr 2009).

Within Scarabaeidae, Britton (Britton 1987) describes *Telura* as closely related to a Southern Chilean genus and states that *Telura* is a montane genus in Tasmania and south-eastern Australia. Two species occur in Tasmania, *T. vitticollis* and *T. alta*. It would appear, however, that *T. vitticolis* is not restricted to high altitudes, as it occurred in pitfall traps along the Warra-Mount Weld Altitudinal Transect at 400 and 600 m and has been recorded at low altitudes in other studies in Warra and elsewhere in Tasmania (e.g. Grove 2009). On the other hand, *T. alta* has only been collected at high attitudes in Tasmania, though not along the Warra-Mount Weld Altitudinal Transect.

A small number of Chrysomelidae associated with higher altitudes have been described for Tasmania. *Semelvillea tasmaniae* (Galerucinae) is the sole Tasmanian representative in a genus of rare species found only at moderate to high altitudes with restricted geographic ranges. It is considered to be plesiomorphic to Australian mainland species (Reid 1991). Similarly, *Microdonacia truganina* (Galerucinae) is an endemic Tasmanian species associated with *Nothofagus* in a genus of largely rare species with restricted ranges at high altitudes (Reid 1992). The exceptions are *M. octodentata* (Tasmanian endemic) and *M. incurva* (Tasmania and Victoria) which are widespread. Another endemic Tasmanian species, *Ewanius nothofagi* (Chrysomelinae: Gonioctenini), is the sole representative of a genus that is plesiomorphic within Gonioctenini (Reid 2002). *Ewanius nothofagi* has only been collected in Central Tasmania at altitudes above 600 m and was not collected along the Warra-Mount Weld Altitudinal Transect.

Work on the taxonomy of Tasmania's beetle is ongoing, with a large number of morphologically distinct taxa still undescribed. The use of standardised code-names for such species has facilitated work on their ecology and distribution, although the consistent identification over time of some 500 species for a project such as the Warra-Mount Weld Altitudinal Transect remains problematic. For this reason, if there is ever a need to identify indicators of climate-change amongst the beetles of Mount Weld, then it will be necessary to select a suite of adequately abundant, distinctive target species to minimise these taxonomic issues, as discussed below.

Changes with altitude and habitat

The number of species shared between pairs of sites can be seen in Fig. 5.2. The higher-altitude sites shared the fewest species with all other altitudes, as demonstrated by the lines bearing solid black symbols (Fig. 5.2). Sites at other altitudes shared a decreasing number of species as altitude increased; this trend was particularly apparent for the lower-altitude sites, represented by the lines bearing unfilled symbols (Fig. 5.2).

If adjacent sites shared more species than distant sites, this would have been evident in a hump-shaped curve shifting across each altitude for successively higher altitudes of the comparison sites. Instead, pairs of sites compared with any altitude mirrored each other in their steady decrease. All sites shared a higher number of species with low-altitude sites and a low number of species with high-altitude sites. This suggests that species from the lowland assemblages are gradually lost as altitude increases such that species with the widest altitudinal range persist to the highest altitudes.

What this means is that assemblages at high altitudes are effectively nested subsets of lower-altitude assemblages, with altitude successively filtering out species from the lowland species-pool. Darlington (1961) similarly observed that Tasmanian high-altitude carabids primarily comprised a reduced subset of lowland species rather than specifically alpine-adapted species.

Many pitfall-trapped species (113) were unique to single altitudes (Fig. 5.3). However, the lack of replication of sites at a given altitude, and the generally low abundance of the species concerned, means that it would be premature to assume that such species are restricted to a single altitude.

Table 5.1 Number of specimens per species for four beetle families with sufficient species to examine overall patterns of distribution in relation to altitude.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
CARABIDAE															
Prosopogmus tasmanicus		1													1
Simodontus australis		10													10
Lestignathus cursor			2	2	1										5
Lestignathus foveatus				3	6			1							10
Percosoma carenoides							2		4						6
Chylnus ater		7	18	7	3				1						36
Pterocyrtus globosus				2	2	9		2	3	96	7				121
Acallistus TFIC sp 01				1				1	4	1	6				13
Sloaneana tasmaniae	1	8	11	41	30			46	2	57	9	7			211
Acallistus longus	1	12	35	23	9		1					17	15	5	117
Notonomus politulus	5	37	19	12	2		1					2		2	75
Promecoderus gibbosus		2	2	2		3					2	44	30	29	114
Rhabdotus reflexus	42	38	69	12	10	42	6	11	76	8	6	20	34	9	341
Stichonotus piceus			5	10	6	1		5	4	160	24	11	123	55	404
Pterocyrtus TFIC sp 02					3	2		12	9	112	3	1	1	1	144
Notagonum marginellum												2			2
Tasmanorites nitens												30			30
Pogonoschema robustum								1		2			2		5
Percodermus niger											1	18	1		20
Tasmanorites sp aff *tasmaniae*												199	1		200
Paratrechodes macleayi												1			1
Amblytelus montiscampi												1	1	1	3

Promecoderus TFIC sp 01													1		1
Mecyclothorax ambiguus														1	1
Trechistus terricola				1			1		1	101	62	18	1	2	187
Scopodes boops											2	11	2	10	25
Calyptogonia atra occidentalis										4		9	5	11	29
CURCULIONIDAE															
Decilaus TFIC sp 01		1	1	2											4
Decilaus TFIC sp 02					1										1
*Decilaus T*FIC sp 21					1										1
Mandalotus blackburni			1	1	1										3
Decilaus bryophilus	2	1	1		6										8
Decilaus TFIC sp 24								2							2
Mandalotus arciferus	1	3	4	8	6	11		4							36
Decilaus lateralis			3	2	8	1		6	2						22
Decilaus nigronotatus			6	3	14	4		5	6						38
Decilaus TFIC sp 23			1		1	1			1						4
Decilaus striatus			2	11	9	8		3		1					34
Decilaus TFIC sp 03		1			12	5		3	4	5					30
Roptoperus tasmaniensis		2	8	27	13	6	2	3		3					64
Decilaus TFIC sp 22									1		2				3
Mandalotus muscivorus	1	3	4	2	4	2		3	4	13		1			36
Decilaus TFIC sp 04		1	2	12	24	11	1	3		2			1		57
LEIODIDAE															
Sogdini SEAGO gen nov A TFIC sp 01				8		2									10
Nargiotes gordoni			6	3	4	4	1								18
Zeadolopus TFIC sp 02	2	1	2	8	2	1	1	1							16

Catoposchema tasmaniae			5	3	2		7	3	13			33
Sogdini ANIC gen B TFIC sp 01			2	6	1	8	4	6	3			30
Choleva TFIC sp 01	2	8	24	10	7	20	123	46	225	59		522
STAPHYLINIDAE												
Quedius baldiensis	5	2										2
*Quedius sidneensis**	1	7										7
Rybaxis CHANDLER Tasmania 1			2		1	1						4
Zyras TFIC sp 01	5	1	19	23		1	1					45
Atheta TFIC sp 01	1		8	1		3	2					14
Anotylus TFIC sp 04							23	2				25
Atheta TFIC sp 02			1		1		1	3	1			7
Aleocharinae TFIC sp 057	1		2	1		4	6	8	51			72
Anotylus TFIC sp 02				2					3	1		6
Atheta TFIC sp 03	1	4	26	72	15	44	154	42	61	19		437
Rybaxis parvidens	1		1	1		2					1	5

*collected in malaise traps

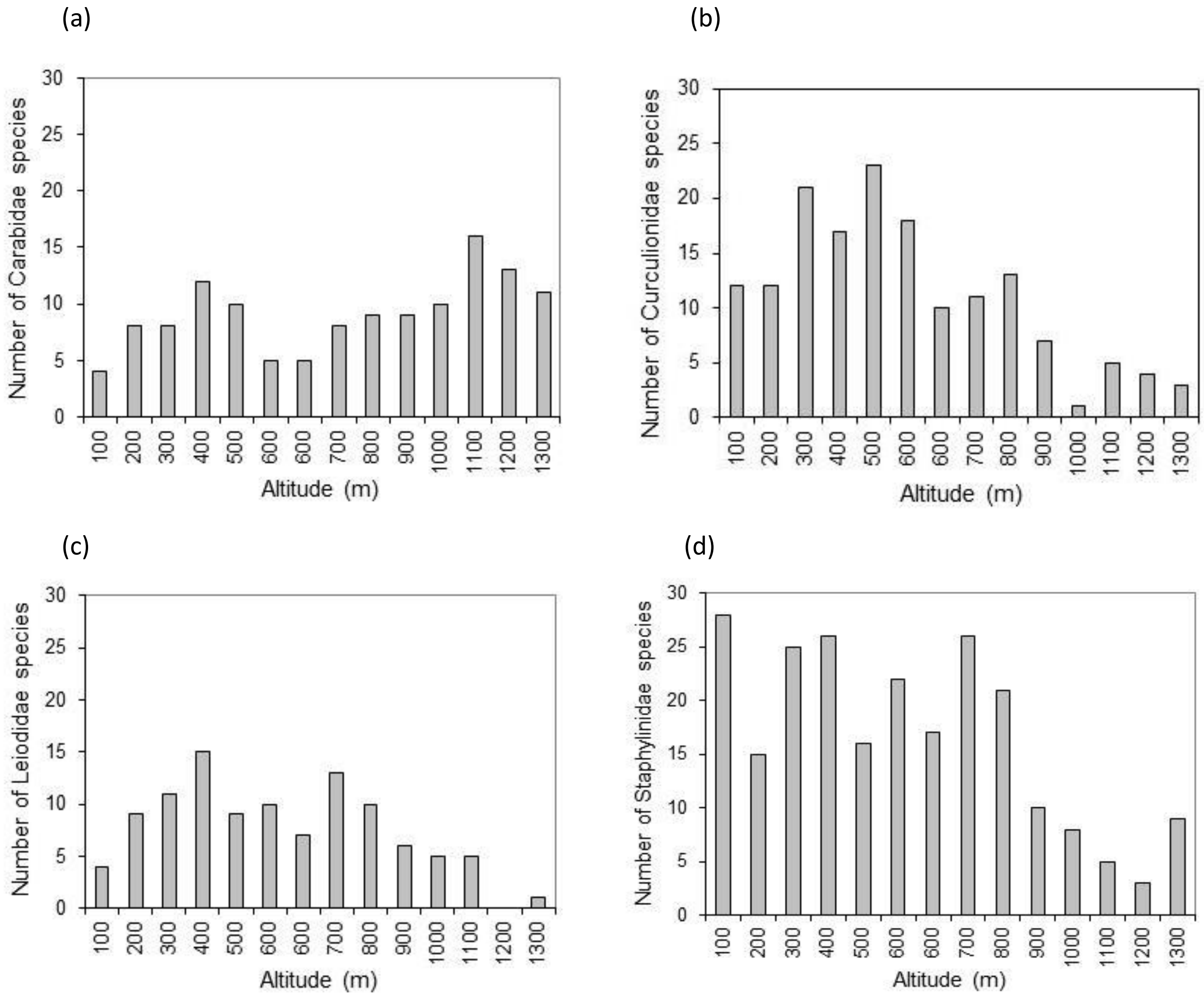


Fig. 5.1 Number of species at different altitudes within four dominant families found in pitfall samples: (a) Carabidae, (b) Curculionidae, (c) Leiodidae, (d) Staphylinidae.

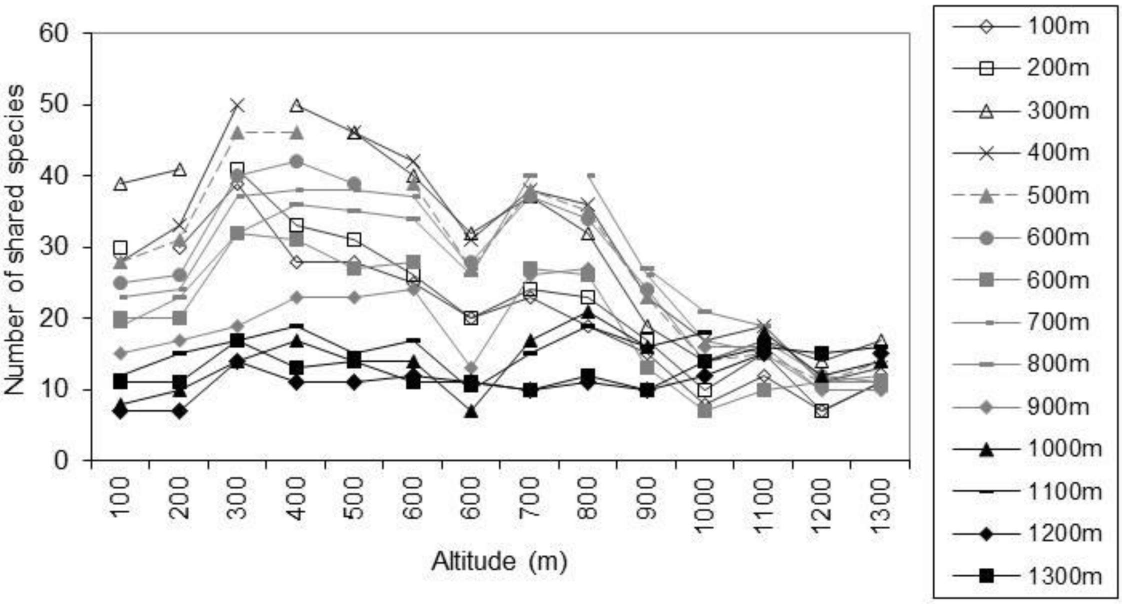


Fig. 5.2 Number of species shared between each pair of altitudinal groups. Each line plots the number of shared species between one altitude (e.g. 100 m) and each of the other attitudes.

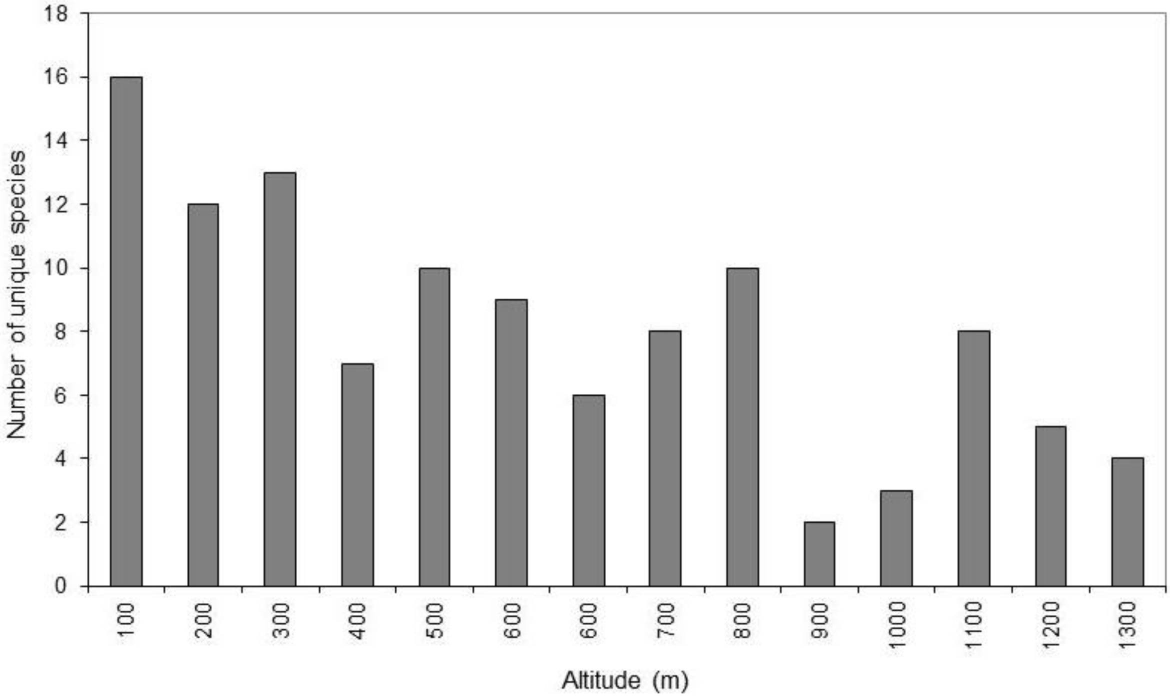


Fig. 5.3 Number of pitfall-trapped species unique to each altitude.

Taxa linked to particular altitudinal ranges

Most of the beetle species found at high altitudes are euryaltitudinal, i.e. they are found from low to high altitudes. However, a few apparently stenoaltitudinal, high-altitude specialists were identified (Fig. 5.4).

- *Calyptogonia atra occidentalis* (Carabidae: Migadopinae) 36 specimens, 900–1300 m, flightless, only known from Mount Weld.
- *Nat vandenbergae* (Coccinelidae: Coccinelinae: Coccidulini) two specimens in malaise traps at 800 and 100 0m, winged. The species (and genus of which the species is the sole member) is a rare Tasmanian endemic, having only been collected a few times in southern Tasmania. However, it should be noted that two specimens have been collected below 300m at Warra.
- *Notolioon gemmatus* (Byrrhidae: Byrrhinae) four specimens, 1100 and 1200 m. This cryptic, flightless Tasmanian endemic species, associated with moss, is uncommon but widespread at higher altitudes.
- *Coripera adamsi* (Tenebrionidae: Lagriinae: Adeliini) one specimen, 1300 m, flightless, Tasmanian endemic. This is an uncommon species found in low numbers at high altitudes.
- *Semelvillea tasmaniae* (Chrysomelidae: Cryptocephalinae) four specimens in malaise traps at 800 m and at 1000m, winged. This endemic species was originally described as associated with *Nothogafus cunninghami* from Hartz Mountain at 800 m (Reid 1991). *Semelvillea tasmaniae* has been recorded from altitudes below 300 m at Warra (Yee 2005) and its occurrence on Mount Weld further extends its range.
- *Microdonacia truganina* (Chrysomelidae: Galerucinae) eight specimens in a malaise trap at 1000 m, winged. An endemic, rare species only previously collected above 1000 m at Mount Field and the summit of Mount Wellington (Reid 1992). Its occurrence on the Warra-Mount Weld Altitudinal Transect extends the range of high altitude locations at which it may be encountered.

Fig. 5.4 High-altitude beetles found at altitudes from 900 to 1300 m. Left to right: *Calyptogonia atra occidentalis* (Carabidae), *Nat vandenbergae* (Coccinelidae), *Notolioon gemmatus* (Byrrhidae) and *Coripera adamsi* (Tenebrionidae).

A few additional species were found only at high altitude on Mount Weld. These include the stag-beetles *Lissotes bornemisszai* and *L. subcaeruleus* (Lucanidae), which are associated with rotting logs, and the flighted ground-beetle *Scopodes boops* (Carabidae), which favours open ground. However, they cannot be considered high-altitude specialists because they also occur regularly at low altitudes, including at Warra (where *S. boops* is a characteristic species of younger silvicultural regeneration). Other researchers have also noted their presence at low altitudes (Michaels & Bornemissza 1999, Baker *et al.* 2009, Grove 2009).

Possible indicator species

Four families of beetles were represented by sufficient species to examine their overall patterns of distribution in relation to altitude (Carabidae, Curculionidae, Leiodidae, Staphylinidae; Table 5.1). This assemblage of coleopteran species provides a multispecies data set which could potentially be used to examine the effects of climate change on an invertebrate species assemblage over the Warra-Mount Weld Altitudinal Transect. Within these families, several species occur in relatively large numbers and over a very restricted altitudinal band (e.g. *Tasmanorites* sp. aff tasmaniae 1100–1200 m, *Percodermus niger* 1000–1200 m, *Tasmanorites nitens* 1100 m; all in the family Carabidae); these three species are potentially useful indicator species. In addition, the handful of species identified as steno-altitudinal (high-altitude specialist) found at altitudes from 900–1300 m (*Calyptogonia atra occidentali* Carabidae, *Nat vandenbergae* Coccinelidae, *Notolioon gemmatus* Byrrhidae and *Coripera adamsi* Tenebrionidae) also represent potential indicator species.

6 COLLEMBOLA (springtails)

by Penelope Greenslade and Singarayer Florentine

Summary

1. The distributions of Collembola on the Warra-Mount Weld Altitudinal Transect were investigated based on samples taken from February–April 2001, November–December 2001 and January–February 2002.
2. The Collembola of the Warra-Mount Weld Altitudinal Transect was species rich with more than 40 species collected; the majority of species recorded have not been described.
3. Most of the species collected are considered endemic to Tasmania and some endemic genera were present.
4. The Malaise traps performed well indicating that a suite of species are arboreal and highly vagile.
5. No exotic (introduced, alien) species were detected in this study indicating that the area sampled has been little disturbed and is of high conservation value.
6. Altitudinal trends were evident with a small number of species only occurring at the high altitudes and others only at low altitudes. Only a few species appeared to occur at all altitudes sampled.
7. Ordination plots showed that Collembola assemblages at lower altitude sites on the Warra transect were more similar to each other than those at the higher altitude sites on Mount Weld which formed three clusters: 1100; 1200 and 1300 m; and 800, 900 and 1000 m.
8. Mount Weld sites 600 and 700 m faunas were most similar to Warra sites so forming a continuum in altitudinal zonation between Warra and Mount Weld.
9. PERMANOVA analysis of monthly pitfall catches in 2001 and 2002 showed differences between months and altitudes on both transects and that the differences between months were more distinct at the lower altitude Warra sites than on the higher altitude Mount Weld sites. This difference was particularly marked for the month of February, which was the only month surveyed in both years.
10. Much of the change in faunal assemblages along the Warra and Mount Weld altitudinal transect seemed to be the result of changes in vegetation cover. The most abrupt faunal transitions took place across the tree line between 1000 and 1100 m and a smaller change from lowland forest to subalpine woodland on the Mount Weld transect.
11. Much material in the pitfalls was in very poor condition because of the long trapping time with unsuitable preservative so could not be identified to species but rough estimates were made of numbers of individuals in each family or genus.

Tasmania’s collembolan fauna

The Tasmanian collembolan fauna consists of nearly 85 genera including 17 genera with only introduced species and five genera endemic to Tasmania (Table 6.1) (Greenslade 1987, 2007). In Australia as a whole, there are 144 genera and subgenera of which 23 are endemic. Tasmania therefore has a high proportion (25%) of endemic genera although its land mass is only 1% of the continent. This is probably because of its complex topography, wide range of vegetation types, humid climate and relatively intact native vegetation over nearly half the island. The number of species in Tasmania is around 120, a third of the 361 species currently recorded for the whole of

Australia. A catalogue of Australian Collembola giving distributions of each species is freely available online (Greenslade 2007).

Of the native Tasmanian genera, close to 50% have cosmopolitan distributions and 23% have Gondwanan distributions. The remainder comprise Australian endemics (19%), Tasmanian endemics (7%) and genera from the northern, warmer parts of Australia and south-eastern Asia (Greenslade 1987). The preferred vegetation types and habitats of the endemic genera are varied (Table 6.1).

The vegetation types with highest conservation value, based on the presence of endemic genera are *Nothofagus* rainforest, montane vegetation and buttongrass moorland (*Gymnoschoenus sphaerocephalus)*. Disturbed habitats such as cropping land, improved pastures and horticultural situations tend to be dominated by introduced exotic species and genera, some of which are considered pests. For instance, *Sminthurus viridis*, the clover springtail, is a pest of poppies and cucurbits in northern Tasmania and *Protaphorura fimata* feeds on roots and seedlings and can cause total non-emergence of peas and poppies also in northern Tasmania (Greenslade 2007).

Comments on field methods

Survey methods are provided in Chapter 2 of this compilation of reports. Because Malaise traps and pitfall traps were used to collect Collembola, only the arboreal and more active ground species were caught and not soil-living or humus restricted species. As the active species are those most likely to be affected by environmental change, these methods were appropriate ones to fulfil the overall aims of the study.

The methods used in this survey were not ideal for collecting and preserving soft bodied, minute invertebrates, such as Collembola, so that results may be biased to some extent. The Malaise trap samples were in better condition than the pitfall trap samples. This was because they had been collected directly into 70% ethanol rather than ethylene glycol. This latter preservative is not normally used for Collembola, as it does not preserve them adequately. In addition, the pitfall traps had been left out for four weeks resulting in dilution from surface runoff and some decay and damage to Collembola; one week is normally the maximum for this group. Also, catches were sieved through a 0.9 by 0.3 mm sieve, and the specimens retained on the sieve sorted to Order. This procedure certainly again led to loss and damage of specimens, as many Collembola are less than 0.9 mm in length. In all, 14 sites were sampled at 13 altitudes, six on Warra and eight on Mount Weld with six pitfalls run at each site as described earlier in Chapter 2 (Table 6.2). Two sites, one on the Mount Weld transect and one on Warra transect, were at the same altitude of 600 m.

Identification

As only about 20% of the Australian Collembola fauna is described, not all species could be identified below genus. However the different species could be distinguished and were therefore considered morphospecies and so numbered rather than named.

Analysis

Differences in species composition between sites were assessed using non-metric multidimensional scaling (MDS) based on a Bray-Curtis distance/similarity matrix. This ordination arranges sites in a reduced set of dimensions based on the rank order of similarities so that similar objects are near each other and dissimilar objects are farther away. We have used square-root transformed data for all analyses, taking the option for a dummy variable in the Bray-Curtis calculation because there are a few site/altitude/month combinations with sparse data. The goodness of the fit of the ordination plot is indicated by a stress value < 0.20 (Clarke 1993).

Only pitfall data were analysed as the Malaise trap collections were more limited in altitude and species collected. Because not all six pitfalls were retrieved from each site due to disturbance (e.g. from lyrebirds), mean numbers per pitfall were used in the analysis.

To investigate the effect of month and altitude on Collembola assemblages we used a two-way crossed design with no replication using PERMANOVA. Each transect was analysed separately. Note that sites are confounded with altitude because all sites on the Warra transect range from 100 to 600 m altitude and all Weld sites range from 600 to 1300 m altitude.

Primer 6© (Primer-E, Ltd, Lutton U.K) was used for multivariate analyses.

Results

Over 40 species and morphospecies were collected. No exotic (introduced) species were collected and it is likely that most if not all species, based on current knowledge, were endemic to Tasmania and some even local endemics.

Description of fauna and changes with altitude and habitat

Malaise traps

Sixteen species/morphospecies were collected (Table 6.3) altogether on both transects, which is relatively high for an arboreal collection. Abundance also was high with nearly 2500 specimens counted. Altitude changes in abundance were evident with relatively low numbers at 100 m, 600 m and 1000 m. The highest numbers of Collembola were at 200–400 m. There was a distinct change in family composition with altitude with the elongate Entomobryidae being more abundant up to 400 m and the globular Katiannidae and Bourletiellidae more abundant at higher altitudes. Exceptions to this family pattern were the elongate Paronellidae species which responded differently with sp. 1 and sp. 2 more common below 600 m and sp. 3, sp. 4 and sp. 5 more common above 600 m, although numbers of some species were low (≤10). This change is certainly related to changes in vegetation, in particular, the loss of tree cover and an increase in low, heathy vegetation although species restricted to higher altitudes were only in low numbers. One other globular family, the Dicyrtomidae, appeared restricted to lower altitudes in the malaise traps but few individuals were collected. This family is highly dependent on moist conditions so is normally restricted to ground habitats and would not be expected to be trapped above ground. The genus *Cassagnella* was rare and is normally a leaf litter inhabitant.

Pitfalls

A total of 6488 specimens were identified belonging to over 40 species (Table 6.4) from both transects and so provided a more complete inventory of the species present in the transects than did the Malaise traps. Collembola abundance in pitfall traps was overall greater at the higher altitude sites on the Mount Weld transect than at the lower altitude sites on the Warra transect (Table 6.2). Considering the Warra transect data alone, abundance was similar from 100 to 400 m and then dropped at 500 and 600 m. There was no apparent trend in species richness on this transect although species richness was highest at 400 m. On the Mount Weld transect abundance generally increased with altitude to 1100 m and then dropped at 1200 and 1300 m. Species richness on this transect tended to decrease with altitude with the lowest number of species recorded at 1200 and 1300 m.

More individuals were caught in 2002 compared to 2001 (mean numbers per trap in Feb. 2001 = 2, Mar. 2001 = 12, Apr. 2001 = 7, Nov. 2001 = 7, Dec. 2001 = 11, Jan. 2002 = 16, Feb. 2002 = 23). In particular, the February 2002 samples had many more specimens than the February 2001 samples. The most abundant taxa were *Acanthomurus* sp., *Isotoma* sp. 1, *Lepidophorella* sp., cf. *Pseudachorutella* sp., immature Symphypleona, Odontellidae, Dicyrtomidae, immature *Poduromorpha*, Paronellidae sp. 5, in that order (Table 6.4).

Few species were distributed evenly over the Mount Weld transect compared to Warra (Table 6.4), and many showed distinct altitudinal preferences as indicated by the number caught in traps. Species that were also collected in Malaise traps showed the same altitude preferences as shown by the pitfall catches except perhaps for the Dicyrtomidae. This apparent restriction of Dicyrtomidae to low altitudes in Malaise samples but presence in pitfalls at higher altitudes reflects the biology of this family with regards to movement above the ground in different microclimatic conditions. The pitfall fauna was dominated by different species compared to the Malaise traps and was richer in species. Several species in the same genera showed different altitudinal distributions notably *Isotoma* sp. 1 and 2, Paronellidae sp. 2, and sp. 4, 5 and 6, and *Lepidocyrtus* sp. 1 and 2 and possibly Paronellidae sp. 3.

Possible indicator species

Based on the Malaise trap catches, two *Katianna* species, *Rastriopes* sp. 1 and *Paronellides* sp. 5 appear to show a preference for the higher altitudes while *Lepidocyrtoides* sp. 1 is abundant in traps at mid to low altitudes at Warra (200–400 m). The pitfalls caught *Paronellides* sp. 4, *Paronellides* sp. 5, several Katiannidae species, *Lepidocyrtus* sp. 2 and *Isotoma* sp. 2 in highest numbers at high altitudes.

On the other hand *Isotoma* sp. 1, Odontellidae and Neanuridae and other Poduromorpha seemed to be absent or nearly absent at the higher altitudes (1000 m and above). This is probably due to a loss of habitat such as leaf litter which is less developed in montane heath compared to woodlands and forest

Table 6.1 Distributions and habitats of Tasmanian endemic Collembola genera.

Genus	Family	Distribution	Vegetation type	Habitat
*Megalanura**	Neanuridae: Pseudachorutinae	Throughout Tasmania	Tall wet forest, temperate rainforest	Under and in well-rotted logs
Tasmanura	Neanuridae: Anuridinae	Sporadic, at and above 1000 m, ca. 6 sites known	*Nothofagus gunnii*, montane vegetation	In leaf litter, humus
Tasphorura	Tullbergiidae	Only in NE Tasmania, one location 20 km S Scottsdale	Temperate rainforest	In moss
Azeritoma	Isotomidae	Only on Macquarie Island	Tundra, cushion plants	*Azorella* plants and soil
*Lasofinius**	Tomoceridae	SW Tasmania World Heritage Area	Buttongrass moorland *Gymnoschoenus sphaerocephalus*	In leaf litter, humus

*Genera found at Warra-Mount Weld.

Table 6.2 Collembola abundance and number of species/morphospecies recorded in pitfall traps on the Warra and Mount Weld transects.

Site /Altitude (m)	Transect	Abundance	Number of species/morphospecies
100	Warra	329	17
200	Warra	299	10
300	Warra	277	12
400	Warra	302	20
500	Warra	148	16
600	Warra	121	13
600*	Mount Weld	40	10
700	Mount Weld	300	16
800	Mount Weld	721	17
900	Mount Weld	999	20
1000	Mount Weld	378	16
1100	Mount Weld	1522	15
1200	Mount Weld	532	11
1300	Mount Weld	520	11

*Several pitfall traps were lost at this site due to lyrebird disturbance.

Table 6.3 Collembola captured in Malaise traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra			Mount Weld			Total
	100	200	400	600	800	1000	
Brachystomellidae							
cf. *Cassagnella* sp. 1	0	0	0	0	1	0	1
Isotomidae							
Acanthomurus sp. 1	1	4	5	0	6	3	19
Acanthomurus sp. 2	0	0	1	0	0	0	1
Entomobryidae							
cf. *Drepanura* sp. 1	0	0	1	0	0	0	1
Lepidocyrtoides sp. 1	0	326	650	33	0	1	1010
immature & damaged indeterminate	0	300	0	12	0	0	312
Paronellidae							
Paronellides cf. *mjobergi* sp. 1	11	156	293	0	2	19	481
Paronellides sp. 2	3	3	15	0	0	0	21
Paronellides sp. 3	0	0	2	1	0	7	10
Paronellides sp. 4	0	0	1	0	12	20	33
Paronellides sp. 5	0	0	0	0	1	3	4
immature	0	0	0	0	19	34	53
Bourletiellidae							
Rastriopes sp. 1	0	0	0	0	0	93	93
Katiannidae							
cf. *Katianna* sp. 2	0	0	0	0	38	0	38
?*Katianna* sp.	0	0	0	0	170	0	170
cf. *Polykatianna* gen & sp. Indeterminate sp. 1	0	0	1	0	0	0	1
cf. *Pseudokatianna* sp. 1	10	0	1	1	0	0	12
Symphypleona							
immature & damaged indeterminate sp. 2	0	0	0	0	190	5	195

Dicyrtomidae							
gen & sp. indeterminate sp. 1	0	1	2	0	0	0	3
Total	25	790	972	47	439	185	2458

Table 6.4 Collembola captured in pitfall traps on the Warra (100–600m) and Mount Weld (600–1300m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Neanuridae															
cf. *Pseudachorutella* sp. 1	0	17	0	7	16	14	3	66	124	59	35	0	0	3	344
Megalanura tasmaniae	0	0	0	1	0	0	0	2	1	1	0	0	0	0	5
Australonura cf. *wellingtonia* sp. 1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2
cf. *Pseudachorutes* sp. 1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
gen & sp. indeterminate	30	38	13	23	6	7	4	3	5	5	0	3	0	0	137
Acanthanura sp.	6	7	3	2	2	1	0	3	1	0	0	0	0	0	25
Brachystomellidae															
cf. *Cassagnella* sp. 1	0	1	0	15	0	0	1	0	1	0	1	0	0	0	19
n.gen. sp. 1	0	1	3	3	2	0	0	1	2	0	0	1	0	0	13
gen. & sp. indet.	0	1	0	35	8	2	0	0	0	0	0	0	0	0	45
Poduromorpha															
immature & damaged indeterminate	8	17	23	9	12	11	0	19	57	47	11	5	0	0	219
Isotomidae															
Acanthomurus sp. 1	50	27	34	23	20	38	15	66	129	97	69	1259	236	302	2365
Acanthomurus sp. 2	0	0	0	0	0	0	1	0	1	1	2	1	0	10	16

Acanthomurus sp. 3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Isotoma sp. 1	0	0	0	0	0	0	0	5	20	559	82	8	0	0	674
Isotoma sp. 2	0	0	0	0	0	0	0	0	0	0	0	13	1	0	14
Cryptopygus antarcticus group	1	0	0	0	0	0	0	0	0	1	0	1	0	0	3
immature & damaged indeterminate	0	0	0	0	0	0	0	0	0	0	0	41	0	14	55
Entomobryidae															
Australotomurus cf. *echidnus* sp. 1	0	0	0	0	2	0	0	0	5	17	0	0	0	0	24
cf. *Entomobrya* sp. 1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Entomobrya cf. *virgata* sp. 1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Lepidocyrtus sp. 1	8	5	9	7	3	2	0	1	14	5	5	1	0	0	60
Lepidocyrtus sp. 2	0	0	0	0	0	0	0	0	0	0	0	13	1	10	24
cf. *Drepanura* sp. 1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Lepidocyrtoides sp. 1	7	5	3	9	4	2	2	11	0	0	0	0	0	0	43
immature & damaged indeterminate	6	2	19	19	14	4	0	14	25	6	19	0	0	0	128
Odontellidae															
gen & sp. indeterminate	2	0	1	14	0	1	1	1	134	54	0	0	18	56	282
Paronellidae															
Paronellides cf. *mjobergi* sp. 1	12	9	7	3	5	0	1	10	1	1	0	0	2	18	69
Paronellides sp. 2	0	2	19	17	4	0	0	0	0	0	0	0	0	0	42
Paronellides sp. 3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Paronellides sp. 4	0	0	0	0	0	0	0	0	0	0	0	1	21	20	43
Paronellides sp. 5	1	0	0	0	0	0	0	0	1	1	29	11	103	63	209
Paronellides sp. 6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
immature & damaged indeterminate	8	0	11	14	2	5	0	2	2	10	17	4	4	7	87
Tomoceridae															
Novacerus cf. *tasmanicus* sp. 1	2	2	3	25	8	11	0	11	4	17	10	2	2	0	97

Lepidophorella sp. 1	86	64	0	13	4	4	2	79	146	23	12	4	21	0	458
Lasofinius sp. 1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
Bourletiellidae															
Rastriopes sp. 1	0	0	0	0	0	0	0	0	3	3	9	13	0	0	28
Katiannidae															
cf. *Pseudokatianna* sp. 1	6	2	0	3	7	10	2	4	0	3	0	0	42	0	79
cf. *Polykatianna* gen & sp. indeterminate sp. 1	0	0	0	8	5	0	0	0	0	0	5	0	0	16	34
?K*atianna* sp. 1	6	0	0	1	0	0	0	0	0	2	1	0	0	0	10
cf. *Katianna* sp. 2	0	0	1	43	0	9	0	0	0	6	0	0	16	0	75
cf. *Katianna* sp. 3	1	0	0	0	0	0	0	0	0	0	0	2	0	0	3
Symphypleona															
immature & damaged indeterminate sp. 1	14	3	5	8	3	0	2	0	5	9	43	17	54	0	163
immature & damaged indeterminate sp. 2	35	1	5	0	19	0	0	0	40	65	18	120	11	0	329
Dicyrtomidae															
gen & sp. indeterminate sp. 1	37	78	118	0	0	0	6	0	0	1	4	1	0	0	245
gen. & sp. indeterminate sp. 2	0	0	0	0	0	0	0	0	0	6	5	0	0	0	11
Total	329	284	277	302	148	121	40	300	721	999	378	1522	532	520	6473

Multivariate comparison of Collembola assemblages in pitfall traps

Faunal assemblages from the lower altitude sites at Warra were more similar to each other than were the higher altitude Mount Weld sites (Fig. 6.1). Mount Weld sites fell into three clusters, with the two highest altitudes isolated together as did the 800, 900 and 1000 m sites, while the position of the 1100 m site indicates it is least like any other site. The Mount Weld sites at 600 m and 700 m were in intermediate positions between Mount Weld and Warra indicating to some extent the validity of the altitudinal continuum. Eight species distributions seem to be responsible for the position of these sites' positions close to the Warra sites. *Acanthanura* sp. and *Lepidocyrtoides* sp. were only found at or below 700 m, while *Paronellides* sp. 4, 5 and 6 and *Rastriopes* sp. are only found above 700 m (Table 6.4).

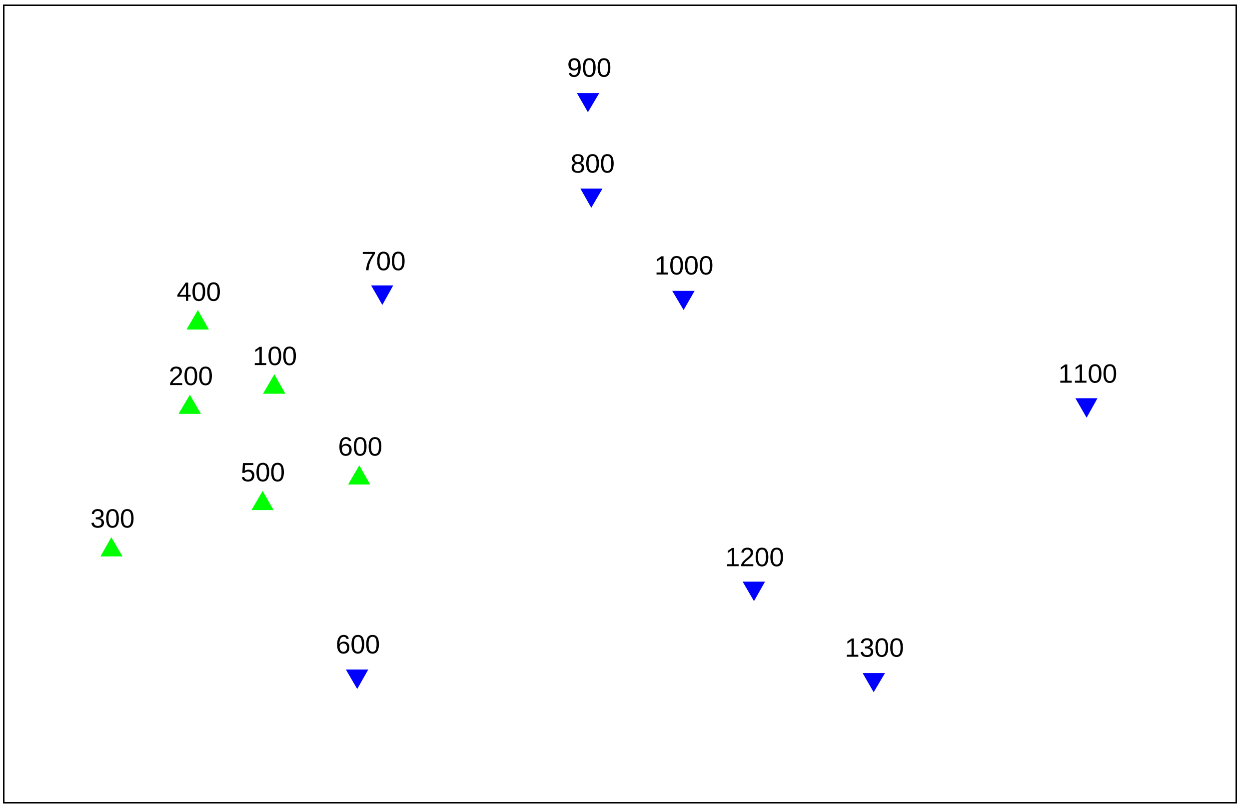


Fig. 6.1 MDS ordination of Collembola assemblages at each altitude on the Warra (▲) and Mount Weld (▼) transects for pitfall trap samples. Data has been averaged across sampling months. Stress value = 0.1

The influence of vegetation is paramount here in determining faunal assemblages. For instance the tree line was just above 1000 m on Mount Weld and sites on this transect at 1100, 1200 and 1300 m all carried alpine heath while sites 800, 900 and 1000m all carried subalpine *Eucalyptus coccifera* woodland. Sites up to 700 m carried a mix of *Eucalyptus delegatensis* and *E. obliqua* (Doran *et al.* 2003). The different vegetation types seem to reflect the positions of the sites in Fig. 6.1. The isolated position of Mount Weld at 1100 m is due to very large numbers of *Acanthomurus* sp. 1 and this may be an artefact of pitfall sampling

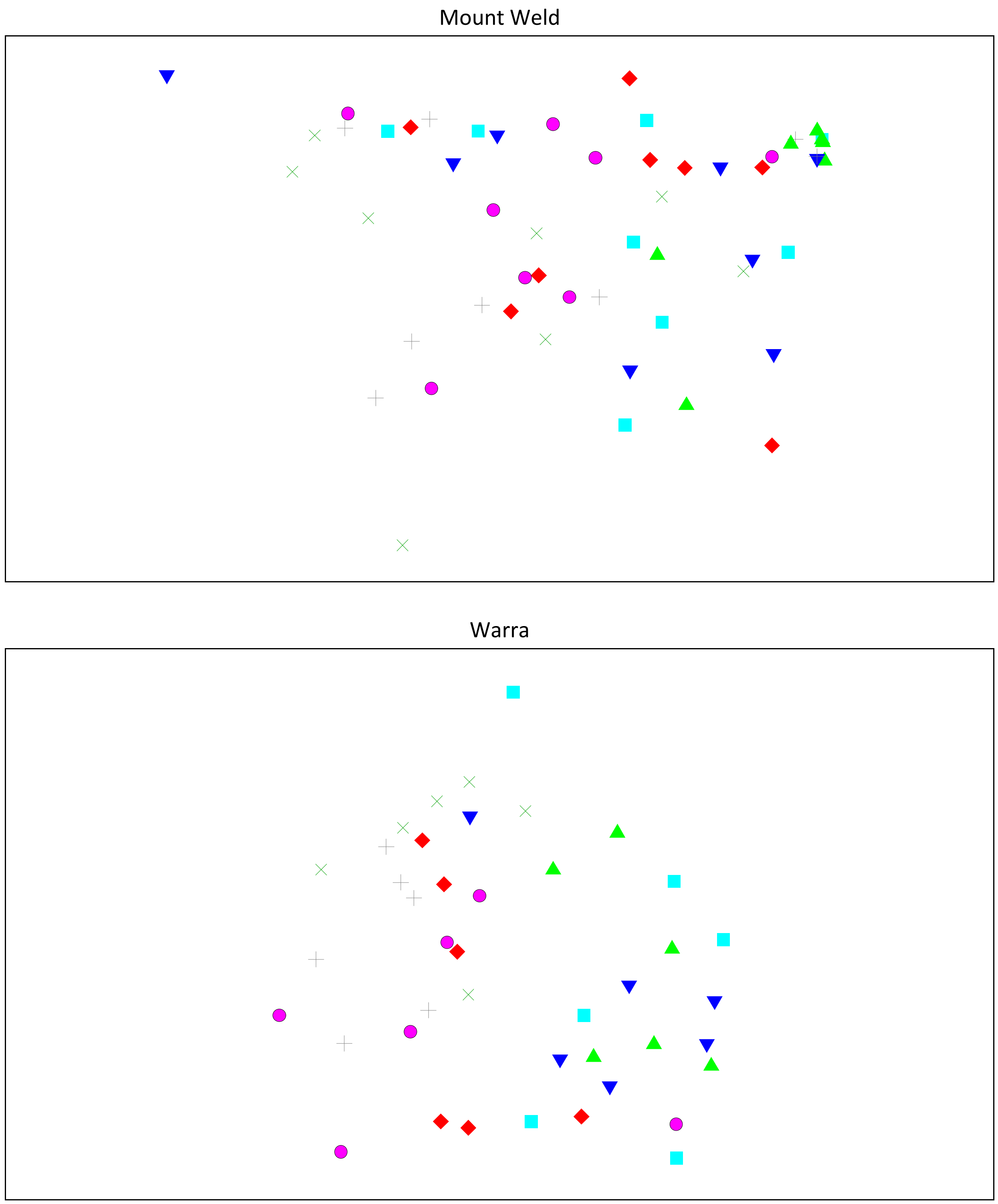
PERMANOVA analysis showed a significant effect of both month and altitude on Collembola assemblages on both the Warra and Mount Weld transects (Tables 6.5 and 6.6). Fig. 6.2 indicates that on the Warra sites there was also an effect of season with the early summer months November 2001–February 2002, tending to the left of the graph, while the late summer months February 2001–April 2001 tending to the right. There was also a difference between years with February 2001 and 2002 assemblages well separated with the February 2001 assemblage grouping with the later summer months and the February 2002 grouping with the early summer months. By contrast, on Mount Weld, there was less demarcation between assemblages in early summer months and late summer and between February 2001 and 2002 (Fig. 6.2).

Table 6.5 PERMANOVA test of month and altitude on Collembola pitfall assemblages for Warra

Factors	Df	SS	MS	Pseudo-F	P
Month	6	19887	3314.5	2.9417	0.0001
Altitude	5	17367	3433.4	3.0828	0.0001
Residuals	30	33801	1126.7		
Total	41	71055			

Table 6.6 PERMANOVA test of month and altitude on Collembola pitfall assemblages for Mount Weld.

Factors	Df	SS	MS	Pseudo-F	P
Month	6	26925	4487.4	2.6986	0.0001
Altitude	5	55409	7915.5	4.7602	0.0001
Residuals	42	69840	1662.9		
Total	55	15217			



Mount Weld

Warra

Fig. 6.2 MDS ordination of Collembola assemblages for each site and month sampled using pitfall traps on the Mount Weld (top, stress value = 0.13) and Warra (bottom, stress value = 0.23) transects. Triangle = Feb. 2001, inverted triangle = Mar. 2001, square = Apr. 2001, diamond = Nov. 2001, circle = Dec. 2001, plus sign = Jan. 2002, and cross = Feb. 2002.

Discussion

The results from the Warra-Mount Weld Altitudinal Transect in Tasmania can be compared to a similar altitudinal survey, using pitfall traps only, in subtropical and cool temperate rainforest on Mount Lamington, south-eastern Queensland (Kitching *et al.* 2013). Sites there ranged from 300 to 1100 m, a similar range to the survey in Tasmania, but at Lamington *Nothofagus* rainforest was only present at 1100 m. Similarities between the two data sets were that Collembola abundance generally increased with altitude but with a decline in abundance at the highest altitudes. Species richness increased on Mount Lamington between 300 and 900 m with a small decline at 1100 m. Similarly there was a decline in species richness with altitude on the Mount Weld transect between 700 and 1300 m. In both studies, broad altitudinal changes in Collembola abundance and taxon richness were associated with changes in vegetation type. On Mount Lamington the decrease in abundance and taxon richness between 900 and 1100 m was associated with a change from subtropical rainforest to cool temperate rainforest. The increase in abundance of Collembola on Warra-Mount Weld is associated with a change from lowland E. *obliqua*/*E. delegatensis* forest to subalpine woodland and alpine heathland.

There was no congruence in species between the two State locations and the only generic similarity was that species of *Rastriopes*. In Tasmania a single species of this genus was restricted to the highest altitude while on the Lamington transect, one species was found only at low altitudes and another at the highest altitude. Major differences were that on Mount Lamington, species in the genus *Acanthanura* were found at and below 900 m on the transect in but only at the highest altitude of 1100 m on Mount Lamington. Also, on Mount Lamington, all species of Paronellidae were restricted to low altitudes while Poduromorpha were most abundant at the highest altitude. One genus on Mount Lamington, *Isotopenola*, was not collected on the Tasmanian transect, this genus tends to be found at lower altitudes, in drier, more open habitats while the related genus, *Cryptopygus*, present at high altitudes at Lamington and in low numbers in Tasmanian transects, is found in moister vegetation types and further south, even occurring on the Antarctic Continent. Greenslade and Kitching (2011) suggested that under a climate warming scenario, the Tasmanian fauna may develop some of the characteristics of the Lamington fauna. What is significance here is that species of *Rastriopes*, some Paronellidae and Isotomidae species are selective as to their habitat and environmental requirements.

Greenslade and Kitching (2011) selected several taxa that appeared, on this limited sampling effort, to be restricted to particular altitudes. None of the five 'sentinel' species (represented by multiple specimens collected from only a single elevation), that were considered promising candidates for future monitoring of climate change belonged to the same genera as the altitudinally restricted taxa in Tasmania.

More recently, Maunsell *et al.* (2013), using only Isotomidae, Symphypleona and Neelipleona from sieved leaf litter samples at the three highest altitudes on Mount Lamington, also found changes in species composition with altitude. As well as elevation, these authors found that collembolan changes with altitude correlated with a number of abiotic factors, such as organic matter, ammonia, calcium, potassium, sodium, soil moisture, tree base area and various temperature measures.

Conclusion

Collembola were collected in adequate numbers of individuals and species in the pitfalls for the total fauna to be amenable to statistical analysis**.** We found a statistically significant effect of altitude on both Weld and Warra transects and the ordination revealed that the pattern of change and separation differs between the two transects being greater on Mount Weld than at Warra, that there were slight indications of a continuum of altitudinal effects from Warra to Mount Weld and that vegetation strongly influenced faunas as did season and year, the latter being more marked at lower altitudes than on Mount Weld. There were a number of species that were restricted as to the altitude at which they were found.

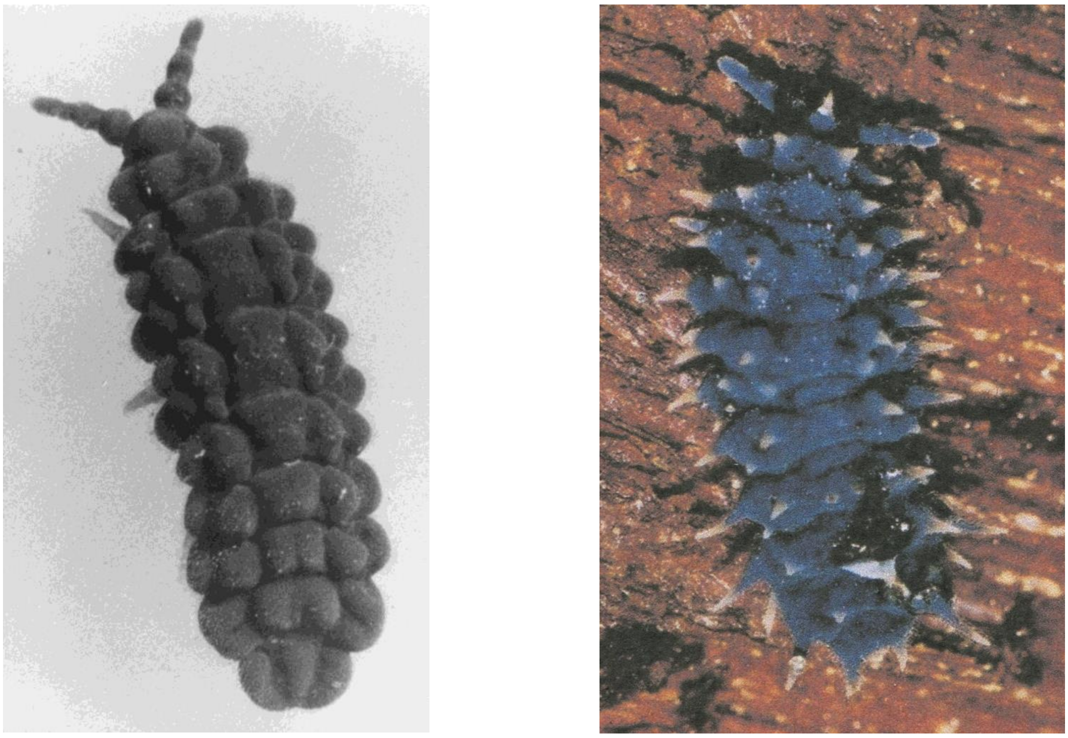


Fig. 6.3 Images of *Megalanura tasmaniae* (left) by J. E. Ireson and *Acanthanura dendyi* (right) by S. Grove.

Fig. 6.4 Images of *Acanthomurus* sp. (top left), *Paronellides* sp. cf. *tasmaniae* (top right), *Lepidocyrtoides* sp. (middle left), Katiannidae gen. & sp. indet. (middle right), *Novacerus* sp. (bottom left), Dicyrtomidae gen & sp. indet. (bottom right) from water colour paintings by G. Davis.

7 FORMICIDAE (ants)

by Richard Bashford and Peter McQuillan

Summary

1. The distributions of Formicidae on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001.
2. Only six species of ants were recorded on the Warra-Mount Weld Altitudinal Transect.
3. The two formicine species (*Prolasius* nr *pallidus* and *Myrmecorhynchus* sp.) dominated samples at low to mid altitudes.
4. All other species were singletons and occurred at low to mid altitude. No ants were recorded above 900 m and only one species (*Myrmecia esuriens*) was recorded at 900 m.
5. Due to low species richness and the paucity of species and specimens captured at higher altitudes, the ant fauna is unlikely to yield useful indicator species for climate change monitoring using unbaited pitfall traps.

Tasmania's ant fauna

Australia has a very diverse ant fauna by global standards; approximately 1200 species from 100 genera have so far been described, although this represents only a fraction of the exceptionally rich ant fauna (Andersen 1991). By contrast, Tasmania has a relatively depauperate ant fauna. The collection of Bede Lowery contains 125 species in 43 genera with an additional unidentified 21 morphospecies (Bashford 1998). The Tasmanian ant fauna is richest in the warm, open country of the north east and poorest in wetter shaded forests in the west of the island. However, the State's ant fauna has been relatively poorly studied and further work is certain to expand the number of species. For example the genus *Prolasius* is likely to be more diverse than is currently documented.

Mount Weld ants: description of fauna and changes with altitude and habitat

The ant fauna on the Warra-Mount Weld Altitudinal Transect was low in species richness, with a total of six species recorded. All ant species were generalist forest species, reflecting the primarily forested habitats on the transect up to 1000 m. The highest altitude at which ants were captured was 900 m, and there were no ants recorded above the treeline.

The ant fauna was dominated numerically by two formicine species: *Prolasius* near *pallidus* and *Myrmecorhynchus* sp. (Table 7.1). *Prolasius* nr *pallidus* occurred over a low to mid-altitudinal range of 100–600 m, and was most abundant in the mid-altitudinal samples (300–500 m; Table 7.1). The genus *Prolasius* is a primarily Australian ant group. Of the 19 species so far described, 18 occur in Australia with one of these species also occurring in New Guinea, and the remaining species found in New Zealand (Shattuck 1999). *Prolasius* is most diverse and abundant in wet forests of south-eastern Australia (Andersen 1991, Shattuck 1999). *Prolasius* nest in soil under rocks and logs, or occasionally arboreally. Some species are known to feed on seeds (Shattuck 1999). In their study of the invertebrate fauna of cool temperate rainforest in Tasmania, Coy *et al.* (1993) collected 20 ant species of which ten were species of *Prolasius*. This distinctively Australian group of ants is urgently in need of revision.

Myrmecorhynchus sp. had a very broad altitudinal range (100–800 m), although absent in the 600 m samples. *Myrmecorhynchus* sp. was most common at low altitude (100 and 200 m samples), with abundance in samples generally declining as altitude increased (Table 7.1). The genus *Myrmecorhynchus* has five described species, all from south-eastern Australia. They are small and inconspicuous ants which are largely arboreal in habitats and which nest in twigs on shrubs and trees, rarely on the ground (Andersen 1991). Species of *Myrmecorhynchus* occur in forested areas, including dry and wet forest and rainforests, where they can be locally common but are often overlooked (Shattuck 1999).

The remaining species (*Amblyopone australis, Notoncus spinisquamis, Camponotus hartogi, Myrmecia esuriens*) were represented by a single specimen each, all below 900 m. A single specimen of *Amblyopone australis* was captured at 100 m (Table 7.1). The genus *Amblyopone* occurs throughout the world in tropical and temperate areas. Seventeen of the 62 described species occur in Australia, mostly in moist sites where they nest in soil and under rocks and logs. Workers are predators of centipedes and other soft-bodied arthropods (Shattuck 1999). *Amblyopone australis* occurs in mesic habitats throughout eastern and south-eastern Australia (Andersen 1991).

A single specimen of *Notoncus spinisquamis* was captured at 200 m (Table 7.1). *Notoncus* is an Australian genus with one species also occurring in New Guinea (Shattuck 1999). They are found in a wide range of forested habitats from dry forests to rainforests, and are also common in urban parks and gardens (Shattuck 1999). Nests of these ants are found in open soil and under stones and logs on the ground. They are general predators, foraging on the ground surface. *Notoncus spinisquamis* is restricted to wetter forests of south-eastern and south-western Australia and may remain active over winter (Andersen 1991).

A single specimen of *Camponotus hartogi* was captured at 100 m (Table 7.1). *Camponotus* is the largest ant genus in the world, and is one of the most common and widespread groups of ants in Australia (Shattuck 1999). They are general scavengers and predators, and occur in all terrestrial habitats. Most species occur in arid zones, but there are many species in mesic regions (Andersen 1991). Species of *Camponotus* are frequently among the most conspicuous ants due to their large size and often bright coloration, and the genus includes the well-known sugar ants which occur in suburban areas.

A single specimen of the endemic Tasmanian inchman *Myremecia esuriens* was captured at 900 m (Table 7.1). The genus *Myremecia* (the well-known ’jack-jumpers’ and ‘bull ants’ or ‘inchmen’) occurs in Australia and New Caledonia (Shattuck 1999). Most species occur in the southern parts of Australia, where they occur primarily in woodland and forest habitats. Species of *Myremecia* forage on the ground or on foliage and consume animal prey as well as nectar and plant juices. Most species nest in the soil, often in large nests forming a conspicuous mound, often ‘decorated’ with pebbles or plant fragments. They are aggressive and have a potent venom which can cause a severe allergic reaction in some people (Shattuck 1999). *M. esuriens* is widespread in woodland and forest habitats in Tasmania (Andersen 1991).

Possible indicator species

Due to the low species richness and the paucity of species and specimens captured at higher altitudes, the ant fauna of the Warra-Mount Weld Altitudinal Transect is unlikely to yield useful indicator species for climate change monitoring using the current method of unbaited pitfall traps. The positioning of pits and pit design are important factors if used as tools for ant diversity studies. It should be noted that in Table 7.1, 76% of *Prolasius* nr *pallidus* were collected in just two traps and 46% of *Myrmecorhynchus* sp. were captured in one trap, indicating placement of traps near nests. Altitudinal transect surveys conducted specifically for ants have been well documented and provide a template if future surveys at the Warra-Mount Weld Altitudinal Transect are to include ants. A general trend of these surveys indicates that there is a decrease in species richness with altitude with peak diversity occurring between 400 and 800 metres (Bruhl *et al.* 1999, Sanders *et al.* 2003, Yek *et al.* 2009).

Table 7.1 Ants captured in pitfall traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Prolasius nr *pallidus*	32	40	290	95	260	2	1	0	0	0	0	0	0	0	720
Myrmecorhynchus sp.	42	20	7	6	1	0	0	8	6	0	0	0	0	0	90
Amblyopone australis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Notoncus spinisquamis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Camponotus hartogi	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Myrmecia esuriens	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1

8 GASTROPODA (snails and slugs)

by Kevin Bonham

Summary

1. The distributions of Gastropoda on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001, November–December 2001 and January–February 2002.
2. The gastropod fauna on the Warra-Mount Weld Altitudinal Transect included ten species, including at least one undescribed species.
3. Three gastropod species were recorded above the treeline, and a single species (the undescribed *Victaphanta* sp 'Weld') appeared to be exclusively alpine (1200–1300 m).

Tasmania's terrestrial gastropod fauna

The formal taxonomy of Tasmania's land gastropod fauna is out-dated. A recent overview of the fauna by Smith *et al.* (2002) is employed here, while noting that less than 30% of the fauna has been formally described. Two species of unresolved status, but which may be referrable to published names that formal reviews have listed as synonyms, are treated here as if undescribed (*Paralaoma* sp. and *Stenacapha* sp.). The Tasmanian terrestrial gastropod fauna is distinct from the south-eastern mainland Australia snail fauna, probably as a result of repeated isolation by Bass Strait, climatic differences and impacts of past glaciation. Nearly all the terrestrial gastropod fauna of Tasmania is endemic to the island at species level, including several unusual endemic genera such as *Caryodes* and *Anoglypta*. The Tasmanian land snail fauna is dominated by the family Charopidae, containing around 100 species (mostly undescribed), nearly all of which are endemic. There is also an extensive introduced land snail fauna in the state.

Mount Weld Gastropoda: description of fauna and changes with altitude and habitat

The gastropod fauna on the Warra-Mount Weld Altitudinal Transect was moderately diverse, with a total of ten species recorded including three species that are either undescribed or described only under names of unresolved taxonomic status. The majority of species were recorded below the treeline (1000–1100 m) (Table 8.1). *Caryodes dufresnii* (family Caryodidae) was recorded between 400 and 800 m. *Caryodes dufresnii* is Tasmania's largest terrestrial snail and wholly confined to the Tasmanian mainland and several adjacent smaller islands. It is common in a wide range of forest habitats (Bonham *et al.* 2002, Smith *et al.* 2002). *Helicarion cuvieri* (family Helicarionidae) was the most commonly sampled species, recorded between 100 and 900 m. The taxonomy of the genus *Helicarion* in Tasmania requires more research but forms assigned to and resembling *H. cuvieri* are widespread and common in damp situations in wet and dry native forest in Tasmania (Smith & Kershaw 1981, Bonham *et al.* 2002). *Pernagera kingstonensis*, *Stenacapha hamiltoni* and *Thryasona diemenensis* (family Charopidae) are widespread and common in damp situations in woodland and forest (Smith & Kershaw 1981). *Pernagera kingstonensis* was recorded once at 700 m, *S. hamiltoni* was recorded in low numbers between 100 and 700 m, and *T. diemenensis* was recorded in low numbers between 200 and 700 m (Table 8.1).

Only three gastropod species were recorded above 1000 m. *Mulathena fordei* (family Charopidae) occurs in wet forests in southern and western Tasmania (Smith & Kershaw 1981). *Mulathena fordei* was recorded between 600 and 800 m with a further six specimens all recorded well above the treeline at 1200 m (Table 8.1). The altitudinal range of sampled specimens of *Tasmaphena sinclairi* was highly disjunct. A single specimen was recorded at 100 m, and the species was also recorded at 1200 m (seven specimens) and 1300 m (three specimens). However, this species occurs in other localities at all altitudes from sea level to about 1300 m (K. Bonham, unpublished data). A single species, the undescribed *Victaphanta* sp 'Weld' appeared to be exclusively alpine, with three specimens recorded at 1200 m (Table 8.1).

Possible indicator species

Victaphanta sp. 'Weld', as the only purely alpine species recorded in the project, is a possible indicator of climate change. Similar specimens have been collected from some other south-western mountains at altitudes above 800 m (K. Bonham unpubl. data). The data provide an impression that the two species of *Stenacapha* recorded may exhibit an altitude sequence. However, this is not consistent with results for the same two species on other mountains. (K. Bonham unpubl. data).

Table 8.1 Gastropoda captured in pitfall traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Caryodes dufresnii	0	0	0	1	3	1	0	0	2	0	0	0	0	0	7
Helicarion cuvieri	1	9	0	1	1	2	1	0	0	1	0	0	0	0	16
Mulathena fordei	0	0	0	0	0	0	2	1	1	0	0	0	6	0	10
Paralaoma sp. indet.	0	1	1	1		1	0	0	0	0	0	0	0	0	4
Pernagera kingstonensis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Stenacapha hamiltoni	1	0	0	0	1	0	0	1	0	0	0	0	0	0	3
Stenacapha sp. indet.	0	0	0	0	0	1	0	2	1	3	3	0	0	0	10
Tasmaphena sinclairi	1	0	0	0	0	0	0	0	0	0	0	0	7	3	11
Thryasona diemenensis	0	1	0	0	1	0	0	2	0	0	0	0	0	0	4
Victaphanta sp. 'Weld'	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3

9 ORTHOPTERA (crickets and grasshoppers)

by Michael Driessen

Summary

1. The distributions of Orthoptera on the Warra-Mount Weld Altitudinal Transect were investigated using samples taken from February–April 2001, November–December 2001 and January–April 2002.
2. The Orthoptera on the Warra-Mount Weld Altitudinal Transect included five families and ten species.
3. Two species accounted for 90% of all Orthoptera collected in pitfall traps; the grasshopper *Russalpia longifurca* and the cricket *Parvotettix maydenaensis*
4. The cricket *Tasmanalpina clavata* was only recorded above the treeline (1100–1300 m) on slopes with exposed dolerite and this species represents a potential climate change indicator species.
5. Because Orthoptera demonstrate clear associations with altitude they can be useful for climate change monitoring. They are also readily surveyed and identified, and because they are highly mobile will respond quickly to environmental changes.

Tasmania's Orthoptera

Tasmania supports 63 described species of Orthoptera comprising 28 Caelifera (grasshoppers) and 35 Ensifera (crickets) (Semmens *et al.* 1992). Over a third of these species (37%, 23 species) are endemic to Tasmania. Most (14 species) of the endemic species are crickets in the family Rhapidophoridae (cave or camel crickets) and many are restricted to offshore islands or cave systems. Five genera comprising six species of flightless catantopine Acrididae are endemic to Tasmania (Key 1991). One of these endemic Acrididae, *Tasmanalpina clavata*, has only been recorded above an altitude of 900 m, typically in association with talus slopes. The only other Orthoptera in Tasmania known to be restricted to higher altitudes is the endemic *Kosciuscola tasmanicus* which is limited to the elevated central area of Tasmania (Rehn 1957).

Mount Weld Orthoptera: description of fauna and changes with altitude and habitat

A total of 1193 Orthoptera were collected in pitfall and malaise traps comprising five families and ten species (Tables 9.1 and 9.2). The majority (97%) were collected in pitfall traps. Two species, *Truganinia bauerae* and *Phaulacridium vittatum* were caught only in malaise traps whereas five species were caught only in pitfall traps.

Truganinia bauerae was the most commonly caught Orthoptera in malaise traps; all specimens were caught at 1000 m except for one specimen caught at 800 m (Table 9.1). The raspy cricket, *Kinemania ambulans*, was recorded at lower altitudes (100–800 m) in malaise traps than in pitfall traps (≥900 m). Single records of the acridids *Tasmaniacris tasmaniensis* and *Phaulacridium vitattum* were recorded in the malaise trap at 100 m.

Two species accounted for 90% of all Orthoptera collected in pitfall traps; the grasshopper *Russalpia longifurca* and the cricket *Parvotettix maydenaensis* (Table 9.2). There was no overlap in the distribution of these two species along the altitudinal transect. *Parvotettix maydenaensis* was recorded at altitudes from 100 to 900 m and *R. longifurca* was recorded from 1000 to 1300 m. Three additional Orthoptera species were only recorded in pitfall traps above 800 m; *Tasmanalpina clavata*, *Bobilla poene* and *Kinemania ambulans*. *Tasmaniacris tasmaniensis* was also predominantly recorded at higher altitudes but a small number were also recorded at 100 m. Single specimens of *Paratettix argillaceous* and the cave-inhabiting *Micropathus tasmaniensis* were recorded at mid-altitudes.

The Orthoptera of the Warra-Mount Weld Altitudinal Transect demonstrate clear associations with altitude that are linked to altitudinal changes in vegetation. From 100 to 900 m the Orthoptera are dominated by the endemic camel cricket *Parvotettix maydenaensis*. This is a species that requires cool, moist and dark conditions (Richards 1971, 1974) that are found in mixed-rainforest at lower altitudes on the Warra-Mount Weld Altitudinal Transect. Above 900 m the Orthoptera are dominated by several species of endemic flightless grasshoppers belonging to the family Acrididae. These species require grasses and herbs for food and vegetation surveys of the Warra-Mount Weld Altitudinal Transect have shown that monocotyledons and herbs increase significantly with altitude (Doran *et al.* 2003).

Tasmaniacris tasmaniensis, *Russalpia longifurca* and *Truganinia bauerae* have all been recorded from sea level to above the treeline elsewhere in Tasmania but not in mixed-rainforest habitats. *Tasmaniacris tasmaniensis* and *Phaulacridium vittatum* were both recorded at 100 m and this probably reflects the additional presence of a dry forest element in the vegetation at this altitudinal plot (Doran *et al.* 2003).

Possible indicator species

Because the Orthoptera demonstrate clear associations with altitude they are useful for climate change monitoring. They are readily surveyed and identified, and because they are highly mobile will respond quickly to environmental changes. *Tasmanalpina clavata* in particular is a good candidate for a climate change marker. It was only recorded above the treeline (1100–1300 m) on slopes with exposed dolerite. Throughout Tasmania *T. clavata* occurs on mountains above 900 m where it shows a strong habitat preference for talus slopes (Key 1991). The colouration of the species is mostly black and relatively hairy, both adaptations to cold environments. The black colouration may also provide camouflage on the rocky dolerite slopes.

Table 9.1 Orthoptera captured in malaise traps on the Warra (100–400 m) and Mount Weld (800–1000 m) altitudinal transects. Malaise traps were not set at other altitudes.

Taxa	Warra			Mount Weld		Total
	100	200	400	800	1000	
Phaulacridium vittatum	1	0	0	0	0	1
Russalpia longifurca	0	0	0	0	3	3
Tasmaniacris tasmaniensis	1	0	0	0	0	1
Truganinia bauerae	0	0	0	1	17	18
Kinemania ambulans	1	1	1	1	3	7

Table 9.2 Orthoptera captured in pitfall traps on the Warra (100–600 m) and Mount Weld (600–1300 m) altitudinal transects.

Taxa	Warra						Mount Weld								Total
	100	200	300	400	500	600	600	700	800	900	1000	1100	1200	1300	
Russalpia longifurca	0	0	0	0	0	0	0	0	0	0	4	191	255	127	577
Tasmaniacris tasmaniensis	7	0	0	0	0	0	0	0	0	0	8	16	9	15	55
Tasmanalpina clavata	0	0	0	0	0	0	0	0	0	0	0	1	5	5	11
Paratettix argillaceous	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Parvotettix maydenaensis	33	47	55	56	55	50	29	55	62	32	0	0	0	0	474
Micropathus tasmaniensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Kinemania ambulans	0	0	0	0	0	0	0	0	0	3	1	13	16	2	35
Bobilla poene	0	0	0	0	0	0	0	0	0	0	1	8	0	0	9

10 COMPARISON OF INVERTEBRATE ASSEMBLAGES BETWEEN 2001 AND 2002

by Michael Driessen and Stephen Mallick

Introduction

To assess the potential impact of climate change or other disturbance events on the invertebrate assemblages of the Warra-Mount Weld Altitudinal Transect, it is important to gain an appreciation of the yearly variation in the invertebrate abundance and composition. Invertebrate abundance can vary widely over relatively short time periods (months or years) and in response to a wide range of biological and physical factors. Previous studies in temporal ecosystems have found that invertebrate assemblages can vary between years (e.g. Recher *et al.* 1996), particularly in terms of changes in the magnitude of abundance (e.g. Bell 1985, Southwood *et al.* 2004). Documenting interannual population dynamics of multispecies invertebrate assemblages is important because it provides basic baseline knowledge of the ecological processes operating within an ecosystem and this information is particularly important for monitoring and understanding fauna responses to environmental change (Grimbacher & Stork 2009).

Doran *et al.* (2003) analysed the invertebrate data from the Warra-Mount Weld Altitudinal Transect at the ordinal level for the monthly samples collected in February, March, April, November and December 2001 and in January and February 2002. At the time of the Doran *et al.* (2003) article, the March and April 2002 samples had not yet been sorted. Here, the invertebrate assemblages collected in February–April 2001 are compared with those collected February–April 2002.

Methods

The number of invertebrates for each Order in each pitfall traps was averaged across each functioning pitfall trap (maximum n = 6) for each altitude for each month of sampling. To visualise the relationships among samples (6 sampling times by 14 altitudes = 84 samples), they were ordinated using non-metric multidimensional scaling (MDS) in PRIMER6 (Clarke & Gorley 2006) based on Bray-Curtis similarities and fourth-root transformed abundances.

To test for differences in invertebrate assemblages between sampling times and altitudes we used the ANOSIM routine in PRIMER6 for two way crossed designs with no replicates. To enable pairwise tests between sampling times one-way ANOSIM was performed treating the different altitudes as replicates. This is justified if the one-way ANOSIM test is significant; i.e. the altitude differences are small in relation to sampling time differences (Clarke & Gorley 2006). ANOSIM returns an R-value which gives a measure of how similar groups are; large values (close to unity) are indicative of complete separation of groups and small values (close to zero) imply little or no separation.

Results

The two-dimensional MDS ordination of the 84 samples shows that the 2001 invertebrate assemblage was clearly distinguished from the 2002 invertebrate assemblage (Fig. 10.1). Two-way ANOSIM confirmed significant differences between sampling times (Rho = 0.665, 0 out of 9999 permuted statistics greater than Rho, significance level = 0.0001) and altitudes (Rho = 0.540, 0 out of 9999 permuted statistics greater than Rho, significance level = 0.0001). One-way ANOSIM on sampling times treating different altitudes as replicates was significant (Global R = 0.44, 0 out of

9999 permuted statistics greater than Rho, significance level = 0.0001) and pairwise comparisons are given in Table 10.1. Although all but two pairwise comparisons are statistically different (<0.05), interpretation should be based on the R values which are an absolute measure of differences between the groups in the high dimensional space of the data (Clarke & Gorley 2006). In 2001 the differences in invertebrate assemblages, at the ordinal level, between February, March and April were negligibly small (R ≤ 0.2). In 2002 there were moderate differences (R = 0.4–0.5) in invertebrate assemblages between February and March and between February and April but no differences between March and April. There were moderate to moderate–strong differences (R = 0.4–0.8) in invertebrate assemblages between years for the same months.

For the Order-level counts, there were significant differences in the numbers of individuals captured in pitfalls between 2001 and 2002, with more individuals captured in 2002 compared to 2001 for most taxa (Table 10.2). There were also more taxa recorded overall in 2002 (n=40) compared to 2001 (n=25) (Table 10.2). We also compared the total number of species or morphospecies captured in pitfall traps between 2001 and 2002 using chi-square analysis for those invertebrate groups which were identified to species level and where there were sufficient number of captures to warrant a comparison between years (Orthoptera, Collembola, and Coleopteran families Carabidae, Curculionidae, Leiodidae and Staphylinidae) (Table 10.3). There was a trend for increased captures of individual species in 2002 compared to 2001 in the Collembola (20 out of 21 significant comparisons between years increased from 2001 to 2002), Curculionidae (5 out of 5 significant comparisons between years increased from 2001 to 2002), Leiodidae (7 out of 8 significant comparisons between years increased from 2001 to 2002) and Staphylinidae (10 out of 11 significant comparisons between years increased from 2001 to 2002) (Table 10.3). For The Curculionidae and Staphylinidiae, there were also significantly more species captured in 2002 compared to 2001 (Table 10.3).

These differences between years could potentially be an artefact of different sorters used for different months. Personnel at Forestry Tasmania sorted the February–April 2001 samples and the February 2002 samples, while different personnel at DPIPWE sorted the March–April 2002 samples. To test this possibility, Order-level counts for the February 2001 and February 2002 samples (both sorted by Forestry Tasmania) and for the March–April 2001 and March–April 2002 samples were calculated and compared (Table 10.2). The results suggest that the significant increases in abundance in many taxa between 2001 and 2002 were not primarily the result of different sorters, as the trend was clearly apparent in the Order-level counts between the February 2001 and February 2002 samples, which were sorted by the same sorters (Table 10.2). However, there may have been some sorter differences in the detection of smaller or less common taxa, as a number of minor taxa were recorded by DPIPWE sorters but not by Forestry Tasmania sorters (Table 10.2).

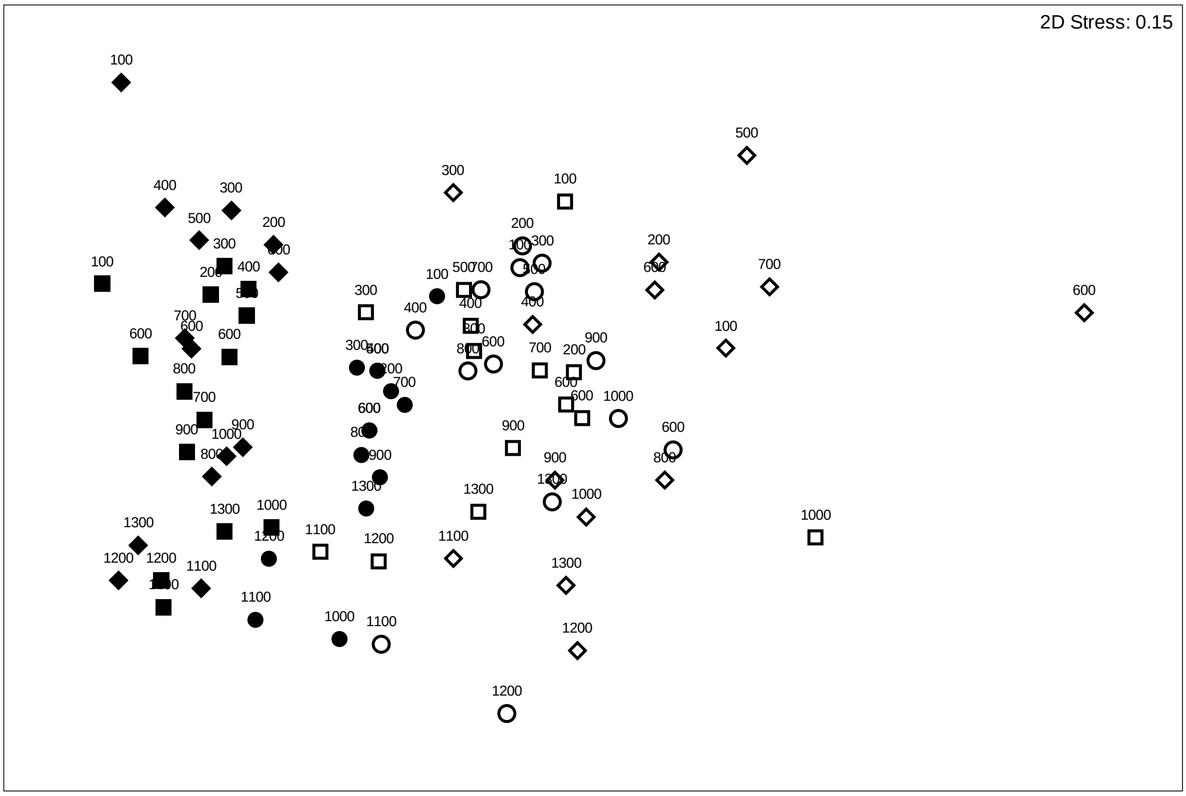


Fig. 10.1 MDS ordination of 14 sites (100–1300 m, including two 600 m sites) surveyed in February (circle), March (square) and April (diamond) in 2001 open symbols and 2002 (closed symbols). Ordination is based on Bray-Curtis similarities and fourth-root transformed abundances.

Table 10.1 R values from pairwise comparisons of monthly invertebrate assemblages using one-way ANOSIM on sampling time treating different altitudes as replicates. ns = non-significant differences (P<0.05).

	February 2001	March 2001	April 2001	February 2002	March 2002	April 2002
February 2001						
March 2001	0.0^{ns}					
April 2001	0.2	0.1				
February 2002	0.4	0.2	0.5			
March 2002	0.8	0.6	0.9	0.4		
April 2002	0.6	0.6	0.8	0.5	0.0^{ns}	

Conclusion

We found that the ordinal composition and abundance of invertebrates, as well as species for selected taxa, did differ significantly between 2001 and 2002 on the Warra-Mount Weld Altitudinal Transect. This is consistent with previous studies undertaken in forest communities elsewhere in Australia (e.g. Bell 1985, Recher *et al.* 1996). Indeed interannual variation in invertebrate assemblages in response to resource availability and climatic conditions has been well documented across the globe (Barrow & Parr 2008). This interannual variation needs to be taken into consideration when assessing potential impacts of climate change, or other environmental impacts, on the invertrate assemblages of the Warra-Mount Weld Altitudinal Transect. We suggest that the focus of detecting changes due to climate change should be on on monitoring the distribution of taxa that have a limited altitudinal range that (identified in previous sections of this report and summarised in Table 11.4 in the next chapter). The limitations of, and options for, the Warra-Mount Weld Altitudinal Transect invertebrate survey are discussed further in section 11.

Table 10.2 Comparison of the total number of invertebrate taxa captured in pitfall traps between February–April 2001 and 2002, between February 2001 and 2002 (both 2001 and 2002 samples sorted by Forestry Tasmania), and between March–April 2001 and 2002 (2001 samples sorted by Forestry Tasmanian and 2002 samples sorted by DPIPWE). Data pooled over altitude. Data from Mount Weld 600 m has been omitted due to four lost pitfall traps in 2001 (refer to Table 2.1 in Chapter 2). * = P < 0.05, ** = P < 0.01, *** = P < 0.001. Chi-squared tests were not performed were both expected values where less than 5. Trend: I = counts of taxa increased between 2001 and 2002. D = counts of taxa decreased between 2001 and 2002. V = trends in counts varied between 2001 and 2002 for February and March–April.

Taxa	February–April				February				March–April				Trend
	2001	2002	X^2	P	2001	2002	Chi^2	p	2001	2002	X^2	P	
Acarina	593	2541	1210.82	***	276	699	202.67	***	317	1842	1077.18	***	I
Amphipoda	696	1095	88.89	***	270	433	45.88	***	426	662	51.19	***	I
Annelida	24	26	0.08		15	0	15.00	***	9	26	8.26	**	V
Araneae	1778	2006	13.74	***	704	759	2.98		1074	1247	12.89	***	I
Blattodea	629	172	260.74	***	85	38	18.58	***	544	134	247.94	***	D
Chilopoda	146	137	0.29		79	45	7.34	**	67	92	3.93	*	V
Coleoptera adult	1865	3619	561.00	***	860	1668	455.05	***	1005	1951	302.75	***	I
Coleoptera larva	35	54	4.06	*	33	3	25.00	***	2	51	45.30	***	V
Collembola	1726	17369	12815.05	***	179	2871	2407.58	***	1547	14498	10453.62	***	I
Dermaptera	27	154	89.11	***	9	91	67.24	***	18	63	25.00	***	I
Diplopoda	108	206	30.59	***	31	68	18.24	***	77	138	17.31	***	I
Diplura	1	36	33.11	***	1	0			0	36	36.00	***	I
Diptera adult	5434	25468	12988.19	***	2125	11844	7729.60	***	3309	13624	6283.54	***	I
Diptera larva	208	1128	633.53	***	36	353	258.33	***	172	775	383.96	***	I
Gastropoda	29	43	2.72		10	6	1.47		19	37	5.79	**	V
Hemiptera	128	608	313.04	***	49	167	79.87	***	79	441	252.01	***	I
Formicidae	920	1176	31.27	***	287	422	25.15	***	633	754	10.56	**	I
Harpacticoidea	0	66	66.00	***	0	0			0	66	66.00	***	I
Hymenoptera adult (less Formicidae)	152	645	304.95	***	49	217	135.11	***	103	428	198.92	***	I

Hymenoptera larva	0	169	169.00	***	0	7			0	162	162.00	***	I
Isoptera	0	6			0	0			0	6			
Isopoda	442	436	0.04		123	169	11.69	***	319	267	4.61	*	V
Lepidoptera adult	18	188	140.29	***	6	49	34.57	***	12	139	106.81	***	I
Lepidoptera larva	11	72	44.83	***	7	2			4	70	58.86	***	I
Opilionida	112	739	461.96	***	48	148	55.62	***	64	591	424.01	***	I
Orthoptera	502	415	8.25	**	287	193	13.31	***	215	222	0.11		V
Parasitic Worms	7	0			6	0			1	0			
Plecoptera	0	2			0	0			0	2			
Thysanoptera	5	257	242.38	***	1	67	65.06	***	4	190	178.33	***	I
Mecoptera	0	1372	1372.00	***	0	0			0	1372	1372.00	***	I
Nemata	0	1			0	0			0	1			
Neuroptara larva	0	5			0	0			0	5			
Onychophora	0	5			0	0			0	5			
Ostracoda	0	17	17.00	***	0	0			0	17	17.00	***	I
Psocoptera	0	7			0	0			0	7			
Pseudoscorpionida	0	53	53.00	***	0	0			0	53	53.00	***	I
Siphonoptera	0	25	25.00	***	0	0			0	25	25.00	***	I
Symphyla	0	4			0	0			0	4			
Trichoptera larva	0	18	18.00	***	0	0			0	18	18.00	***	I
Turbellaria	0	51	51.00	***	0	0			0	51	51.00	***	I
Unknown	0	18	18.00	***	0	0			0	18	18.00	***	I
Number of taxa	25	40	3.46	(0.06)	25	23	0.08		24	40	4.00	*	

Table 10.3 Comparison of the total number of invertebrate species or morphospecies captured in pitfall traps between 2001 and 2002 using chi-square analysis for Orthoptera, Collembola and Coleoptera (families Carabidae, Curculionidae, Leiodidae and Staphylinidae). Counts have been pooled over altitudes (0–1300 m) and months (February–April, except Collembola where only data for February were available). * = P < 0.05, ** = P < 0.01, *** = P < 0.001. Chi-squared tests were not performed were both expected values where less than 5. Trend: I = increase from 2001 to 2002, D = decrease from 2001 to 2002.

Taxa	2001	2002	X^2	P	Trend
ORTHOPTERA					
Acrididae				**	D
Russalpia longifurca	239	184	7.15		
Tasmaniacris tasmaniensis	7	23	8.53	**	I
Tasmanalpina clavata	1	6			
Gryllacrididae					
Kinemania ambulans	11	13	0.17		
Gryllidae					
Bobilla poene	1	8			
Raphidophoridae					
Parvotettix maydenaensis	181	155	2.01		
Number of species	5	5	0.00		
COLLEMBOLA					
Brachystomellidae					
cf. *Cassagnella* sp. 01	6	0			
gen. & sp. indet.	0	45	45.00	***	I
Dicyrtomidae					
gen. & sp. indet. sp. 01	6	96	79.41	***	I
Entomobryidae					
cf. *Entomobrya* sp. 01	0	2			
cf. *Drepanura* sp. 01	1	0			
imm. & damaged indet.	17	4	8.05	**	D
Lepidocyrtoides sp. 01	9	12	0.43		
Lepidocyrtus sp. 01	2	8	3.60		
Lepidocyrtus sp. 02	0	10	10.00	**	I
Isotomidae					
Acanthomurus sp. 01	19	641	586.19	***	I
Acanthomurus sp. 02	1	0			
Isotoma sp. 01	6	330	312.43	***	I
Isotoma sp. 02	0	1			
Neanuridae					
Acanthanura spp	1	4			
Australonura cf. *wellingtonia* sp. 01	0	1			
Australotomurus cf. *echidnus* sp. 01	1	2			
cf. *Pseudachorutella* sp 01	0	14	14.00	***	I
gen & sp. indet.	1	33	30.12	***	I
Odontellidae					
gen. & sp. indet.	13	76	44.60	***	I
Paronellidae					
Imm. & damaged indet.	2	15	9.94	**	I

Paronellides cf. *mjobergi* (Schott, 1917) sp. 01	1	44	41.09	***	I
Paronellides sp. 02	2	17	11.84	***	I
Paronellides sp. 04	0	23	23.00	***	I
Paronellides sp. 05	1	14	11.27	***	I
Tomoceridae					
Lepidophorella sp. 01	59	94	8.01	**	I
Novacerus cf. *tasmanicus* sp. 01	11	26	6.08	*	I
Bourletiellidae					
Rastriopes sp. 01	3	9	3.00		
Katiannidae					
cf. *Polykatianna* gen. & sp. indet. sp. 01	0	16	16.00	***	I
cf. *Pseudokatianna* sp. 01	0	50	50.00	***	I
Poduromorpha					
imm. & damaged indet.	0	92	92.00	***	I
Symphypleona					
imm. & damaged indet. sp. 01	1	24	21.16	***	I
imm. & damaged indet. sp. 02	0	247	247.00	***	I
Number of species	22	30	1.23		
COLEOPTERA					
Carabidae					
Acallistus longus	44	40	0.19		
Acallistus TFIC sp 01	4	6	0.40		
Calyptogonia atra occidentalis	5	7	0.33		
Chylnus ater	16	1	13.24	***	D
Lestignathus cursor	3	2			
Lestignathus foveatus	2	1			
Notagonum marginellum	1	0			
Notonomus politulus	17	28	2.69		
Paratrechodes macleayi	1	0			
Percodermus niger	6	2			
Percosoma carenoides	2	3			
Pogonoschema robustum	4	0			
Promecoderus gibbosus	56	27	10.13	***	D
Promecoderus TFIC sp 01	1	0			
Prosopogmus tasmanicus	0	1			
Pterocyrtus globosus	12	107	75.84	***	I
Pterocyrtus TFIC sp 02	123	0	123.00	***	D
Rhabdotus reflexus	96	158	15.13	***	I
Scopodes boops	4	10	2.57		
Simodontus australis	0	1			
Sloaneana tasmaniae	54	81	5.40	*	I
Stichonotus piceus	105	175	17.50	***	I
Tasmanorites nitens	15	1	12.25	***	D
Tasmanorites sp aff tasmaniae	62	13	32.01	***	D
Trechistus terricola	41	31	1.39		
Number of species	23	20	0.21		
Curculionidae					

Cryptorhynchinae TFIC sp 07	5	10	1.67		
Cryptorhynchinae TFIC sp 20	7	3	1.60		
Cryptorhynchinae TFIC sp 57	0	1			
Curculionidae TFIC sp 52	0	1			
Curculionidae TFIC sp 53	0	1			
Curculionidae TFIC sp 54	0	1			
Curculionidae TFIC sp 56	0	1			
Curculionidae TFIC sp 58	0	1			
Curculionidae TFIC sp 61	0	1			
Curculionidae TFIC sp 63	1	0			
Entiminae TFIC sp 01	1	1			
Entiminae TFIC sp 15	1	0			
Entiminae TFIC sp 17	1	0			
Tychiinae TFIC sp 08	1	0			
Tychiinae TFIC sp 37	0	1			
Ancyttalia oleariae	0	2			
Chrysophoracis pulcher	1	0			
Decilaus bryophilus	0	5			
Decilaus lateralis	3	10	3.77		
Decilaus nigronotatus	4	14	5.56	*	I
Decilaus striatus	4	21	11.56	***	I
Decilaus TFIC sp 02	0	1			
Decilaus TFIC sp 03	4	15	6.37	*	I
Decilaus TFIC sp 04	6	32	17.79	***	I
Decilaus TFIC sp 23	0	3			
Decilaus TFIC sp 24	0	1			
Deiantha TFIC sp 01	3	4			
Dinichus terreus	10	15	1.00		
Dryophthorus ECZ sp 02	0	1			
Exeiratus carinatus	1	0			
Exeiratus TFIC sp 01	1	0			
Exeiratus TFIC sp 07	6	4	0.40		
Exeiratus TFIC sp 09	1	0			
Exithius cariosus	0	2			
Exithius loculiferus	0	1			
Exithius TFIC sp 02	0	1			
Exithius TFIC sp 04	0	1			
Exithius TFIC sp 08	0	3			
Exithius TFIC sp 11	0	1			
Mandalotus arciferus	8	10	0.22		
Mandalotus blackburni	0	3			
Mandalotus muscivorus	8	7	0.07		
Mandalotus TFIC sp 12	1	0			
Microcryptorrhynchus pygmaeus	0	1			
Pachyporopterus satyrus	3	11	4.57	*	I
Perperus TFIC sp 01	0	2			
Poropterus alboscutellaris	0	2			
Poropterus antiquus	0	2			
Pseudometyrus ANIC sp 01	0	1			
Rhamphus acaciae	0	1			
Roptoperus tasmaniensis	16	27	2.81		

Tyrtaeosus pollux	1	0			
Number of species	23	42	5.55	*	I
Leiodidae					
Agyrtodini SEAGO gen nov TFIC sp 01	0	5			
Cholevinae gen nr *Austronemadus* TFIC sp 01	166	0	166.00	***	D
Sogdini ANIC gen B TFIC sp 01	4	0			
Sogdini ANIC gen B TFIC sp 01	0	23	23.00	***	I
Sogdini SEAGO gen nov A TFIC sp 01	1	2			
Agyrtodes atropos	1	0			
Austronemadus TFIC sp 03	199	378	55.53	***	I
Austronemadus TFIC sp 04	4	12	4.00	*	I
Catoposchema tasmaniae	2	27	21.55	***	I
Choleva TFIC sp 01	32	435	347.77	***	I
Colenisia TFIC sp 01	0	1			
Colon TFIC sp 03	0	1			
Myrmicholeva acutifrons	0	1			
Nargiotes gordoni	1	7			
Nargomorphus apicalis	1	0			
Nargomorphus confertus	0	4			
Nargomorphus globulus	31	41	1.39		
Nargomorphus jeanneli	0	5			
Nargomorphus leanus	7	291	270.66	***	I
Nargomorphus victoriensis	1	44	41.09	***	I
Zeadolopus TFIC sp 02	0	9			
Number of species	13	17	0.53		
Staphylindae					
Aleocharinae TFIC sp 004	0	2			
Aleocharinae TFIC sp 007	17	33	5.12	*	I
Aleocharinae TFIC sp 008	0	1			
Aleocharinae TFIC sp 009	7	0			
Aleocharinae TFIC sp 015	2	2			
Aleocharinae TFIC sp 016	1	0			
Aleocharinae TFIC sp 019	0	2			
Aleocharinae TFIC sp 024	1	2			
Aleocharinae TFIC sp 027	0	1			
Aleocharinae TFIC sp 028	0	2			
Aleocharinae TFIC sp 031	0	1			
Aleocharinae TFIC sp 042	0	1			
Aleocharinae TFIC sp 057	2	69	63.23	***	I
Aleocharinae TFIC sp 064	0	2			
Aleocharinae TFIC sp 066	0	1			
Oxypodini TFIC sp 02	1	0			
Pselaphitae TFIC sp 01	0	1			
Trichonychini TFIC sp 01	0	1			
Tyrini TFIC sp 01	0	1			
Tyrini TFIC sp 02	1	0			
Aleochara TFIC sp 01	1	0			

Anabaxis CHANDLER type 1	0	5			
Anotylus TFIC sp 02	0	4			
Anotylus TFIC sp 04	0	25	25.00	***	I
Atheta TFIC sp 01	0	14	14.00	***	I
Atheta TFIC sp 02	0	7			
Atheta TFIC sp 03	37	322	226.25	***	I
Aulaxus Chandler Tasmania 1	0	1			
Baeocera TFIC sp 01	0	1			
Baeocera TFIC sp 02	0	3			
Euconnus TFIC sp 07	5	14	4.26	*	I
Eupinella tarsalis	1	1			
Euplectops CHANDLER Tasmania 1	1	0			
Falagria TFIC sp 04	2	2			
Heterothops TFIC sp 04	0	2			
Heterothops TFIC sp 06	5	4			
Horaeomorphus TFIC sp 03	0	3			
Horaeomorphus TFIC sp 09	2	0			
Horaeomorphus TFIC sp 12	6	5	0.09		
Horaeomorphus TFIC sp 12	0	1			
Hyperomma bryophilum	2	1			
Logasa TFIC sp 01	0	1			
Macroplectus tasmanicus	2	13	8.07	**	I
Microsilpha ANIC Thayer sp 15	44	14	15.52	***	D
Phloeonomus tasmanicus	0	1			
Pselaphaulax CHANDLER Tasmania 1	3	19	11.64	***	I
Quediomimus TFIC sp 01	0	1			
Quedius ANIC Newton sp 03	18	27	1.80		I
Quedius baldiensis	0	1			
Quedius duplopunctatus	0	6			
Quedius TFIC sp 07	0	3			
Rybaxis CHANDLER Tasmania 1	0	1			
Rybaxis parvidens	0	4			
Rybaxis TFIC sp 01	0	1			
Sagola CHANDLER Tasmania 2	5	6	0.09		
Sepedophilus TFIC sp 08	14	9	1.09		
Spanioda carissima	10	15	1.00		
Tasmanityrus auricomus	1	0			
Tetrabothrus claviger	0	2			
Tyrogetus occidentalis	0	1			
Zyras TFIC sp 01	22	26	0.33		
Number of species	27	53	8.45	**	I

11 REVIEW OF THE WARRA-MOUNT WELD ALTITUDINAL TRANSECT AND OPTIONS FOR FUTURE DIRECTIONS

by Stephen Mallick and Michael Driessen

The projected shifts in climate as a result of human-induced-increases in greenhouse gases is predicted to have far-reaching effects on the planet's biota (Gaston *et al.* 2000). One of the many issues raised by these predicted changes is the long-term adequacy of existing conservation reserves in protecting flora and fauna species (Doran *et al.* 2003). Large scale shifts in ecosystem function and processes governing community composition and structure are likely to lead to shifts in treeline margins and the boundaries between ecotones and habitat types (Gaston *et al.* 2000). Inevitably, such shifts will disadvantage some species, such as alpine species where mountaintop 'islands' of habitat could be reduced in area or totally removed through a raising of the treeline. It is also inevitable that other species will be advantaged by habitat shifts as a result of climate change.

In the face of these predicted impacts of climate change on plant and animal distribution, there is an urgent need for establishing long-term monitoring programs to provide baseline data to measure future shifts in biota as a result of climate change. Such monitoring is important for both documenting change, and also provides information on which to base future decisions on the conservation of species, such as reserve design, reserve management, as well as last-resort actions (for example, *ex situ* breeding populations and assisted colonisations) to save species from extinction (Dunlop & Brown 2008, Dunlop *et al.* 2012, Harris *et al.* 2013).

Altitudinal gradients offer an opportunity to examine a number of altitude-determined ecotones over a restricted geographical area, and provide a useful analogue for studying the effect of environmental change over latitudinal gradients (Kitching *et al.* 2011). Altitudinal gradients have been used to investigate species turnover and the mechanism behind patterns in diversity and community structure (Aubry *et al.* 2005, Chatzaki *et al.* 2009). They are also recognised as useful systems in which to study the effects of climate change, where gradients in environmental variables such as temperature and precipitation occur in the same geographical area, thus minimising uncontrolled environmental variation so that any impacts of climate change are more likely to be apparent (Kitching *et al.* 2011).

The Warra-Mount Weld Altitudinal Transect study to date represents an intensive sampling over a 10 year period of the invertebrate biodiversity at a single location, and is of inherent scientific interest as it documents the invertebrate fauna of a single altitudinal gradient in a specific geographic area. The data is also of interest taxonomically as it collects previously undescribed material. However, projects of this type tend to lack replication, and this is the case with the Warra-Mount Weld Altitudinal Transect study. Because of the enormous effort and expense required to characterise the biodiversity of a single location, there is little realistic likelihood of extending the results to cover other locations. As a result, the study design may not provide a particularly useful tool for understanding biodiversity pattern and its likely response to climatic (or any other form of environmental) change (Kitching *et al.* 2011). On the other hand, the results do provide a 'snapshot' of information from a single altitudinal transect which can be useful for identifying particular species to be studied in more detail, and for other locations to be examined with greater efficiency and focus (Kitching *et al.* 2011).

Another limitation in using an altitudinal transect to examine shifts in invertebrates with climate or other environmental change over the longer term is the problem of background variation or noise in the data. As a result, assessing year-to-year variation is particularly pertinent for long-term studies extending over decades, and is likely to be particular important for invertebrate sampling where abundance can vary widely over relatively short time periods (months or years) and in response to a wide range of biological and physical factors. The results of the present study suggest that, at the ordinal level, pitfall trapping of invertebrates on the Warra-Mount Weld Altitudinal Transect may be subject to significant levels of inter-year variation. While this result is based on only two years of baseline sampling, the level of variation detected appeared to be substantial and was present in a wide range of taxa. Whatever the cause of this inter-year variation, the results suggest that the ability of the Warra-Mount Weld Altitudinal Transect to detect long-term, climate-induced shifts in the invertebrate assemblages may be limited when using the full suite of invertebrate data identified to the ordinal level. If invertebrate abundance is found to change significantly in subsequent decades, it may be difficult to distinguish between the sort of variation observed between the two consecutive baseline years of sampling and shifts in invertebrate abundance that are the result of climate change.

Most of the invertebrate groups examined to species level showed marked altitudinal patterns in the abundance and distribution of individual species, and for the majority of groups there are a number of species which appear to be constrained by altitude (Table 11.1). Such altitude-limited species are considerably more likely to demonstrate shifts in abundance and altitudinal range as a result of climate change. They therefore represent potential indicator species which could be used to target the investigation of climate-induced shifts in invertebrates from a ‘scatter gun’ approach looking at the entire invertebrate biodiversity over the transect (cf. Doran *et al.* 2003) to one focussed on a small subset of taxa which are most likely to demonstrate quantifiable shifts in abundance or range.

Options for future directions for the project

The original objective of the Warra-Mount Weld Altitudinal Transect invertebrate project was to record baseline inventory and distributional data for invertebrates along an altitudinal gradient which can then be used to document altitudinal shifts in invertebrate assemblages over time which may result from climate change or other processes such as wildfire (Bashford *et al.* 2001, Doran *et al.* 2003, Grove 2004). Warra is a core site within the International Biodiversity Observation Year (IBOY) global long-term monitoring network, and the Warra-Mount Weld Altitudinal Transect invertebrate project has been accepted as a Satellite Project (Bashford *et al.* 2001, Doran *et al.* 2003). The Warra-Mount Weld Altitudinal Transect invertebrate project is similar in design and scale to the IBISCA-Queensland project examining changes in arthropod assemblages over an altitudinal gradient within the Lamington National Park, south-eastern Queensland (Kitching *et al.* 2011).

To date there has been sampling on the Warra-Mount Weld Altitudinal Transect in two consecutive baseline years (2001 and 2002), and a first decade-period sampling in 2011–2012. While the data from the latter has not yet been analysed, it is appropriate to attempt some reassessment of the original aims of the project against preliminary data and in relation to similar projects elsewhere.

Table 11.1 Altitude-limited species identified on the Warra-Mount Weld Altitudinal Transect.

Taxa	Notes
Coleoptera	
Tasmanorites sp. aff. *tasmania* (Carabidae)	1100–1200 m
Percodermus niger (Carabidae)	1000–1200 m
Tasmanorites nitens (Carabidae)	1100 m
Calyptogonia atra occidentalis (Carabidae)	900–1300m, flightless, only known from Mount Weld.
Nat vandenbergae (Coccinelidae)[1]	800–1000 m, rare Tasmanian endemic, however it should be noted that two specimens have been collected below 300 m at Warra.
Notolioon gemmatus (Byrrhidae)	1100–1200 m cryptic, flightless Tasmanian endemic, associated with moss, uncommon but widespread at higher altitudes.
Coripera adamsi (Tenebrionidae)	1300 m, flightless, Tasmanian endemic, an uncommon species found in low numbers at high altitudes.
Semelvillea tasmaniae (Chrysomelidae)[1]	800–1010 m, winged, endemic species, has been recorded from altitudes below 300m at Warra.
Microdonacia truganina (Chrysomelidae)[1]	1000 m, winged, endemic, rare species only previously collected above 1000 m at Mount Field and the summit of Mount Wellington.
Amphipoda	
Neorchestia plicibrancha (Talitridae)	Dominant amphipod at altitudes above about 900 m, also in smaller numbers at lower altitudes. The increase in *N. plicibrancha* numbers between 1100 and 1200 m is striking. The point at which *N. plicibrancha* numbers sharply increase could serve as a climate change marker.
Collembola	
Paronellides sp. 2 (Paronellidae)	100–500 m
Paronellides sp. 4 (Paronellidae)	800–1300 m
Paronellides sp. 5 (Paronellidae)	800–1300 m
Rastriopes sp. 2 (Bourletiellidae)	800–1100 m
Lepidocyrtus sp. 2 (Entomobryidae)	1100–1300 m
Isotoma sp. 1 (Isotomidae)	700–1100 m
Isotoma sp. 2 (Isotomidae)	1100–1200 m
Gastropoda	
Victaphanta sp. 'Weld' (Rhytididae)	1200 m, obligatorily alpine species, similar specimens have been collected from some other south-western mountains at altitudes above 800 m.
Orthoptera	
Tasmanalpina clavata (Acrididae)	1100–1300 m above the treeline, occurs on mountains above 900 m where it shows a strong habitat preference for talus slopes.

*Captured in malaise traps

In discussing the IBISCA-Queensland project, Kitching *et al.* (2011) note the principal limitation inherent in a single, intensively sampled altitudinal transect study is the lack of replication. One solution to this problem is to attempt to set up replicates of the existing Warra-Mount Weld Altitudinal Transect in comparable locations. However, this presents major problems in locating 'replicate' altitudinal transect sites, as sites even in the near vicinity will differ in a number of parameters, and the introduction of these new sources of variation may outweigh any advantage of replication. In practice, extending the study to additional mountain sites is also highly unlikely to gain viable funding over the long term.

Another option is to expand the design to include replication within the existing transect. This would improve the design of the study and may go some way to addressing the issue of 'normal' background variation in invertebrate abundance drowning out any potential climate-change signal. However, setting up replicate sampling sites on the current transect would significantly increase the labour involved in both setting and collecting traps and in the sorting of material.

A third option is to continue the primary aim of the project in examining long-term shifts in invertebrate assemblages due to climate (or other long-term environmental) change, but narrow the focus of the study from one that examines patterns of change in a broad assemblage of invertebrates, and instead focus on a limited subset of indicator taxa which are most likely to demonstrate altitudinal shifts due to climate or other environmental change. The altitude-limited species identified in the present report (see Table 11.1) provide a number of candidate species for this sort of approach.

Finally, it may be appropriate to alter the original long-term climate-change focus of the study and accept that the (inevitable) lack of replication in the study design and the apparently high levels of natural variation in the system make the study of limited use as a tool for monitoring long-term change (over many decades) in invertebrate fauna. In this connection, it should be noted that the study was not confined to examining climate change, but was set up to provide a baseline of inventory and distributional invertebrate data in the event of other environmental process such as succession after fire or other chance events (Doran *et al.* 2003). The baseline sampling in 2001 and 2002 in addition to the additional 2011—2012 data (when it becomes available) provides an excellent foundation for this alternative objective.

ACKNOWLEDGEMENTS

We thank Niall Doran who co-ordinated and undertook the collection of the invertebrate samples in 2001 and 2002 and conducted an ordinal-level analysis of the data (Doran et al. 2003). We also thank all those involved in field work and sorting of specimens, in particular to: Judi Griggs, Suzette Wood, Jonah Gouldthorpe, Mark Weeding, Colin Shepherd, Kevin Doran, Michael Lichon, Bill Brown, Helen Daly, Andrew Muirhead, Ray Brereton, Sally Bryant, Belinda Yaxley, Ursula Taylor, Alistair Scott, Shaun Thurstans, Paul Fulton, Billie Lazenby, Nicki Meeson, Dick Bashford, Chris Palmer, Robbie Gaffney, Sue Baker, Peter Dalton, Richard Holmes, and Rob Walsh. This project was funded by the Tasmanian and Australian governments through the Tasmanian Wilderness World Heritage Area fauna program.

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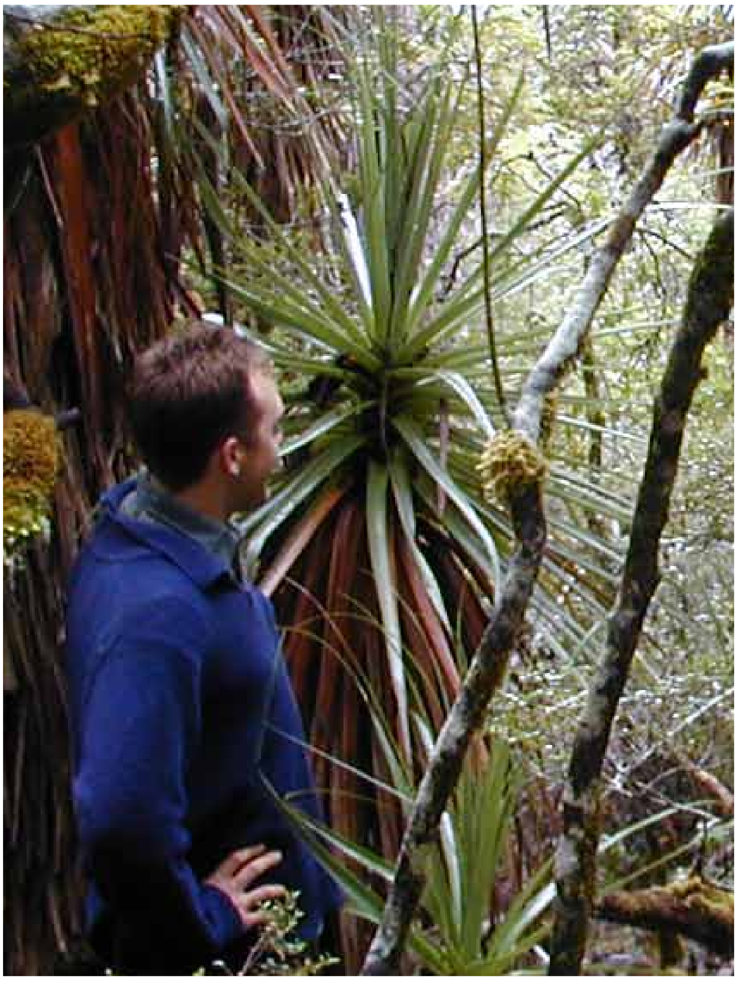

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