Patterns in pitfall captures of millipedes (Diplopoda: Polydesmida: Paradoxosomatidae) at coastal heathland sites in Tasmania

[1]Robert Mesibov and [2]Tracey B. Churchill

[1] Queen Victoria Museum and Art Gallery,
Wellington Street, Launceston, Tasmania, Australia 7316; mesibov@southcom.com.au

[2] Museum and Art Gallery of the Northern Territory,
GPO Box 4646, Darwin, NT, Australia 0801

ABSTRACT

The millipede by-catch from a 1986-88 spider survey in Tasmanian coastal heathland was tallied by species, sex and life-stage. Two species of paradoxosomatid Polydesmida, *Notodesmus scotius* Chamberlin, 1920 and *Pogonosternum* sp., made up 99.8% of the pitfall captures. The *N. scotius* catch (9754 individuals) was 80% adult (stadium VIII) and peaked in October-December with only 23 captures in July-September. The *Pogonosternum* sp. catch (116 individuals) was 91% adult and peaked in September, with 40% of all captures in July-September. These results, together with field observations, indicate that pitfall trapping mainly captured adults wandering during the mating season, and that mating seasons for the two species did not coincide. The *Pogonosternum* sp. captures were tightly clustered in space, showing that pitfall trapping can be an unreliable method for estimating millipede abundance unless the fine-scale spatial patterning of target species is known in advance. A third paradoxosomatid species known to be present near the survey sites, *Dicranogonus* sp., did not appear in any of the 938 pitfall samples containing millipedes. The overwhelming dominance of paradoxosomatid Polydesmida in heathland is in marked contrast to the dominance of dalodesmid Polydesmida in forest habitats in Tasmania.

Key words: Diplopoda, Polydesmida, Paradoxosomatidae, millipede, pitfall, heathland, Tasmania

Introduction

In Tasmania, as elsewhere, millipede diversity and abundance are greatest in forest (Mesibov 2000), although millipedes can also be found in woodland, scrub, heathland, moorland and alpine vegetation. A division in macrohabitat use is apparent in the Tasmanian Polydesmida (flatback millipedes), with numerous species of Dalodesmidae predominating in more closed and wet vegetation, and a small number of Paradoxosomatidae predominating in more open and dry habitats. The former observation was documented in a year-long pitfall study in wet eucalypt forest in central Tasmania (Mesibov *et al.* 1995) which yielded 190 dalodesmid specimens and only one paradoxosomatid; the totals for parallel hand-sampling in the same areas were 663 and one, respectively.

In this paper we document the dominance of Paradoxosomatidae in Tasmanian coastal heathland. Our data are incidental results of a spider survey undertaken by the junior author in 1986-88 (Churchill 1993, 1996). Four coastal heathland sites in northeast Tasmania were intensively sampled by searching, sweep-netting and pitfall trapping over a 16-month period. The aim was to document species composition, local-scale distribution and seasonal abundance of spider communities, as background for assessing the biogeographical and conservation significance of the coastal heathlands. The sampling resulted in a by-catch of nearly 10000 millipedes in pitfall traps, which to our knowledge is the largest single millipede collection in Tasmania. Curation of this material as discrete samples has allowed an assessment, presented below, of spatial and temporal patterns in the millipede capture data.

Methods

The study sites were in weed-free heathland grazed/browsed only by native animals. The heathlands are managed by occasional burning but the detailed fire histories of the study sites are unknown. Two 90 x 90 m sites were located at each of two study areas in northeast Tasmania. Site 1 (40°50'51"S, 147°38'07"E, 40m above sea level) and Site 2 (40°50'20"S, 147°40'45"E, 30m) were at Waterhouse Point, and Site 3 (40°59'44"S, 148°19'27"E, 10m) and Site 4 (41°00'02"S, 148°19'15"E, 10m) at Eddystone Point (Fig. 1). A description of the vegetation can be found in Churchill (1996).

At each site a pitfall trap array was laid out at the northwest corner, centre and southeast corner of the 90 m square. Each array consisted of nine pitfall traps 4.5 m apart in a 3 x 3 grid. At each trap point, PVC pipe was set into a hole in the soil and a 9 cm diameter plastic cup placed within so that the soil surface was flush with its rim. A 10 cm diameter plastic lid was held above the trap by wire supports when the trap was open, and covered the cup when the trap was closed. Traps were filled with 100 ml of 60% ethylene glycol + 2% formalin in water, with 1 ml detergent, and were exposed for one week at five-weekly intervals between October 1986 and January 1988. All captures were drained and stored in 70-80% ethanol.

The survey generated 14 samplings x 108 traps = 1512 pitfall trap samples. Residues (samples with spiders removed) were labeled and stored at QVMAG, and further sorting of some samples was carried out in the Museum's Zoology section in the 1990s. In 2001 all remaining millipedes were removed from the samples and

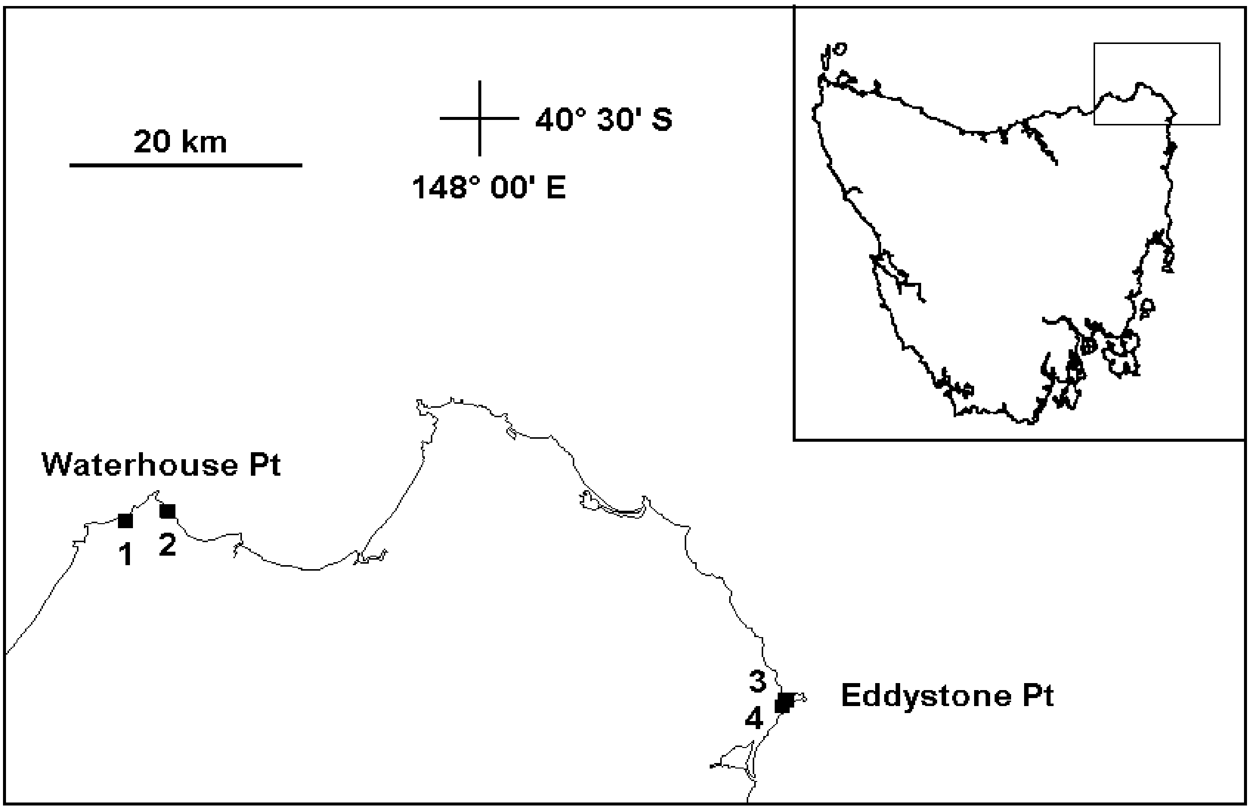

Fig. 1. Locations of the four sampling sites in northeast Tasmania. Inset shows location of main map.

the residues re-packed for continued storage. Millipedes were tallied by species, sex and stadium by the senior author; only anterior portions of fragmented specimens were counted.

In our results we present only simple descriptive statistics and data displays. The 1986-88 heathland survey was designed to compare spider diversity and abundance between sites, and details of within-site habitat heterogeneity (particularly details relevant to millipede distribution on a fine scale, such as litter structure and depth) were not recorded. Thus we can neither stratify sites which we know were non-uniform, nor separate the effects of habitat heterogeneity from other factors contributing to spatial autocorrelation. We have also been cautious in our interpretation of weather data, which are monthly totals or averages, as compared to one-week millipede samplings at five-weekly intervals.

Table 1. Tally of *Notodesmus* captures by sex (m,f) and stadium (V-VIII) 'Date' is the day on which pitfall traps were emptied after one week's exposure.

Date	mV	mVI	mVII	mVIII	fV	fVI	fVII	fVIII
20 - Oct - 86	2	36	308	705	1	46	358	489
24 - Nov - 86	0	18	229	974	0	24	363	430
29 - Dec - 86	0	1	49	674	0	4	78	234
03 - Feb - 87	0	0	4	144	0	0	6	88
10 - Mar - 87	0	0	6	654	0	0	6	194
22 - Apr - 87	0	0	1	17	1	0	4	15
25 - May - 87	0	0	25	26	1	1	52	8
01 - Jul - 87	0	0	0	2	0	0	0	0
05 - Aug - 87	0	0	1	0	0	0	0	1
11 - Sep - 87	0	0	1	11	0	0	3	4
14 - Oct - 87	0	1	4	57	0	1	11	68
18 - Nov - 87	0	5	103	915	0	9	117	517
21 - Dec - 87	0	1	17	836	0	0	24	388
25 - Jan - 88	0	0	3	222	0	1	10	145
Totals	2	62	751	5237	3	86	1032	2581

Results

Overview

A single unidentified Polyxenida specimen and 9886 Polydesmida were found in 938 of the 1512 pitfall trap samples. The polydesmidans comprised *Notodesmus scotius* Chamberlin, 1920 (9754 specimens; Fig. 2), an undescribed *Pogonosternum* species (116 specimens) and four unidentifiable juveniles, all Paradoxosomatidae. There were also 12 specimens of two undescribed, locally endemic species of Dalodesmidae.

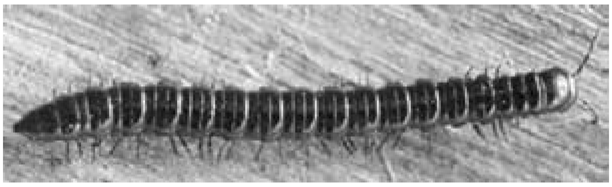

Figure 2. Adult female *Notodesmus scotius,* live length *ca.* 20 mm. Specimen collected 9 November 2002 near Site 1.

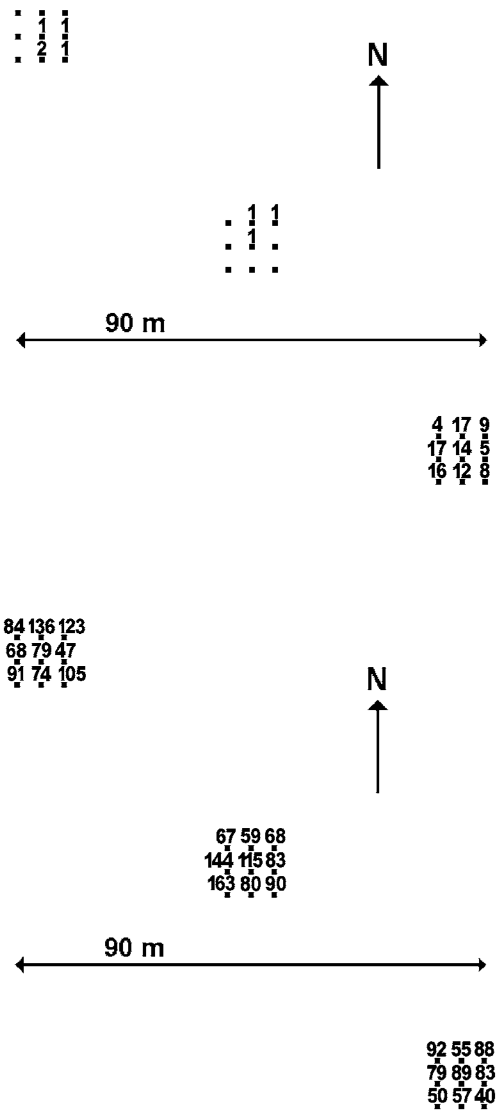

Figure 3. Total millipede captures (number of specimens) at Site 2. Each small square represents a single pitfall trap; traps were 4.5 m apart. Top: *Pogonosternum* sp.; bottom: *Notodesmus scotius.*

Sex and age classes

Adults (stadium VIII) made up 80% of all *Notodesmus* captures (Table 1) and at least one adult male or one adult female *Notodesmus* were found in each of the 108 pitfall traps during the sampling period. On average, roughly one adult *Notodesmus* female was trapped for every two adult males (Table 1; female/male ratio 0.49, range over the four sites 0.41-0.60), while the average female/male ratio was 1.4 for both stadium VI and stadium VII (range for VI, 0.8-2.0; VII, 1.3-1.6). Of the 116 *Pogonosternum* captures, 106 were adults, with a similar sex ratio to that in *Notodesmus*: 36 females to 70 males.

Spatial patterns

Pogonosternum captures were highly clustered. Of the 110 specimens trapped at Site 2, 102 were in one pitfall array in the southeast corner of the 90 x 90 m layout (Fig. 3). The remaining six *Pogonosternum* specimens appeared in a single pitfall trap at Site 4 in December 1986.

The proportion of juvenile *Notodesmus* (stadia V-VII) captures varied almost four-fold across the study area, from 0.08 at Site 3 to 0.30 at Site 2. The two sites with the highest total of *Notodesmus* captures (2 and 4) had the highest proportion of juveniles. Of the anomalously high 77 captures of stadium VII juveniles in May 1987 (Table 1), 76 were from Waterhouse Point (Site 1, 54 individuals; site 2, 22).

Temporal patterns

There was a notable contrast in the seasonal pattern of catches of *Notodesmus* and *Pogonosternum* species. *Notodesmus* captures peaked in October-December, with only 23 of 9754 specimens trapped in July-September (Fig. 4). A 'spike' of *Notodesmus* captures in March 1987 at Waterhouse Point (Sites 1 and 2) was not seen at Eddystone Point (Sites 3 and 4), but otherwise the seasonal trend was similar at these two study areas (Fig. 5). *Pogonosternum* captures in 1987 peaked two months earlier than those for *Notodesmus*, with nearly 40% of *Pogonosternum* specimens trapped in July-September (Fig. 4). The seasonal pattern for *Notodesmus* was also apparent in the 9 x 9 m pitfall array at Waterhouse Point which yielded 102 of the 116 *Pogonosternum* specimens (Fig. 4).

There was no obvious succession of life-stages (stadia) through the year in the pitfall record for *Notodesmus* (Table 1). Few specimens in stadia earlier than VII were trapped, and capture totals for stadium VII juveniles were highest for those periods with the highest totals for adults. As noted above, however, there was an anomalously high number (and proportion) of stadium VII *Notodesmus* captures in May 1987 at the two Waterhouse Point sites.

Mean monthly temperature minima and maxima at Low Head are shown in Fig. 5 for comparison with *Notodesmus* captures at Waterhouse Point, 75 km to the east along the Bass Strait coast. (Weather data for the study period were supplied by the Bureau of Meteorology. There was

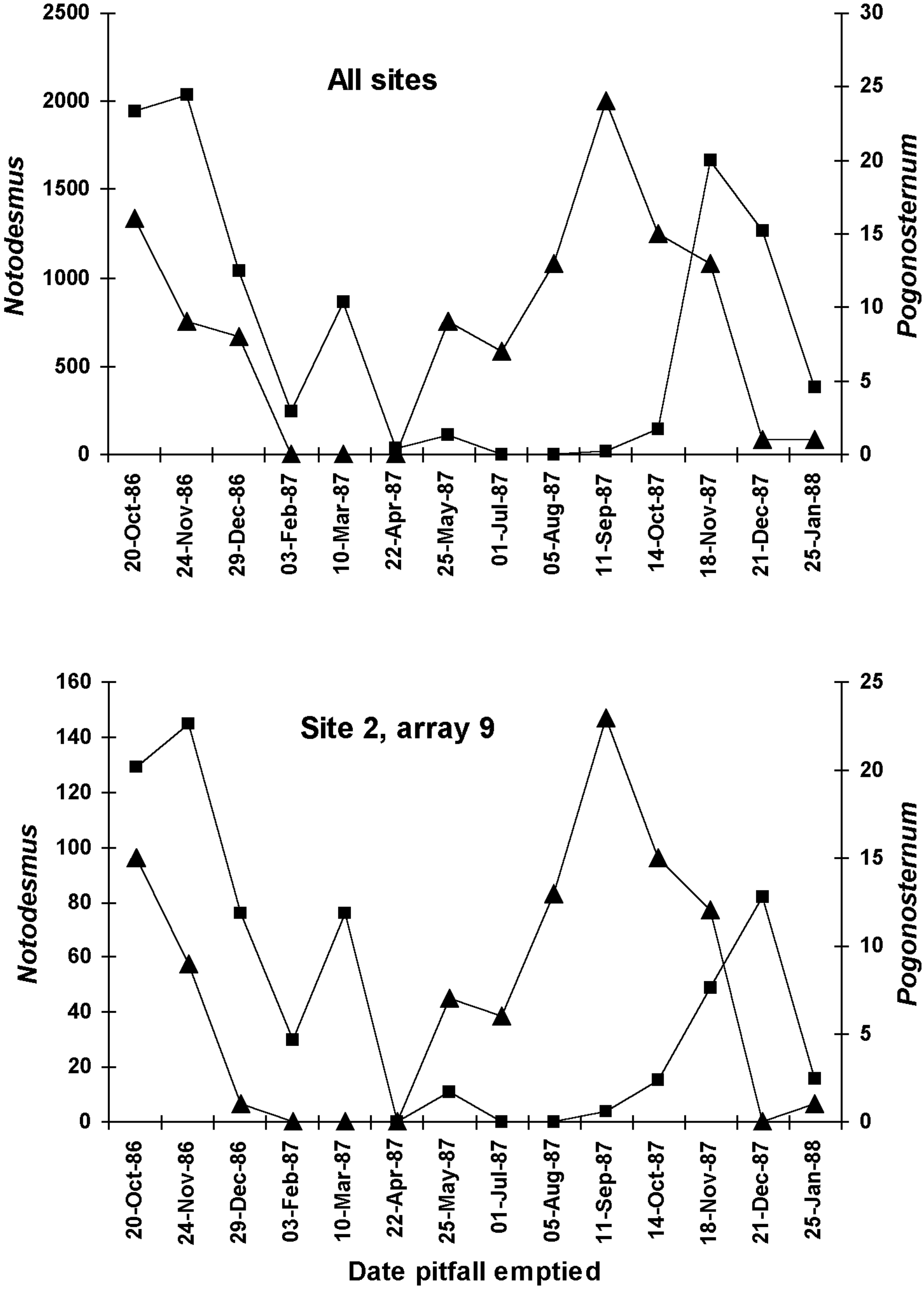

Figure 4. Monthly captures (number of specimens) of *Notodesmus scotius* (squares) and *Pogonosternum* sp. (triangles). Top: captures summed over all traps; bottom: Site 2, array 9 only. (This array is in the southeast corner in each of the maps in Fig. 3.)

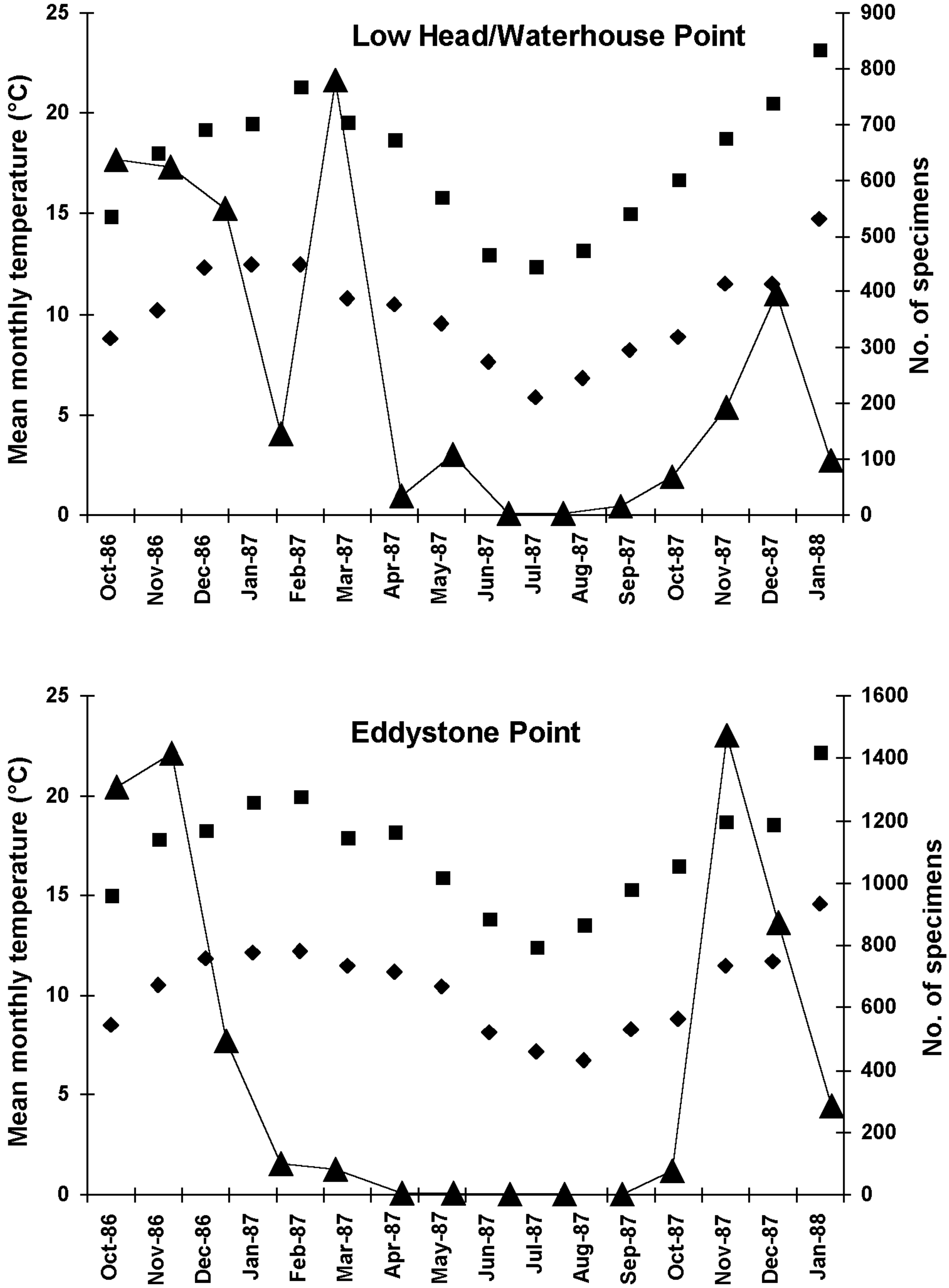

Figure 5. Mean monthly temperature minima (diamonds) and maxima (squares). Top: Low Head, with *Notodesmus* captures (triangles) at Sites 1 and 2, Waterhouse Point (data combined). Bottom: Eddystone Point, with *Notodesmus* captures (triangles) at Sites 3 and 4 (data combined).

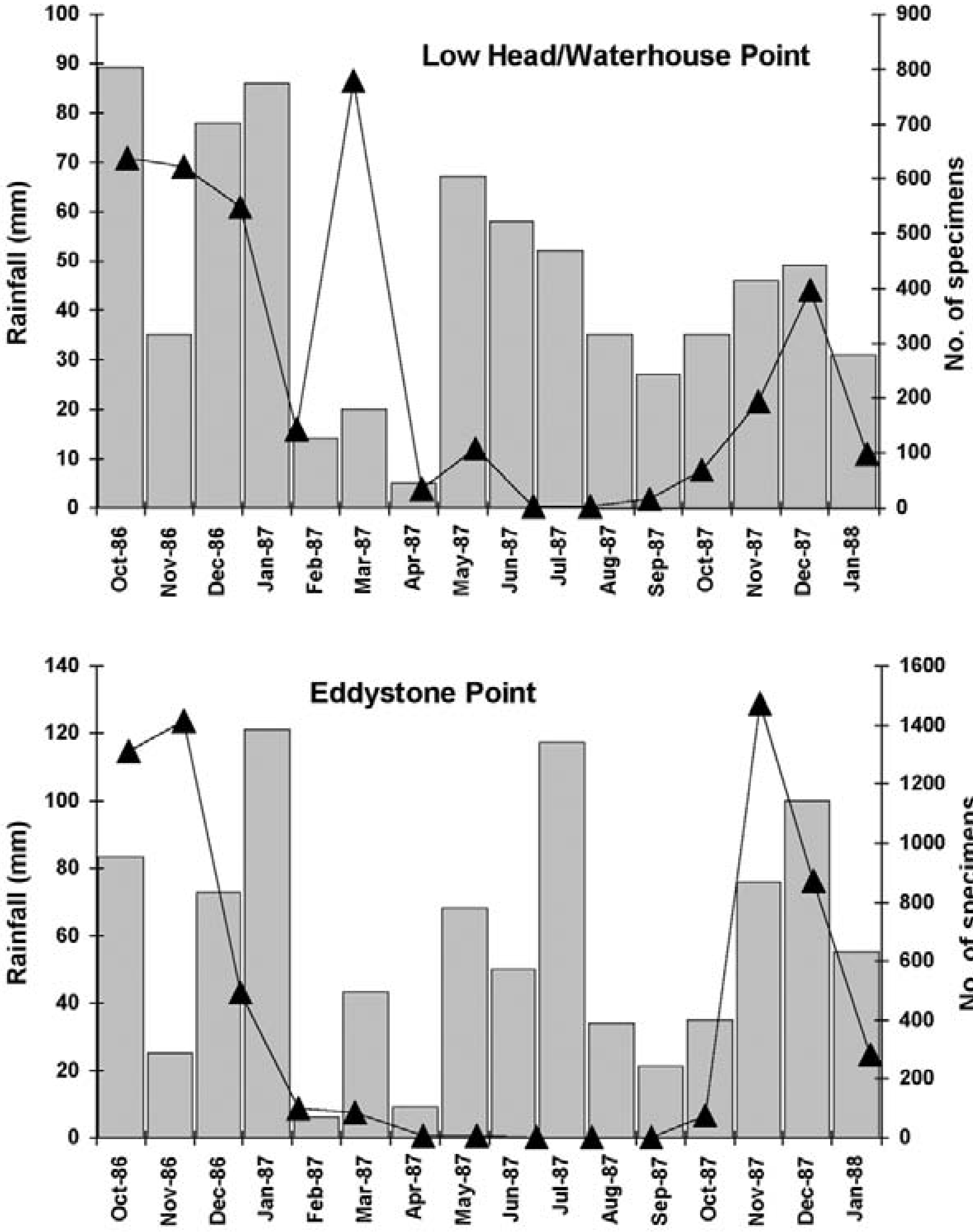

Figure 6. Monthly rainfall totals (bars). Top: Low Head, with *Notodesmus* captures (triangles) at Sites 1 and 2, Waterhouse Point (data combined). Bottom: Eddystone Point, with *Notodesmus* captures (triangles) at Sites 3 and 4 (data combined).

no coastal recording station closer to Waterhouse Point at the time.) Fig. 5 also compares mean monthly minima and maxima with *Notodesmus* captures at Eddystone Point. In both areas the *Notodesmus* capture peaks were neither at the warmest nor the coolest times of year. Captures during the sampling period also did not clearly correlate with monthly rainfall totals at Low Head and Eddystone Point (Fig. 6). There is no sharply defined rainy season on the northeast coast of Tasmania, and no corresponding peak in millipede surface activity.

Discussion

Pitfall trapping has previously been shown to be less efficient than hand-sampling for millipede inventory in Tasmania (Mesibov *et al.* 1995), one reason being that millipedes can sometimes be clustered at fine spatial scales. An example of such clustering was given in that paper: a species represented by only one individual in intensive hand-sampling of 80 circular plots, each 10 m in diameter. During a familiarisation visit to the study site just prior to hand-sampling, ca. 40 individuals of this species were collected from half a square metre of forest floor. The present study offers a similar result for *Pogonosternum* sp., whose presence at Eddystone Point was only evidenced by six specimens in one of 54 pitfall traps in one of 14 five-weekly samplings. The distinct clustering of *Pogonosternum* captures in the southeastern corner of Site 2 at Waterhouse Point further demonstrates that detection and inferences of abundance can be strongly dependent on the location of a trapping grid, even within a 0.8 ha (90 x 90 m) sampling site. If pitfall-based studies of *Pogonosternum* sp. in heathland are carried out in future, they will need to be preceded by exploratory investigations aimed at clarifying the spatial patterning exhibited by this species.

The cause of clustering in *Pogonosternum* captures is unclear. It is not known whether this species is spatially selective in microhabitat use throughout its life, or whether it is more or less uniformly distributed in its juvenile stages and aggregates when it reaches maturity.

Clustering may partly explain why the 1986-88 spider survey failed to yield any specimens of the undescribed paradoxosomatid *Dicranogonus* sp., which was independently collected near Waterhouse and Eddystone Points in the 1980s and 1990s (QVMAG specimen records). *Dicranogonus* is common in the Furneaux Group in eastern Bass Strait but has only a 'toe-hold' distribution on the main island of Tasmania, where it is restricted to coastal areas in the far Northeast. It is also possible that *Dicranogonus* is restricted to coastal habitats other than those sampled for spiders in this study, e.g. grassland and open dune vegetation. Habitat partitioning could be more closely investigated with pitfall trapping or hand-sampling along multi-habitat transects in coastal areas.

Capture of the other two paradoxosomatid millipedes was expected. *N. scotius* is known to be widespread in eastern Tasmania (Jeekel and Mesibov, in preparation) where it appears to prefer dry, open-structured habitats such as dry eucalypt forest and woodland, scrubs produced by frequent burning of forest, and coastal scrub and heathland. *N. scotius* has not been found in closed wet forest, even in areas where it is abundant. *Pogonosternum* sp. is known to be abundant on Clarke and Flinders Islands in the Furneaux Group, and like *Dicranogonus* has a 'toe-hold' distribution along the coast of northeast Tasmania.

The overwhelming dominance of Paradoxosomatidae in coastal heathland and the overwhelming dominance of Dalodesmidae in wetter, more closed vegetation in Tasmania is in agreement with the observation of Jeekel (1981: 46) for mainland Australia that 'Paradoxosomatidae occur in thin populations in the rainforests, but ... many species prefer the more open Eucalyptus forests, where under the right weather conditions they may be found in fairly large numbers'. Nevertheless, the abundance of heathland millipedes is low when compared to millipede abundance in dry eucalypt forest in the Northeast (Mesibov, unpublished observations). A possible explanation is the nutritional poverty of heathland soils (Kirkpatrick and Harris 1999), and correspondingly low nutrient levels in the plant litter on which millipedes feed.

Previous field studies of paradoxosomatid populations (e.g. Bhakat 1987, 1989; Lewis 1971) have been based on intensive hand-sampling of all life-stages. Pitfall trapping in the present study selectively captured adults, and the results do not allow conclusions to be drawn about life histories, breeding cycles or population densities. For example, the striking difference found between sex ratios in juvenile and adult *Notodesmus* could be attributed to a differential increase in male activity in stadium VIII, a differential decrease in female activity in stadium VIII or differential mortality in the stadium VII/VIII transition; the pitfall data alone do not favour one explanation over another. However, adults of *Dicranogonus* sp.and *N. scotius* have been seen by the senior author to form day-active 'mating swarms' in northeast Tasmania in springtime (Mesibov 2000). It seems likely that the bulk of the millipedes captured in this study were trapped while searching for mates or dispersing after mating. If so, the seasonal spacing of the *Notodesmus* and *Pogonosternum* peaks suggests that these two species divide the mating season between them, perhaps to avoid interference in finding partners and in mating.

In the temperate zone of the Northern Hemisphere, surface activity in millipedes is often seasonal (Hopkin and Read 1992: 170), with most species inactive in winter. It is interesting that both *Notodesmus* and *Pogonosternum* have seasonal peaks of trap captures in the relatively mild and uniform climate of the northeast Tasmanian coastland, and that the *Pogonosternum* peak occurs at the coldest time of year.

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References

Bhakat, S.N. 1987. Ecology of an Indian grassland millipede *Streptogonopus phipsoni* (Diplopoda: Polydesmoidea). *Journal of Zoology, London* **212**: 419-428.

Bhakat, S.N. 1989. The population ecology of *Orthomorpha coarctata* (Diplopoda: Polydesmidae [sic]). *Pedobiologia* **33**: 49-59.

Churchill, T.B. 1993. Effects of sampling method on composition of a Tasmanian coastal heathland spider assemblage. *Memoirs of the Queensland Museum* **33**: 475-481.

Churchill, T.B. 1996. Coastal heathland spiders: spatial distribution and biogeographic significance. Pp. 151-158 in Mesibov, R. (ed.), *Biogeography of northeast Tasmania. Records of the Queen Victoria Museum* **103**.

Hopkin, S. P. and Read, H.J. 1992. *The Biology of Millipedes*. Oxford University Press, Oxford (UK).

Jeekel, C.A.W. 1981. Australia Expedition 1980; legit C.A.W. Jeekel and A.M. Jeekel-Rijvers. List of collecting stations, together with general notes on the distribution of millipedes in eastern Australia and Tasmania. *Verslagen en Technische Gegevens, Instituut voor Taxonomische Zoölogie (Zoölogisch Museum), Universiteit van Amsterdam* **30**: 1–59.

Kirkpatrick, J.B. and Harris, S. 1999. *The Disappearing Heath Revisited: A Guide to the Conservation and Ecology of the Flora and Communities of Tasmanian Lowland Heathlands*. Tasmanian Environment Centre, Hobart, Tas.

Lewis, J.G.E. 1971. The life history and ecology of three paradoxosomatid millipedes (Diplopoda: Polydesmida) in northern Nigeria. *Journal of Zoology, London* **165**: 431-452.

Mesibov, R. 2000. An overview of the Tasmanian millipede fauna. *The Tasmanian Naturalist* **122**: 15-28.

Mesibov, R., Taylor, R.J. and Brereton, R. N. 1995. Relative efficiency of pitfall trapping and hand-collecting from plots for sampling of millipedes. *Biodiversity and Conservation* **4**: 429-439.