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A NEW SPECIES OF *DELEATIDIUM (PENNIKETELLUM)* AND THE ADULT OF *D. (P.) CORNUTUM* TOWNS AND PETERS (EPHEMEROPTERA: LEPTOPHLEBIIDAE) FROM NEW ZEALAND

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ABSTRACT

A new species of mayfly, *Deleatidium (Penniketellum) patricki*, and the previously undescribed imago of *D. (P.) cornutum,* both from New Zealand, are described. The larval stage of both species is associated with its respective adult. The diagnosis of the subgenus *D. (Penniketellum)* is revised. Notes on ecology are given and distribution maps are provided. Diagnostic characters of the species are illustrated and keys provided for the described life stages.

KEYWORDS

Ephemeroptera; key; mayflies; mayfly; *Deleatidium; Penniketellum*; new species; New Zealand; revision; taxonomy

INTRODUCTION

Deleatidium is a cool-adapted genus of the Leptophlebiidae endemic to New Zealand. With ten presently described species in two subgenera, it is the most common mayfly genus in New Zealand streams. The subgenus D. (Penniketellum) is confined to the Southern Alps and neighbouring ranges of the South Island. The environment of mountain streams in the Southern Alps is characterised by a steep and dissected landscape, geological instability, frequently heavy rainfall but high water quality (Winterbourn 1997).

Towns and Peters (1996) reviewed the genus, redescribed the existing seven species and added three new ones. They also erected two subgenera, *Deleatidium (Deleatidium)* and *D. (Penniketellum)*, the former with eight species and the latter with two.

This work describes a new species, *D. (P.) patricki*, and also the male and female imagos of *D. (P.) cornutum* Towns and Peters, with keys to their identification and distribution maps. In their erection of the subgenus, Towns and Peters (1996) nominated as type species *D. (P.) insolitum* Towns and Peters although the larval stage was not described. In the absence of fresh material, the description remains incomplete. Larval stages of the subgenus have been difficult to distinguish using morphological characters.

MATERIALS, METHODS AND CONVENTIONS

Larvae were associated with adults by proximity and/or rearing in an aquarium. Specimens, including the type specimens, have been collected and stored in 80% ethanol. Dimensions of body lengths for imagos and larvae are given with their means in parentheses, as are those for the fore and hind wings. Length ratios of the foreleg segments (femur: tibia: tarsomeres 1-5) are based on the length of the tibia (absolute measurement in mm, in parentheses).

Abbreviations in site descriptions: Bldg – Building, Bn – Burn, Ck – Creek, L – Lake, Mt – Mount, R – River, Sdle – Saddle, Stm – Stream, Trib – Tributary, Vly – Valley. Other abbreviations include asl – above sea level, i – imago, si – subimago.

Collecting sites are grouped into regions of New Zealand using the system proposed by Crosby et al. (1976, 1998). Regions referred to in this paper are indicated by a two letter code as follows: CO – Central Otago; FD – Fiordland; KA – Kaikoura; MB – Marlborough; MC – Mid Canterbury; MK – McKenzie; NC – North Canterbury; NN -- Nelson; OL – Otago Lakes; SC – South Canterbury; WD – Westland.

Map references are given in metric coordinates from the map series NZMS 260. The first group of five figures gives the east-west coordinate to the nearest 100 m and the second group the north-south coordinate, similarly. The height above mean sea level in metres is given in the final group of figures.

Where stated, material examined is held at the following locations:

IMHC IM Henderson private collection, Massey University, Palmerston North, New Zealand
NZAC New Zealand Arthropod Collection, Landcare Research, Auckland, New Zealand
NMNH National Museum of Natural History, Washington DC, USA

Otherwise it is deposited at CMNZ Canterbury Museum, Christchurch, New Zealand or at Cawthron Institute, Nelson, New Zealand.

Collectors: BHP, BH Patrick; BML, BM Lyford; EDW, E Edwards; GCP, GC Penney; IPS, IP Smith; J&B, JB Ward & BH Patrick; J&N, PM Johns & D Nicholls; JBW, JB Ward; JGP, JG Penniket; JRJ, JR Jackson; MLP, ID McLellan, P Lambert & J Porteous ; OSF, OS Flint jr; P&B, PM Johns & B Boag; P&C, BH Patrick & R Cuthbert; P&E, BH Patrick & E Edwards; P&J, PE Penney & JA Hitchings; PMJ, PM Johns; RPM, RP Macfarlane; S&G, SF Watson and G Temm; SFW, SF Watson; SJM, SJ Morris; TRH, TR Hitchings; T&T, DR & EL Towns; VMS, VM Stout.

SYSTEMATIC SECTION

Order EPHEMEROPTERA Hyatt and Arms, 1891
Family LEPTOPHLEBIIDAE Banks, 1900
Genus DELEATIDIUM Eaton, 1899

Subgenus *Deleatidium (Penniketellum)* Towns and Peters

Penniketellus Towns and Peters 1979, p. 449-450

Type species *Penniketellus insolitus* Towns and Peters, by original designation

Deleatidium (Penniketellum) Towns and Peters 1996, p. 46

Description

Dimensions (mm)

Male imago: length of body 8.2-14.9; forewings 9.1-13.2. Female: length of body 7.8-11.5; forewings 9.4-13.3. Mature larva: 9.0-13.0.

Imago and subimago

As described by Towns and Peters 1996, p. 46. Wings (Fig. 1a-d): the wings of the described subimagos of this subgenus are uniformly grey, without clouding at the cross veins.

Mature larva

In their diagnosis of *D. (Penniketellum)* Towns and Peters did not include data for larvae, as only the larva of *D. (P.) cornutum* had been confirmed at that stage. The association of larvae with adults for *D. (P.) cornutum* described here has been confirmed by rearing. Larval stages of *D. (P.) patricki* have been associated by proximity. The diagnosis of the larvae of the subgenus given here is based upon a comparison of mature larvae of *D. (P.) cornutum* and *D. (P.) patricki.*

Antennae. 1.8-2.3 x as long as head.

Mouth parts. Labrum: length 0.65-0.81 x that of clypeus, width 1.13-1.23 x that of clypeus; anterior

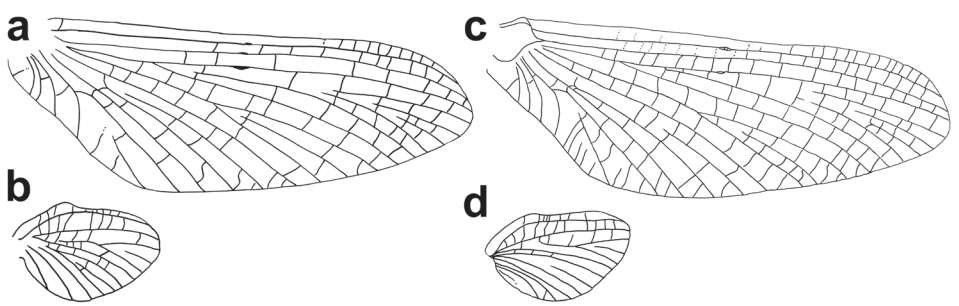


Figure 1. Fore and hind wings of male imagos: a, **b** - *D. (P.) cornutum*; **c**, **d** - *D. (P.) patricki*

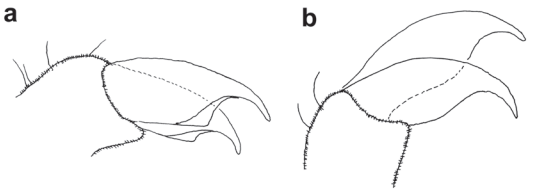


Figure 2. Fore claws of male imagos: **a** - *D. (P.) cornutum*; **b** - *D. (P.) patricki*

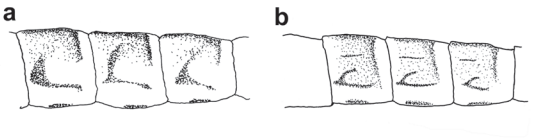


Figure 3. Abdominal segments 6-8 of male imagos in lateral view: **a** - *D. (P.) cornutum*; **b** - *D. (P.) patricki*

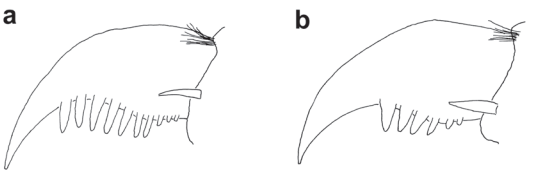


Figure 4. Fore claws of mature larvae: **a** - *D. (P.) cornutum*; **b** - *D. (P.) patricki*

margin smoothly curved with a deep anteromedian cleft with or without 4-6 round-topped denticles, which are often irregular in shape. Mandibles: with a single tuft of 5-10 hairs on the middle of outer margin; small prosthecal tuft; incisors with serrated teeth. Maxillae: galea-lacinia with a subapical row of 19-24 spines; maxillary palp segment 2 0.80-0.89 x as long as segment 1, segment 3 0.56-0.78 x as long as segment 2. Labium: submentum shoulder without spines; palp segment 2 0.71-0.82 x as long as segment 1, palp segment 3 0.35-0.47 x as long as segment 2.

Thorax. Pronotum with small cluster of medial fine hairs; posterior mesonotum with sparse single row of hairs.

Abdomen. Terga predominantly blackish. Posterolateral projections on segments 1-9, sometimes well developed on segment 9 only. Gills on segments 1-7 each a single, broad, undivided lamella with blackish tracheae. Gill 1 extending 1.2-1.6 x length of lamella. Gills 2-7 usually rounded but sometimes tapering to blunt points apically. Gill 7 folded or partly folded ventrally. Sterna 6-9 with short, fine hairs, most dense on sternum 9. Blackish ganglia with hyaline connectives on sterna 1-6. Caudal filaments 1.1-1.2 x as long as body.

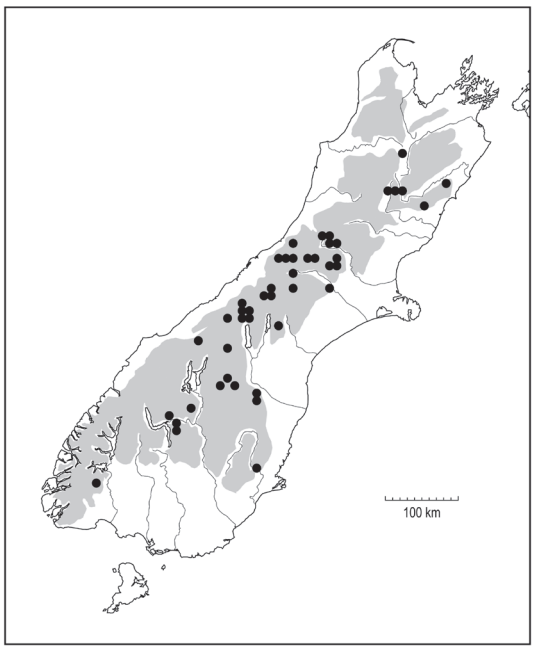
Remarks

Species of *Deleatidium (Penniketellum)* can be distinguished from those of *D. (Deleatidium)* in the subimago and imago by a combination of the following: (1) claws of a pair similar and hooked. There is some development of the retrolateral claw as a pad in one species (Fig. 2a, b); (2) forewings with posterior margin basal to vein CuP concave (Fig. 1a, c); (3) forewing/hind wing length ratio 0.31-0.35 (0.33) compared with 0.23-0.30 (0.27). Wings of the subimagos of the two *D. (Penniketellum)* species described here are grey without clouding at the cross veins.

Larvae of *D. (Penniketellum)* spp. most closely resemble those of *D. (D.) myzobranchia,* but the former can be distinguished by: (1) the presence of sharp, abdominal posterolateral projections on segment 8 and especially on segment 9, whereas the latter have small, blunt projections on segments 7-9. (2) Hairs which diminish in density from abdominal sterna 9 to 4, whereas the latter have a dense patch of hairs confined to the ventral surface of sternum 9 only. (3) Blackish maculae on sterna 3-7, expanded on the latter segment; in contrast a macula usually present on sternum 7 of *D. (D.) myzobranchia*.

The male and female imagos and the female subimago of *D. (P.) insolitum* (Towns and Peters, 1979) were described by them, but lack of fresh material has prevented description of the remaining life stages. Old material in the Canterbury Museum collection is consistent with the subgeneric characters given below. *D. (P.) insolitum* seems to be confined to streams of the Polar Range, Arthurs Pass National Park.

Deleatidium (Penniketellum) cornutum **(Towns and Peters, 1996)**
Map 1



Map 1. Collection localities for *D. (P.) cornutum*. Land over 700m shown in grey.

In their original description of the species, Towns and Peters (1996) supplied figures of larva, male subimaginal abdomen and genitalia, female imaginal abdomen, larval legs and gills, and eggs. Additional drawings included here for comparative purposes are: abdominal segments 6-8 of male imago in lateral view (Fig. 3a); fore claw of mature larva (Fig. 4a).

Material examined
The following non-type examples:
CO ♂, ♀ si and i, larvae, Roaring Meg, Pisa Ra, 33064 55861, 1680m, 31 Dec 2001, BHP; ♀ i, Camp Ck, Omarama Sdle, 22629 56123, 1100m, 25 Oct 1999, BHP; ♀ si, Dunstan Ck Trib, 22459 56106, 1100m, 28 Jan 2004, EDW; ♀ i, L Hope, Hector Mts, 21818 55551, 1700m, 4 Feb 2005, BHP & EDW; larvae, Little Omarama Stm Trib 22646 56164, 920m, 20 March 2007, TRH; ♀ si, The Remarkables Skifield, 21805 55640, 1600m, 2 Mar 2001, PMJ & SJM; ♂, ♀ si, Rastus Bn, 21804 55646, 1600m, 27 Jan 2004, OSF (NMNH); larvae, St Marys Ra, 22977 55992, 1550m, 16 Jan 1999, BHP.
KA Larvae, Lottery R, 25214 58615, 1370m, 9 Mar 2007, TRH; larvae, ♀ i, Wandle R, Mt Lyford, 25222 58590, 890m, 13 Apr 2002, TRH; ♀ i, Kowhai R, Seaward Kaikoura Ra, 25599 58828, 1300m, 15 Jan 1997, P&C.
MB Larvae, Pass Stm Trib, Clarence R, 24900 58772, 1000m, 11 March 2003, TRH.
MC Larvae, Erewhon Skifield, 23411 57442, 1730m, 20 Feb 2005, JBW; larvae, McKinnon Stm, Godley, 23096 57395, 1060m, 22 Oct 2004, SFW; ♂, ♀ si, Mt Hutt Skifield, 23918 57448, 1600m, 18 Mar 2000, BHP; larvae, Porter R, 24080 57755, 620m, 3 Oct 2001, SJM; ♀, ♂ i, Pudding Hill Stm Trib, 23928 57419, 1300m, 8 Feb 2005, TRH; ♂, ♀ si, Rakaia R, Trib, 23449 57690, 830m, 10 Jan 1982, PMJ; ♀, ♂ si, Rough Ck, 23928 58056, 750m, 9 Jan 1961, JRJ; larvae, Ryton R, 23928 57743, 675m, 11 Nov 2001, TRH.
MK ♂ si, larvae, Birch Hill Stm, Trib, 22754 57088, 1020m, 24 Nov 2002, SFW; larvae, Black Birch Stm, Mt Cook, 22753 57141, 870m, 9 Jan 1964, VMS; larvae, Blue Stm, Mt Cook, 22804 57196, 720m, 8 February 2007, IPS; larvae, Hooker glacial lake outlet, 22763 57203, 870m, 23 Nov 2002, TRH; larvae, Hooker R Trib, 22759 57194, 850m, 23 Nov 2002, TRH; ♂, ♀ si and i, Hoophorn Stm, 22770 57111, 725m, 18 Sept 2002, PMJ; larvae, Jollie R Mt Cook, 22865 57060, 670m, 27 Apr 2007, P&J; larvae, Mt., Dobson Skifield, 23227 56933, 1800m, 5 Jan 2002, JBW; larvae, L Ohau Skifield, 22525 56603, 1630m, 15 Jan 2004, J&N; ♂ im Parsons Waterfall, 22815 57097, 750m, 28 Jan 2003, PMJ; larvae, Revell Stm, 23660 57860, 1160m, 15 Mar 2006, SFW; ♀ si, Sawyer Stm Trib, 22774 57125, 760m, 23 Jan 2003, IMH; larvae, ♂, ♀ si and i, Tasman R Trib, 22814 57196, 700m, 24 Nov 2002, TRH; larvae, ♀ si, Tasman R Trib, (no coordinates), 10 Jan 1988, T&T, (NZAC).
NC ♀ i, Agility Ck, 23956 58078, 1900m, 16 Apr 1961, JRJ; ♂, ♀ si, Rough Ck, 23928 58056, 750m, 16 Apr 1961, JRJ; ♂, ♀ si, Sudden Vly, 24035 58076, 1220m, 23 Apr 1961, JRJ; larvae, Sudden Vly Stm, 24040 58067, 1050m, 25 Feb 2001, S&G.
OL ♀ i, Coronet Pk Skifield, 21732 55783, 1180 m 28 Jan 2004, OLF (NMNH).
SC Larvae, Mt Dobson Skifield, 23227 56933, 1800 m,

5 Jan 2002, JBW.
WD Larvae, Hunts Ck, 23863 58148, 1060m, 9 Mar 2000, SJM; larvae**,** Landsborough R Trib, 22543 57013, 1800m, 25 Jan 1996, SJM**;** larvae, Moonbeam Torrent Waitaha, 23315 57827, 460m, 17 Nov 1994, IMH (IMHC); larvae, Pegleg Ck, 23924 58115, 820m, 7 Nov 1995, J&B; larvae, Prices Stm Trib, 23443 57840, 1060m, 27 Jan 2000, SJM; larvae, Robinson Ck, Haast R, 22196 56744, 470m, 2 June 1997, GCP; Twin Ck, 23938 58088, 1360m, 18 Feb 1999, TRH, ♀ si, Whirling Water, Waitaha, 23267 57833, 260m, 20 Oct 1989, IMH (IMHC); ♂ si, Whitcombe R, (no coordinates), 21 Apr 1965, JRJ.

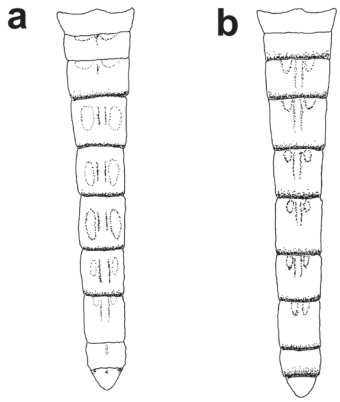


Figure 5. Abdominal terga of male imagos: **a** - *D. (P.) cornutum*; **b** - *D. (P.) patricki*

Description

Dimensions (mm)

Male imago: length of body 9.6-10.3 (10.0); forewings 9.1-11.7 (10.8). Female imago: length of body 9.4-11.0 (10.3); forewings 10.4-10.8 (10.6).

Male imago

Head dark brown, scape of antenna brownish, pedicel and flagellum paler. Eyes, upper portion orange-brown, lower portion black.

Thorax. Pronotum, mesonotum and metanotum brownish black, darker at sutures and margins. Prosternum and mesosternum brownish, darker at margins. Furcasternum yellowish white. Pleura brown.

Legs. Femora with dorsal surface pale whitish brown with dark brown prolateral and retrolateral longitudinal marks, ventral surface pale brown; tibiae and tarsi whitish, tibiae darker at articulations with femora. Length ratios of foreleg segments 0.80-0.94:1.00 (2.51-3.12 mm): 0.060: 0.29-0.31: 0.32-0.33: 0.22-0.27: 0.12-0.13. Fore claw (Fig. 2a).

Wings (Fig. 1a, b). Longitudinal veins brownish, cross veins paler; membranes pale greyish brown, darker in the pterostigmatic region. Forewing width 0.35-0.36 (0.36) x length. Hind wing width 0.57-0.64 (0.60) x length, and length 0.31-0.35 (0.32) x that of forewings; vein Sc 0.96-0.97 (0.97) x length of wing.

Abdomen (Fig. 5a). Unicolorous dark blackish brown. Terga 1-8 with a darker transverse band

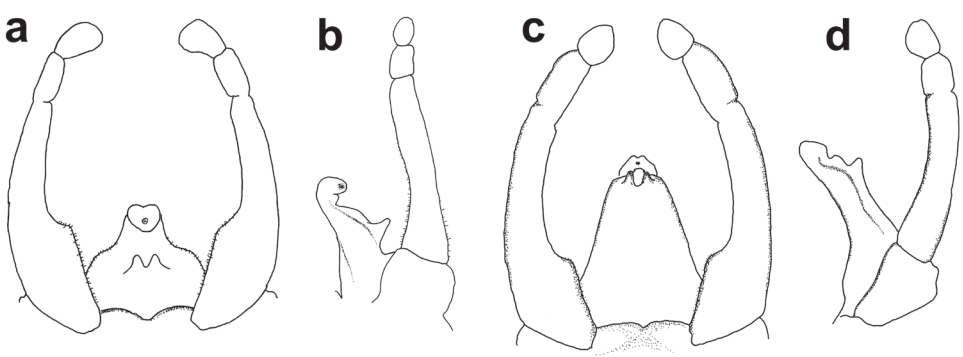


Figure 6. Genitalia of male imagos, ventral and lateral views: **a, b** - *D. (P.) cornutum*; **c, d** - *D. (P.) patricki*

on posterior margin. Terga 2-7 with pair of paler submedian maculae at anterior margins. Terga 3-5 with pair of paler median longitudinal marks. Sterna yellowish white; ganglia greyish. Genitalia (Fig. 6a, b) yellowish white with apices of penes rolled ventrally and with apical purplish spot. Paired ventral rod-like subapical appendages. In ventral view, penes taper to their apices and are expanded strongly at midlength. Lateral bases of penes and adjacent proximal surfaces of forceps 1 with short, fine hairs. Caudal filaments yellowish white with darker annulations at articulations.

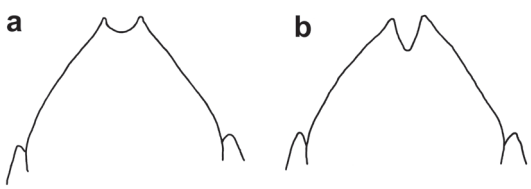


Figure 7. Sternum 9 of female imagos: **a** - *D. (P.) cornutum*; **b** - *D. (P.) patricki*

Female imago

As in male except as follows; head dark brown between eyes, otherwise pale whitish; eyes greyish.

Thorax. Pronotum yellowish, washed with darker brown. Mesonotum brownish with sutures darker, dorsal surface of posterior scutal protruberance and scutellum darker. Sterna whitish, washed with brown. Prosternum and lateral lobes of furcasternum pale brown. Forewing width 0.32-0.35 (0.34) x length; hind wing width 0.56-0.64 (0.60) x length and length 0.29-0.32 (0.31) x that of forewings; length of vein Sc 0.94-0.96 (0.95) x length of wing.

Abdomen. Terga 5 and sometimes 6 with large pale submedian maculae; terga 1-7 with dark anterolateral maculae. Sternum 9 with U-shaped apical cleft (Fig. 7a).

Male subimago

As described by Towns and Peters (1996), except that apices of penes are sometimes more rolled ventrally than in their fig. 128 and the apical purplish spot is not always present.

Larva

The following notes, additional to those of Towns and Peters (1996), may be of assistance in identification. Pronotum with long brown submedian hairs; fore femur pale brown with two dark brown parallel longitudinal marks, the prolateral usually the darker. Abdominal terga usually unicolorous blackish brown, sometimes paler on terga 5 and 6. Pale band on posterior margin of each tergum and pale brown median dorsal mark on terga 2-6. Tergum 10 darker posteriorly. Posterolateral projections well developed on tergum 9, less so on 8. Sternum 9 with a dense mat of hair (best viewed laterally against a dark background), diminishing in density through to sternum 4. Gills plate-like, with margins rounded but tapering somewhat on gill 7, the latter sometimes folded ventrally.

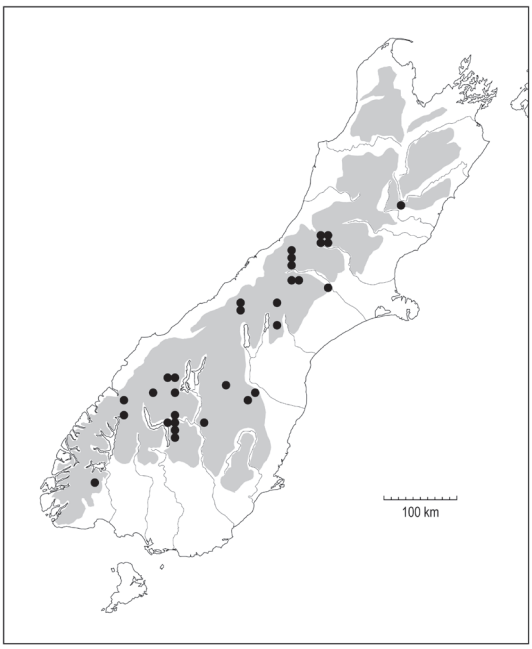
Remarks

The association between larvae and adults was established by rearing specimens collected from a stream near the termination of the Tasman Glacier.

The paired submedian ventral projections or "horns" reported on the posterior margin of the head of the female subimago (Towns and Peters 1996, p. 47) have been confirmed on voucher specimens from a Tasman Glacier stream, the type location, but not on other specimens apparently of the same species, collected and reared from near this site in 2002. The projections are ventral to the scapes of the antennae and separated from the latter by the transverse carina. Blackish and conical in shape, they are directed ventrally. Some specimens apparently of this species from other locations show a single projection and some none at all. A series of twelve female subimagos of *D. (P.) patricki* (see below) from Ben Nevis area, Hector Mountains, show varying development of the "horns". One from the Rastus Burn had them quite fully developed and a few larvae from this area showed some horn development. Some female imagos also show vestiges of this structure. It is concluded that this character is variably developed in *D. (P.) cornutum* and not confined to it.

There is apparently another species of *Deleatidium (Penniketellum)* similar to *D. (P.) cornutum* present on the Mt Hutt and Mt Torlesse ranges. The wings of the subimagos show clouding at the cross veins.

***Deleatidium (Penniketellum) patricki* sp. nov.**
Map 2



Map 2. Collection localities for *D. (P.) patricki*. Land over 700 m shown in grey.

Derivation of name
Named after Brian H Patrick whose extensive field collecting over many years has been a valued contribution towards a better understanding of New Zealand mayfly taxonomy and distribution.

Type material
Holotype: ♂ imago, Flush Stm, Mt St. Bathans, Central Otago, New Zealand. 22533 56129, 1700m, 5 March 2001, Brian H Patrick & Eric Edwards (CMNZ). Allotype: ♀ imago, same data as holotype (CMNZ). Paratypes: CMNZ, NZAC.

Other material examined
The following non-type examples:
CO larvae, Flush Stm, Mt. St. Bathans, 22533 56129, 1700m, 3 Mar 2001, P&E; larvae, ♂ ♀ si, Hector Mts Ben Nevis, 21861 55500, 1800m, 22 Feb 1994, BHP; ♀ si, L Alta, The Remarkables, 21805 55628, 1900m, 24 Mar 2002, BHP; larvae, ♂ ♀ si & i, Manuherikia R headwaters tarn, Mt. St. Bathans 22503 56129, 1700m, 3 Mar 2001, BHP; larvae, ♀ i, Rastus Bn. The Remarkables, 21807 55637, 1700m, 5 Dec 1995, BML; ♂, ♀ si, Remarkables skifield, 21805 55642, 1640m, 4 April 2004, PMJ.
FD ♂, ♀ si & i, Gertrude Vly, 21157 55947, 1080m, 23 Feb 1996, J&B.
MC ♀ si, Cameron R, 23521 57555, 1000m, 13 Feb 1995, SJM.
MK ♂ i, Hooker Corner, Mt Cook, 22764 57184, 800m, 16 Feb 2003, PMJ; ♂ ♀ si, ♂ i , Hoophorn Stm, Mt Cook, 22770 57111, 725m, 18 Sept 2002, PMJ.
OL larva, ♀ i, End Pk, Harris Mts, 21854 56067, 1830m, 13 Feb 1997, BHP; larvae, Leaping Bn, Harris Mts, 21786 56227, 1350m, 12 Feb 1997, BHP; ♀ i, Matukituki R Trib, 21883 56234, 1460m, 16 Mar 1991, BML; ♂, ♀ i & si, Rob Roy Stm, 21702 56282, 740m, 23 Mar 1997, SJM.
WD ♀ si, Cropp R, 23449 57903, 820m, 24 Oct 1996, MLP; larvae, Landsborough R Trib, 22543 57013, 1800m, SJM; larvae, Prices Stm, 23438 57845, 1700m, 26 Jan 2000, SJM; ♀ si, Prices Stm. Trib, 23443 57840, 1060m, 27 Jan 2000, SJM; ♂ ♀ si & i, larvae, Whitcombe R, 23445 57574, 1400m, 2 Feb 2000, SJM.

Description
Dimensions (mm)
Male imago: length of body 8.6-14.9 (11.8); forewing 10.7-13.2 (12.0); hind wing 3.5-4.7 (4.0). Female imago: length of body 9.5-11.5 (10.6); forewing 9.8-13.3 (12.0); hind wing 3.4-4.3 (4.0). Mature larva: length of body 11.2-12.1 (11.7).

Male imago
Head brownish black, pedicels and ocelli greyish, eyes upper portion yellow, lower portion black. Antennae pale brown.

Thorax. Pronotum, mesonotum and metanotum blackish brown. Prosternum dark brown mesosternum paler, furcasternum yellowish white. Pleura dark brown. Legs. Femora dorsal surface dark brown with three longitudinal marks, prolateral, medial and retrolateral, extending the length of the femora, ventral surface yellowish brown medially, tibiae and tarsi yellowish white, the former darker at articulations. Length ratios of foreleg segments 0.79-0.83: 1.00 (3.02-4.10 mm): 0.05-0.06: 0.30-0.34: 0.32-0.33: 0.24-

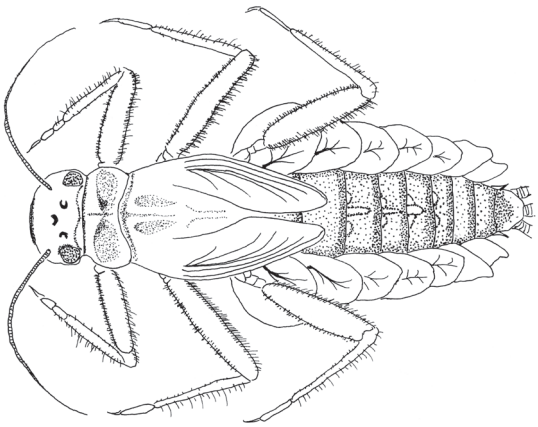


Figure 8. Mature larva (caudal filaments truncated) of *D. (P.) patricki*

0.26: 0.09-0.13. Apical foreclaw (Fig. 2b). Wings (Fig. 1c, d). Longitudinal veins greyish, cross veins paler; membrane hyaline. In the pterostigmatic region costa and subcosta sometimes translucent grey. Forewing width 0.31-0.35 (0.33) x length and hind wing width 0.54-0.60 (0.57) x length and length 0.35-0.37 (0.36) x that of forewing; vein Sc 0.94-0.96 (0.95) x length of wing.

Abdomen (Fig. 3b). Dark brown, terga 1-8 with a darker transverse band on posterior margin. Terga 2-7 with paired anterad dark brown submedian maculae. Between each pair of maculae on terga 1-6 paired blackish submedian longitudinal marks. Lateral terga (Fig. 3b). Sterna yellowish white with blackish ganglia, connectives paler. Genitalia (Fig. 6c, d) with apices of penes fused and not rolled ventrally. Paired rod-like subapical ventral appendages. In ventral view, lateral margins of penes taper almost uniformly to apices.

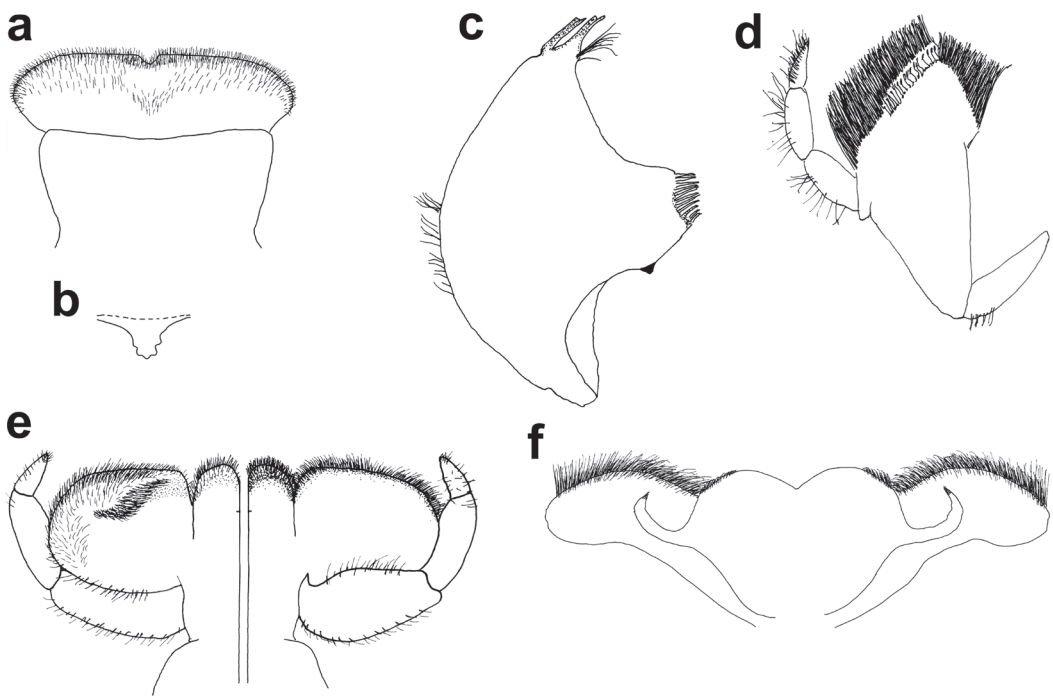


Figure 9. Mouth parts of *D. (P.) patricki*: **a** - clypeus and labrum with **b** - enlarged anteromedian emargination; **c** - left mandible; **d** - right maxilla; **e** - labium, dorsal (left) and ventral views; **f** - hypopharnyx

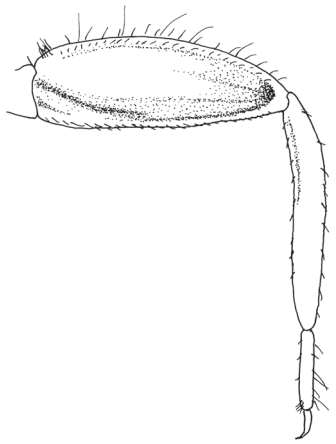


Figure 10. Foreleg of larva of *D. (P.) patricki*

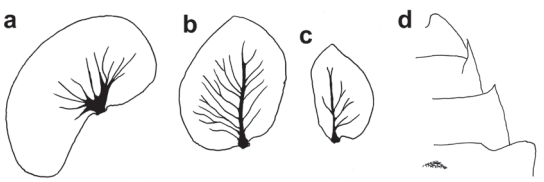


Figure 11. *D. (P.) patricki*: abdominal gills **a** – 1; **b** -4; **c** – 7; **d** - larval posterolateral projections

Caudal filaments yellowish with darker annulations at articulations.

Female imago

As in male except as follows; head greyish black, paler between the ocelli and posterolaterally. Eyes greyish.

Thorax. Pronotum, mesonotum and metanotum uniformly brown, darker at the sutures. Forewing width 0.35-0.38 (0.37) x length; hind wing 0.54-0.56 (0.55) x length and length 0.31-0.33 (0.32) x that of forewing; length of vein Sc 0.92-0.97 (0.94) x length of wing.

Abdomen. Sternum 9 deeply cloven apically (Fig. 7b).

Subimago

As in the imago except as follows; head greyish black, mesonotum greyish with paired submedian longitudinal brown marks and blackish lateral sutures. Scutellum greyish, pleura dark brown. Sterna whitish. Legs: femora dorsally blackish, tibiae and tarsi greyish yellow. Wings translucent greyish white without clouding at cross veins. Dorsal abdomen yellowish black. Segments darker on the posterior margins.

Larva

(Fig. 8)

Head brownish black, labrum, clypeus and mandibles paler. Antennae pale brown, ocelli whitish with black margins. Eyes of female black, male with upper portion brownish. Antennae 2.1 x as long as head.

Mouthparts. Clypeus and labrum (Fig. 9a). Labrum: length 0.77- 0.80 (0.79) x that of clypeus, width 1.14-1.15 (1.15) x that of clypeus; anterior margin smoothly curved with rounded anteromedian cleft as in Fig. 9b and often with irregular denticles. Mandibles (Fig. 9c). Maxillae (Fig. 9d); galea-lacinia with a subapical row of 21-24 spines; palp segment 2 0.82 x as long as segment 1, sparse hairs on outer margin, segment 3 0.86 x segment 2. Labium (Fig. 9e). Submentum without spines. Palp segment 2 0.79 x as long as segment 1, segment 3 0.47 x as long as segment 2. Hypopharnyx (Fig. 9f).

Thorax. Pronotum blackish brown with cluster of long submedian hairs, whitish between anteronotal protruberances. Mesonotum brown with two pairs of darker parasagittal marks. Scutellum whitish, black at margins. Pleura brown, darker at margins and sutures. Sterna pale brown, ganglia darker. Foreleg (Fig. 10). Forefemur: dorsal surface pale brown , darker retrolaterally and apically. Prolateral surface with sparse row of long white hairs. Foretarsal claw (Fig. 4b).

Abdomen (Fig. 5b). Posterolateral projections (Fig. 11d) well developed on segments 8 and particularly 9. Terga brownish black with posterior blackish transverse bands on segments 3-6 and sometimes faint anterior paired submedian maculae on segments 2-5; faint, dark, paired submedian parasagittal marks sometimes on segments 3-7; terga 8 and 9 sometimes paler. Sterna whitish with cluster of hairs on segment 9, sparse on segment 8. Ganglia blackish on sterna 1-6. Gills 1, 4 and 7 (Fig. 11a-c).

Gills broad, translucent and plate-like, with tracheae blackish on anterior half of laminae. Gill 1 extending to 1.2-1.6 (1.4) x length of lamella. Gills 2-7 ovate with somewhat tapering apices. Caudal filaments 1.5 x as long as body, each segment yellowish and with darker distal whorl of denticles.

Remarks

D. (P.) patricki appears to be most closely related to *D. (P.) cornutum,* from which it can be distinguished by a combination of the following characters:

	D. (P.) patricki	*D. (P.) cornutum*
Male imago	In lateral view penis lobes tapered almost uniformly to apices. Apices of penes not rolled ventrally.	In lateral view penis lobes expanded laterally at midlength forming distinct shoulders. Apices of penes rolled ventrally.
Female imago	Sternum 9 deeply emarginated	Sternum 9 with wide U shaped apical cleft.
Late instar larva	Sparser short fine hairs on sternum 9 and a few on 8. Gill tracheae strongly blackish on anterior halves of laminae.	Hairs dense on sternum 9 and diminishing in number to sternum 4. Gill tracheae weakly blackish on anterior halves of laminae.

Both adult and juvenile life stages from Westland sometimes show paired whitish maculae on terga 4 and 5.

Habitat

D. (P.) patricki is found in catchments on both sides of the Main Divide from the Arrowsmith Range in Canterbury, south to the Darran Range, Fiordland and extending into the mountains of Central Otago. The altitudinal range for collecting sites is 1400 ± 600 m. It is also reported as descending to 400 m in the Rob Roy Stream (Winterbourn et al. 2008). In much of its range the species is sympatric with *D. (P.) cornutum.*

DISCUSSION

The two *D. (Penniketellum)* species described here have been collected from both the eastern and western slopes of the main divide of the Southern Alps and also adjoining ranges between the Spenser Mountains in the north and the Darran Mountains in the south. These mountains have arisen from compression across a boundary between the Pacific and Indian/Australian plates (Suggate 1990). They continue to experience uplift, resulting in the present steep and unstable terrain. Regular seismic events add to the instability. Many peaks are over 3000 m high. The region is characterised by strong westerly winds and high annual rainfall in the west, exceeding 10 m in places (Griffiths and McSaveney 1983). The upper limit of the forest is at 1200-1400 m above sea level. Above this, shrub vegetation, tussock and scree extend to permanent snow and ice at 2000-3000 m altitude.

These mountains developed in the early Pliocene (Suggate 1990), reaching sufficient height to establish snowfields with glaciers sloping to the east and west. Evidence is fragmentary but a series of glacial advances may have driven mayfly populations adapted to this cold, hostile environment into isolated refugia where further speciation took place. In the subsequent warmer interglacial periods retreat of the snow line will have exposed mountain streams to recolonisation by newly evolved species. In Western Europe, some elements of the cold-adapted alpine stream fauna are similarly considered to have speciated and developed a high degree of endemism (Ward 1994). This relatively recent speciation is reflected in the similarities shown by the corresponding life stages of members of the subgenus *Penniketellum*.

Species of *Penniketellum* occupy many streams of this region from the upper forested zone to the limits of permanently flowing water. Collecting sites have been chiefly at altitudes of 1300 ± 600 m, typically from trickles and first order streams. Stream slopes exceeding gradients of 0.4 are common. The only larger rivers and gentle gradients reported with *Penniketellum* populations are the Hooker and Tasman Rivers below their glacial lakes. Although New Zealand mountain streams and rivers are characterised by unstable channels with highly variable discharge patterns, they show a high degree of faunal similarity (Winterbourn 1997). In spite

of a decrease in richness of the mayfly fauna generally with increasing disturbance of the lotic environment, *Penniketellum* is able to exploit this apparently hostile habitat.

The Hooker and Tasman Rivers are fed by glacial meltwater made turbid by suspended rock flour. Smaller clear flowing streams may derive from seasonal snowmelt and emerge from scree slopes as seepages, or from groundwater sources. In streams collected from by the author, water temperatures have been consistently in the range 6 ± 3° C at the times of collection in midsummer. *Deleatidium* spp. have been collected at temperatures as low as 1.0° C in the glacial Fox and Waiho Rivers, Westland (Milner et al. 2001), at 230 and 80 m asl respectively. However, apart from *D. (D.) magnum,* mayflies were not identified to species.

The lack of forest canopy above the tree line results in little water-borne organic material in streams at these elevations. Invertebrates adapted for browsing and not dependent on wood debris are favoured, rather than those adapted for shredding (Winterbourn et al. 1981). *Deleatidium,* including *Penniketellum*, is able to feed on epilithic algal films, fine detritus and sometimes silt (Winterbourn et al. 2008). Stream bedrock and large boulders may support heavy growths of aquatic bryophytes. Although these tightly adhering moss masses may retain large amounts of periphyton and debris, they seem to be avoided by Ephemeroptera generally. Possibly their entwined stems inhibit free movement of mayfly larvae (Suren 1991).

Specimens of the subgenus *Penniketellum* described here are very dark coloured dorsally and highly visible from above in daylight, under water, even against a dark grey substrate. Although larvae normally conceal themselves beneath stones, the blackish dorsal colouration seems poorly adapted for predator avoidance. Fish, both indigenous and introduced, are extremely rare above altitudes of 1000 m (McDowell 2000). Bird predators of both mayfly larval and flight stages, such as blue duck (*Hymenolaimus malacorhynchos),* fantail (*Rhipidura fuliginosa*) and welcome swallow (*Hirundo tahitica*) are rare at higher elevations, where the most common insectivorous birds are the rock wren (*Xenicus gilviventris*) and pipit (*Anthus novaeseelandiae*) (P Scofield pers. comm. 2008). The principal predators of mayfly larvae at high altitudes are likely to be the stoneflies *Stenoperla* and *Megaleptoperla*, which are well represented.

Melanins are a group of phenolic-quinonoid biopolymers widespread in the animal kingdom. Typically they are brown and black pigments. In insects they provide photoprotection by the efficient filtration of light, wound healing to control loss of haemolymph and also exercise a protective function from endoparasites (Sugumaran 2002). Mayflies in general avoid ultraviolet-B radiation (Kiffney et al., 1997). Investigations confirming this effect on unidentified larvae of *Deleatidium* were carried out in a clearwater stream at 600 m altitude by Johansson and Nystrom (2004) who found that larvae were able to detect and avoid UV-B. The deep blackening shown on dorsal surfaces of larvae and adults stages of the subgenus *Penniketellum* may be a special melanistic adaptation to the strength of the ultraviolet light in New Zealand's alpine regions. In spite of this, the reported substantial increases in UV-B resulting from decreases in summertime ozone (McKenzie et al. 1999) over New Zealand is likely to have a negative influence on *Penniketellum* populations.

Some New Zealand Leptophlebiidae have well defined upper levels of thermal tolerance (Quinn et al. 1994). Although tolerance levels for *Penniketellum* species have not been determined, a continuing rise in temperature with global warming may result in a loss of habitat and a southward retreat of such cold-adapted aquatic species. Ryan and Ryan (2006) calculated that a 3°C stream temperature increase could shift the regression of annual degree days on latitude 670 km southward, and if so the extinction of *D.* (*Penniketellum*) species would be a distinct possibility (Winterbourn et al. 2008).

D. (D.) myzobranchia shares a number of morphological adaptations to fast water with the subgenus *Penniketellum.* Howeve,r the former's New Zealand-wide distribution suggests that its phylogenetic origins may have been earlier than the Pliocene. In addition, its distribution and presence at altitudes ranging from sea level to 1800 m suggest that populations at present identified as a single species may in fact be a complex of species within the "*myzobranchia* group" as proposed by Winterbourn

(1978). Until this situation is clarified, it seems premature to make further comparisons between *D. (D.)* " *myzobranchia*" and the subgenus *Penniketellum.*

KEYS TO TAXA

The larval stages of *Penniketellum* are difficult to distinguish using morphological characters alone and it may be necessary to confirm identification by rearing through to the imago**.** The following keys have been developed to extend those given by Towns and Peters (1996).

Imago

1. In the male, apices of the penes not rolled ventrally. In ventral view penes taper uniformly at midlength. In the female, sternum 9 emargination V-shaped .....***patricki***
2. In the male, apices of penes rolled ventrally. Penes in ventral view expanded laterally at midlength. In the female, sternum 9 with a U shaped emargination .....***cornutum***

Subimago

1. Tarsal claws obtuse angled at midlength on the retrolateral surface (Fig. 2a) .....***cornutum***
2. Tarsal claws smoothly curved at midlength on the retrolateral surface (Fig. 2b) .....***patricki***

Mature larva

1. Hairs on sternum 9 dense and diminishing progressively to sternum 6 .....***cornutum***
2**.** Few sternal hairs on sternum 9 and sometimes sparsely on 8 .....***patricki***

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REFERENCES

Crosby TK, Dugdale JS Watt JC (1976) Recording specimen localities in New Zealand: an arbitrary system of areas and codes defined. *New Zealand Journal of Zoology* 3:69 + map.

Crosby TK, Dugdale JS, Watt JC (1998) Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology* 25:175-183.

Griffiths GA, McSaveney MJ (1983) Hydrology of a basin with extreme rainfalls – Cropp River, New Zealand. *New Zealand Journal of Science* 26:293-306.

Johansson J, Nystrom P (2004) Effects of ambient UV-radiation on the behaviour of mayfly larvae of the genus *Deleatidium* from trout bearing and fishless streams in New Zealand. *Archiv für Hydrobiologie* 161:403-405.

Kiffney PM, Little EE, Clements WH (1997) Influence of ultraviolet-B radiation on the drift response of stream invertebrates. *Freshwater Biology* 37:485-492.

McDowell RM (2000) *The Reed Guide to New Zealand Freshwater Fishes*. Reed Books (NZ) Ltd, Auckland, New Zealand.

McKenzie R, Connor B, Bodecker G (1999) Increased summertime UV radiation in New Zealand in response to ozone loss. *Science* 285:1709-1711.

Milner AM, Taylor RC, Winterbourn MJ (2001) Longitudinal distribution of macroinvertebrates in two glacier-fed New Zealand rivers. *Freshwater Biology* 46:1765-1775.

Quinn JM, Steele GL, Hickey CW, Vickers ML (1994) Upper thermal tolerances of twelve New Zealand stream invertebrate species. *New Zealand Journal of Marine and Freshwater Research* 28:391-397.

Ryan PA, Ryan AP (2006) Impacts of global warming on New Zealand freshwater organisms: a preview and review. *New Zealand Natural Sciences* 31:43-57.

Suggate RP (1990) Late Pliocene and quaternary glaciations of New Zealand. *Quaternary Science Reviews* 9:175-197.

Sugumaran M (2002) Comparative biochemistry of eumelanogenesis and the protective roles of phenyloxidase and melanin in insects. *Pigment Cell Research* 15:2-9.

Suren AM (1991) Bryophytes as invertebrate habitat in two New Zealand alpine streams. *Freshwater Biology* 26:399-418.

Towns DR, Peters WL (1979) New genera and species of Leptophlebiidae (Ephemeroptera) from New Zealand. *New Zealand Journal of Zoology* 6:439-452.

Towns DR, Peters WL (1996) Leptophlebiidae (Insecta: Ephemeroptera). *Fauna of New Zealand* Number 36. Manaaki Whenua Press, Lincoln, New Zealand.

Ward JV (1994) Ecology of alpine streams. *Freshwater Biology* 32:277-294.

Winterbourn MJ (1978) The macroinvertebrate fauna of a New Zealand forest stream. *New Zealand Journal of Zoology* 5:157-169.

Winterbourn MJ (1997) New Zealand mountain stream communities: stable yet disturbed? In: Streit B, Städler T, Lively CM (eds) *Evolutionary Ecology of Freshwater Animals*. Birkhäuser Verlag, Basel, Switzerland, 31-54.

Winterbourn MJ, Cadbury S, Ilg C, Milner AM (2008) Mayfly production in a New Zealand glacial stream and the potential effect of climate change. *Hydrobiologia* 603:211-219.

Winterbourn MJ, Rounick JS, Cowie B (1981) Are New Zealand stream ecosystems really different? *New Zealand Journal of Marine and Freshwater Research* 15:321-328.