Nymphal life history and growth of *Atalophlebioides cromwelli* (Ephemeroptera: Leptophlebiidae) in the Selwyn River (South Island, New Zealand) and the effect of a very large flood

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Abstract

The nymphal life history of the leptophlebiid mayfly *Atalophlebioides cromwelli* was examined in two successive years at Chamberlains Ford in the lower reaches of the Selwyn River, eastern South Island, New Zealand. Small-medium sized nymphs were first found in August-September and mean nymphal size increased steadily into summer when final instar nymphs were found (December – February). An absence of nymphs from March to August suggests that the species may have delayed hatching eggs, or that very small nymphs may be hyporheic. A massive flood in August 2008 appeared to have little effect on the nymphal population, which was more abundant in September and October 2008 than in the same months the previous year. However, population size declined rapidly thereafter and final instar nymphs were found only in December. Mean specific growth rate of nymphs was 0.01-0.03 day^{-1} in most months but higher immediately after the 2008 floods.

Key words: *Atalophlebioides cromwelli* – Leptophlebiidae – Ephemeroptera – life history – nymphal growth – flood – New Zealand

Introduction

Many New Zealand stream insects are perceived to have flexible or poorly synchronised life cycles characterised by weakly seasonal patterns of development and/or extended flight and egg-hatching periods (Scarsbrook 2000). Of the leptophlebiid mayflies (Ephemeroptera) *Neozephlebia scita* had nymphs of numerous sizes present each month in the Waitakere River, northern North Island, and a lack of clear seasonal growth (Towns 1981). Similarly, some species of *Deleatidium* have non-seasonal life histories, whereas others have more synchronised development (Towns 1983, Winterbourn *et al.* 2008). Collier *et al.* (2004) found that most nymphal size classes of *Acanthophlebia cruentata* were

Figure 1. The study site at Chamberlains Ford in July 2008 looking upstream. Extensive beds of emergent aquatic vegetation can be seen along both banks.

present throughout the year and that emergence extended over 8 months in a forest stream near Hamilton; Norrie (1969) reported that the flight periods of *A. cruentata*, several *Zephlebia* species and *N. scita* extended over 9-10 months at the Waitakere River.

The leptophlebiid genus *Atalophlebioides* is found only in New Zealand where it is represented by a single described species *Atalophlebioides cromwelli* (Phillips, 1930). Its life history has not been documented; however, descriptions of all life stages were made by Towns & Peters (1978, 1996). *A. cromwelli* has been reported from numerous localities from Northland to Southland (Towns & Peters 1996, Hitchings 2001), but according to Hitchings (2001) it is common only in Northland. Towns & Peters (1996) noted that nymphs occur on rocky substrata in running waters ranging from "relatively small streams to large rivers"; Hitchings (2001) gave an altitudinal range for the species of 0-600 m a.s.l.

In this paper I report on the nymphal life history and growth of *A. cromwelli* in the lower Selwyn River, South Island, in two successive years. A massive flood event in one of the two years provided a fortuitous opportunity to assess the effect of a heavy, bed-scouring disturbance on the mayfly population.

Methods

Study site

The study site was on the Selwyn River, which rises in the foothills of the Southern Alps and flows for about 60 km across the Canterbury Plains to Lake Ellesmere, a large coastal lagoon. Sampling was confined to a 20 m long section of riffle (Figure 1) immediately upstream of the Leeston Road bridge at Chamberlains Ford about 10 km from the river mouth (43° 41.132 S, 172° 22.508 E). Here the Selwyn gains water by seepage from shallow aquifers (Datry *et al.* 2007) and had a single, permanently flowing channel. Land-use in the vicinity of the site was principally pastoral farming; grassed picnic areas were present alongside the river. The true left bank of the study site was lined with willows (*Salix fragilis*), whereas the true right bank had no trees and little ground cover. The stream bed had a substratum of smooth, loose gravels and cobbles that supported thin diatom films at most times. Patches of Cyanobacteria (*Phormium* sp.) were also present on the substratum in some months. Beds of emergent macrophytes developed at the margins in spring and summer. The study riffle was 4-5 m wide and mostly < 20 cm deep at base-flow. Surface water has been shown to be moderately alkaline (pH 7-8, alkalinity 42-48 g m^{-3} HCO_3) with conductivity of about 100 μS_{25} cm^{-1} (Close & Davies-Colley 1990; Datry & Larned 2008). Spot water temperatures taken each month at the time of sampling (1000-1100 h) ranged from 10-17.5°C (2007) and 8-18.5°C (2008) with maxima in January-February and minima in June-August.

Discharge of the Selwyn River is monitored at Coes Ford 4.6 km downstream of the study site, where mean daily flow from 1984 to 2007 was 2.9 m^3 s^{-1} (Environment Canterbury 2008a). Larned *et al.* (2008) gave an average rate of flow gain of 0.25 m^3 s^{-1} km^{-1} for the gaining reach, so one might expect discharge at Chamberlains Ford to be a little lower than at Coes Ford. However, because no significant surface inputs occur between the two fords their patterns of flow should be similar.

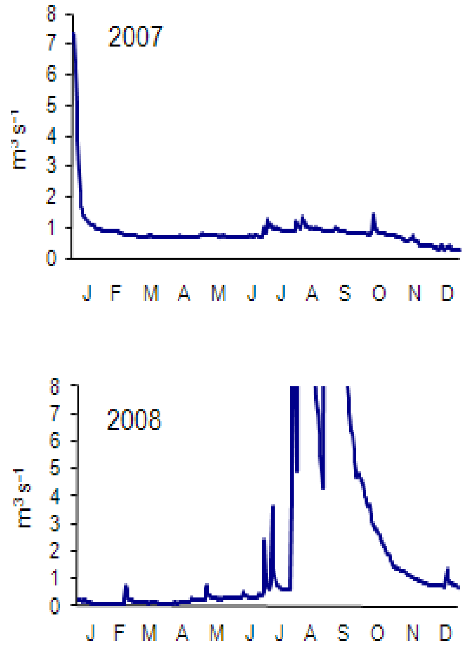

Figure 2. Hydrographs for the Selwyn River at Coes Ford in 2007 and 2008 based on mean daily flows. The period of very high flow in 2008 is not shown but described in the text to enable the flow pattern during the non-flood period to be shown clearly. Data source: Environment Canterbury.

Throughout 2007 mean daily discharge at Coes Ford did not exceed 2 m^3 s^{-1}, except for a few days in early January (Figure 2). Flow remained low until late July 2008 when several storms triggered a series of moderate and high flow events before discharge declined gradually throughout spring (Figure 2). The major flood event in winter 2008 peaked at 400 m^3 s^{-1} on 1 August and was followed by events with smaller peaks on 5 August (62 m^3 s^{-1}), 27 August (190 m3 s-1) and 6 September (40 m^3 s^{-1}) (Environment Canterbury 2008b). The major peak

Figure 3. The study site on 18 August 2008 following the flood. All aquatic vegetation has been washed away and severe disturbance of the riparian zone is evident on both banks**.**

exceeded the 10 year return period of 338 $m^3 s^{-1}$ (URS New Zealand Limited, 2006). The presence of debris in willow trees up to 2 m above base flow level was evidence of the magnitude of this flood event at Chamberlains Ford (Figure 3).

Fieldwork

Six benthic samples were taken each month for two years from February 2007 to March 2009 with a Surber sampler (0.1 m^2, 0.5 mm mesh). Sampling sites were located on a diagonal transect across the stream in run-riffle habitat with water depth of 10-20 cm. The stream bed was disturbed to a depth of 10-15 cm, the depth of loosely packed stones. Collections were preserved in the field with 90% ethanol and returned to the laboratory for processing.

Sample processing

All mayfly nymphs in Surber samples were identified and counted in a Bogorov tray at 10 x magnification. Maximum head capsule widths of all *A. cromwelli* nymphs were measured with a calibrated linear eyepiece micrometer at 10 x magnification. The presence of final instar nymphs was noted and they were sexed based on eye structure.

Biomass of nymphs in sequential 0.2 mm head width groups was estimated from a head width: dry weight regression (Winterbourn *et al.* 2008) for a morphologically almost identical species of *Deleatidium*, and used to estimate mean specific growth rates of nymphs between sampling dates (% dry weight per day). They were calculated as ln (final dry weight/initial dry weight)/days.

The specific identity of *Atalophlebioides* nymphs was confirmed as *cromwelli* by hatching subimagines from final instar nymphs and rearing them through to adults. All life stages conformed to the detailed descriptions of Towns & Peters (1978, 1996). Nymphs also had a distinct orange-yellow posterior end to their abdomens as described by Phillips (1930) in his original description of the species, but not mentioned by Towns & Peters (1978, 1996).

Results

Nymphal life history

In 2007 small nymphs were first collected in August. In subsequent months the mean size of nymphs increased steadily, and attained maximum size in February (Figure 4). No nymphs were found in March. Final instar nymphs (10 male; 10 female) were taken in December, January and February. They had head widths of 1.3-1.5 mm (mean 1.42 mm) and no significant difference in width was found between males and females (t-test, $P > 0.05$). Mean monthly population density ranged from 33 to 110 m^{-2} (Figure 5). However, numbers of nymphs in Surber samples varied considerably, as indicated by the large standard errors shown in Figure 5.

In 2008 sampling was not possible in August because of high discharge, but small-medium sized nymphs were found in September. Mean size of nymphs increased in October and November, although the spread of nymphs among size classes, especially in October, was greater than in 2007 (Figure 6). Following a small increase in mean density between September and October, a substantial decline in population size was seen in November and only one individual was found in

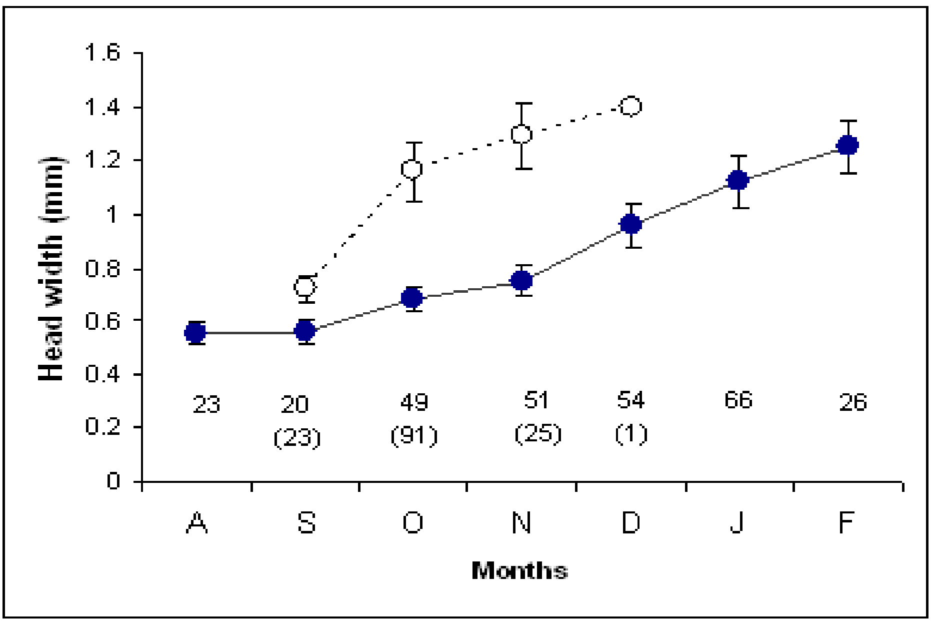

Figure 4. Mean (± SE) head widths of *Atalophlebioides cromwelli* nymphs in successive months, in 2 successive years. ● = 2007 generation; o = 2008 generation. Numbers of nymphs measured each month are shown above the y-axis (2008 generation in parentheses).

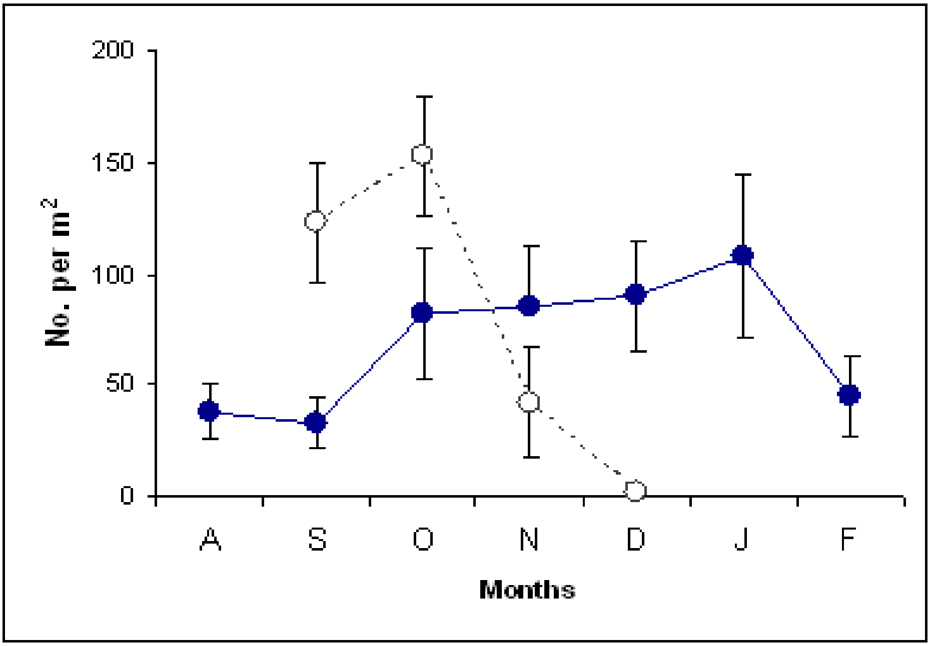

Figure 5. Mean (± SE) abundance of nymphs of *Atalophlebioides cromwelli* in successive months, in 2 successive years. ● = 2007 generation; o = 2008 generation.

December (Figure 5). No nymphs were found in January or February 2009.

Nymphal growth

Mean specific growth rates of nymphs calculated for all sampling intervals ranged from 0.01 to 0.03 day^{-1} in 2007 except in the initial month (August-September) when the growth rate was only 0.002 day^{-1} (Table 1). This very low figure reflects the continuing arrival of very small nymphs to the population. Mean specific growth rate (0.05 mg day^{-1}) was high following the floods in September-October 2008, but declined to <0.01 mg day^{-1} as nymphs approached full size.

Discussion

In 2007-08 *A. cromwelli* had a well synchronised life history in the Selwyn River, with nymphal growth from late-winter to summer. No nymphs were found from March to July in either 2007 or 2008, and final instars (and by implication adults) were only seen from December to February (2007-8) and December (2008). Because mayfly adults live for only a few days, these findings suggest that eggs may survive within the substrata for an extended period before hatching, or that very small nymphs may inhabit hyporheic substrata earlier in the year. Possible delayed hatching of eggs, or over-summering as very small nymphs has been suggested for the New Zealand leptophlebiid, *Neozephlebia scita* (Towns 1981, Storey & Quinn 2011), and is not uncommon in mayflies (Humpesch & Elliott 1999). Mean specific growth rate calculated from field data for *A. cromwelli* in 2007 (excluding August-September when small nymphs were

Table 1. Mean specific growth rates (day^{-1}) calculated for *Atalophlebioides cromwelli* nymphs in all sampling intervals, 2007-2008.

	2007-8		**2008**	
	Intervals (days)	**Growth rate**	**Intervals (days)**	**Growth rate**
August				
	29	0.002	-	-
September				
	29	0.020	29	0.050
October				
	32	0.010	34	0.010
November				
	28	0.030	27	0.008
December				
	31	0.020	-	-
January				
	32	0.010	-	-
February				

entering the population and depressing mean population body size) was about 0.02 day^{-1}, and therefore very similar to the mean growth rate needed to attain full size by a species of *Deleatidium* in Otago (Huryn 1996).

Unexpectedly, the high flows and associated movement and scouring of river bed substrata in 2008 appeared to have little negative effect on the nymphal population of *A. cromwelli*. Although no nymphs were found in samples prior to the August floods, densities were higher in September and October than in the previous year. In contrast, mean abundance of the only co-occurring mayfly, *Deleatidium vernale*, declined from 1018 ± SE 134 m^{-2} in July to only 255 ± 26 m^{-2} in September following the flood, and did not recover until December when a new generation appeared (3508 ± 457 m^{-2}; author's unpublished data).The greater abundance of *A. cromwelli* nymphs in 2008 may reflect a general redistribution of nymphs within the river brought about by the high flows. However, the apparent population "growth spurt" in these two months is difficult to interpret as their most likely food source, epilithic algae and associated fine detritus, had been stripped from cobbles and gravels, which also showed evidence of having been turned over and rolled about. It is possible that the Selwyn River flood resulted in a release of hyporheic carbon and associated micro-organisms that supported rapid population growth. Alternatively, the "growth spurt" may have been a consequence of proportionately greater drift and settlement by larger individuals, thereby increasing the average body size of nymphs on the study riffle. In contrast, the steep decline in population size in November and December when discharge

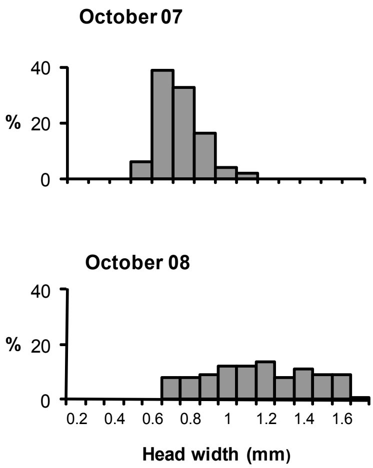

Figure 6. Size frequency distributions (head widths) of *Atalophlebioides cromwelli* nymphs in the Selwyn River in October 2007 and October 2008.

had fallen to levels close to base-flow, suggests that mortality was high, possibly due to limited food availability.

In summary, unlike most species of New Zealand Leptophlebiidae whose life cycles have been studied, *A. cromwelli* had a well synchronised period of nymphal growth in the Selwyn River and a short period of emergence and by inference, adult flight. However, the appearance of nymphs soon after a massive flood event indicated that its population was resilient and well adapted to flooding, consistent with many other New Zealand stream invertebrates (Death 2008). I know of no other streams or rivers where *A. cromwelli* is reasonably common, and therefore cannot comment on whether the nymphal life history pattern observed in the Selwyn River is representative of that found elsewhere in the country.

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