The impacts of reduced flow on instream habitat condition and macroinvertebrate behaviour

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Abstract

The allocation of water and setting of minimum flows is a contentious issue. Despite this, there is little research into the impacts of reduced stream flows on instream habitat and biota. Previous studies tend to concentrate on fish or macroinvertebrate community structure with few studies investigating the behavioural responses of macroinvertebrates to flow reduction. Therefore the aim of my thesis was to assess the impact of severe flow reduction on habitat condition and macroinvertebrate behaviour (drift and refugia use) using before-after, control-impact (BACI) experimental manipulations in natural (Wairarapa, New Zealand) and artificial stream channels (Canterbury, New Zealand). Instream channels were also used to assess the impact of flow reduction duration and magnitude on macroinvertebrate community structure and vertical distribution in the substrate. Reduced flow tended to decrease depth, velocity, and wetted width and increase fine sediment deposition. However, the common assertion that it would lead to increased temperatures and lowered dissolved oxygen levels was not supported by my results, although this may occur in some streams. I found that severely reduced flow in small streams had minimal effect on water temperature, although it can depress nighttime dissolved oxygen minima. Flow reduction markedly increased the drift propensity of some taxa immediately following flow reduction, before it fell back to near background levels for the rest of the reduced flow period. This increased drift occurred as animals redistributed themselves to more suitable microhabitats within the stream. Additionally, flow reduction reduced the drift distance of animals making it unlikely that drifting would be a viable way of escaping low flow conditions. Flow reduction had no impact on the densities or vertical distribution of animals within the substrate, however, most species were present at all depths sampled in the hyporheic zone, providing a source of colonists should some event (flood or drying) denude the benthos of animals. An instream channel experiment showed that apart from changes to the relative abundances of a few common taxa, flow reduction magnitude (up to 98% reduction) had little impact on the macroinvertebrates of a lowland river. Overall, my results suggested that severe flow reduction stresses a number of taxa, causing them to drift as they redistribute themselves within the stream. I found no evidence that animals actively seek refuge in the hyporheic zone, and in a lowland river, the magnitude and duration of flow reduction had minimal effect on the macroinvertebrate community.

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I would not have been able to produce this work without the logistical and emotional support of Zoë Dewson who for the last 9 ½ years has shared all aspects of my life including this project. Stanley (English Cocker Spaniel) and Archer (Schnauzer) have provided much amusement and a welcome distraction. They ensure I get up early and many ideas have come to me whilst walking them. My parents, Hertha and Bryan James have provided endless encouragement, financial and logistical support. Zoë's parents have always been encouraging and I thank them for letting me have their daughter.

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Thesis structure and authorship note

This thesis consists of a series of manuscripts each produced for publication in relevant journals. Thus, there is a certain amount of repetition especially in the methods sections. The numbering of figures, tables and photographic plates restarts at the beginning of each chapter. Manuscripts are co-authored to acknowledge the input of others as appropriate. My main thesis supervisor, Russell Death was instrumental in the design and funding of the New Zealand flow reduction experiment and the idea of the Canadian streamside channel experiment originated with him. Russell edited manuscripts and provided guidance on all aspects of my work. Zoë Dewson completed her Ph.D. thesis alongside mine using the same experimental setup (natural channel severe flow reduction) thus she helped with all the fieldwork. She also processed the benthic invertebrate samples while I processed all drift, hyporheic and pool samples. The literature review that forms chapter 1 originated from Russell's idea to combine two separate reviews on macroinvertebrate community (ZD) and individual (AJ) responses to flow reduction into one complete review for publication. Zoë and I had the greatest and equal input into this review. I was responsible for all aspects (design, fieldwork, sample processing, and analysis) of Chapters 2, 3 and 4. Chapter 5 was the result of a collaborative experiment with Alastair Suren of NIWA. Alastair designed and installed the experiment whilst I assisted in the sampling, processed all the samples, conducted all the analyses of biotic data and wrote the manuscript. Alastair did much of the abiotic analysis, wrote some parts of the methods (abiotic measurements), and had editorial input.

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