Selective Harvesting in Headwater Streams: Investigating the Effects of Habitat Discontinuity on Adult Aquatic Insect Populations

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Published

2012

Thesis Type

Thesis (PhD Doctorate)

School

Griffith School of Environment

DOI

10.25904/1912/1679

Selective harvesting in headwater streams: investigating the effects of habitat discontinuity on adult aquatic insect populations

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Submitted in fulfilment of the requirements of the degree of
Doctor of Philosophy

July 2012

Abstract

Connectivity in aquatic ecosystems is a broad concept that refers to the transfer of both abiotic (i.e. matter and energy) and biotic (organisms) elements through the landscape across a range of spatial and temporal scales. The present study focuses on the patterns of connectivity between populations of aquatic insects in headwater streams. Dispersal, emigration and immigration are the demographic forms of population connectivity, which are largely thought to be by the winged adult stages that spend much of their lives in the riparian zone. These flying adults may disperse laterally and longitudinally to circumvent terrestrial barriers between headwater streams and catchments, thus allowing gene flow between populations in different streams.

Riparian vegetation has a potentially strong influence on the survival and success of adult stages through the alteration of the microclimate, habitat structure and potential food sources. Habitat fragmentation caused by forest harvesting can reduce population connectivity by increasing the area of open forest and altering microclimatic conditions, particularly air temperature and humidity. Degradation of adjacent terrestrial habitat through forest harvesting may negatively affect adult dispersal because altered microclimatic conditions may create a barrier to dispersal. For example, the extreme conditions caused by harvesting may exceed tolerance limits of adult aquatic insects. In addition, aquatic insect life history traits may influence the degree to which forest harvesting affects their populations. For example, if a species with a short emergence period emerges during peak summer temperatures, temperatures could be higher in cleared areas compared to forested, thus exceeding the tolerance limit of the species. However, little direct evidence exists on the effects of selective harvesting and the associated changes to the microclimate on adult dispersal and genetic population connectedness.

This thesis explores the effects of catchment-scale selective forest harvesting on the dispersal of adult aquatic insects in headwaters streams of north-eastern NSW, Australia. This study used a Multiple Control-Impact (MCI) design across a harvesting intensity gradient. Two sub-catchments were selectively harvested and

one was completely cleared during a commercial forestry operation, with two left as unharvested controls. Riparian vegetation was retained in all sub-catchments in accordance with licence conditions for Forests NSW.

The patterns of genetic variation in the leptophlebiid mayfly *Ulmerophlebia* were examined in both selectively harvested and control sub-catchments, but few samples could be collected in the clear-cut catchment. I hypothesised that: 1) patterns of mitochondrial DNA (mtDNA) variation in *Ulmerophlebia* sp. AV2 shows a pattern of structuring that reflects widespread dispersal along the stream network and across catchments; and (2) genetic diversity would be lower in partially deforested sub-catchments compared to forested sub-catchments. I found gene flow was not restricted among headwater streams within sub-catchments but was restricted at distances >15 km. Genetic diversity was high (mean haplotype diversity >0.85) in both control and harvested sub-catchments. Instead, a historical signature of population expansion was detected which is consistent with findings for other aquatic insect taxa of eastern Australia. These findings suggest that the selective harvesting management strategy, including the use of riparian buffer zones, within these sub-catchments does not appear to restrict dispersal between streams or erode diversity within streams for *Ulmerophlebia* sp. AV2

Small-scale movements of individuals were explored across the harvesting intensity gradient using intercept traps and an isotopic enriched label. I hypothesised that the main pathway of aquatic insect dispersal would either be along the stream channel or through the terrestrial environment. Secondly, I predicted that harvesting would reduce their ability to disperse through the terrestrial environment because altered microclimatic conditions may create a barrier to dispersal. Upstream flight of mayflies and caddisflies and the predominance of mayfly individuals captured within 25 m of streams suggest that the stream channel was the main pathway for dispersal. I was not able to make conclusions about caddisfly dispersal through the terrestrial environment because of low sample numbers. However, it is still uncertain if individuals travel similar distances downstream as they do upstream. The low capture of individuals at distances > 50 m from the stream channel suggested between-stream dispersal via this pathway was unlikely, especially in steep forested catchments. Cross-catchment dispersal on this scale is possible along the stream channel and, although it may not be frequent enough to affect population dynamics of nearby populations; it could be frequent enough to maintain high levels of gene flow among nearby streams. Dispersal distances were not lower in harvested compared with forested sub-catchments, which indicated that harvesting did not reduce aquatic insect dispersal throughout the catchments.

Life history traits of several common mayfly and caddisfly species were examined to determine the extent to which aquatic insects are likely to be affected by disturbances like forest harvesting. General life history traits included most larval sizes present in the population through much of the year and an extended emergence period from spring through to autumn. A long emergence period from spring through to autumn would not expose many individuals to peak summer air temperatures in the terrestrial environment. However, temperatures may be more severe as a result of harvesting, thus increasing possible environmental stress experienced by those individuals. Asynchronous development has been hypothesised to spread life stages over time, thereby decreasing the risk of eradication by short-term disturbance events. Based on these results, these life history traits may reduce the possible effects of selective harvesting on the dispersal of emerging adults in this study region.

A lab experiment to examine air temperature tolerance of several species of mayflies and one caddisfly was conducted, with the prediction that extreme conditions (high temperatures) in the terrestrial environment caused by forest harvesting would exceed the tolerance limits of several species of adult mayflies and a caddisfly, thereby reducing their lifespan and ability to disperse through the terrestrial environment. I also predicted that mayflies would be more sensitive to increasing temperature than caddisflies because of thermal sensitivity indicated in nymph studies. I found the predicted lethal temperature values (96-h_{dmax} LT_{50}) for the longer-lived *Atalomicria* mayfly species to be 32^{o}C, while the two day predicted lethal temperature values (48-h_{dmax} LT_{50}) for the shorter-lived mayflies *Austrophlebioides* and *Koorrnonga* sp. and the caddisfly *A. bicoloratus* were slightly lower at around 31^{o}C. Peak day-time air temperatures rarely exceeded 30^{o}C at control and selective harvested sites, but were exceeded up to 33% of the time in open areas in the harvested sites. During that time, these temperatures could cause a mortality rate of 100 % for *Koorrnonga* sp, 30 % for

Austrophlebioides, and 40-50% for the caddisfly *A. bicoloratus*, yet not kill the *Atalomicria* species.

Population connectivity is a fundamental ecological process that influences biotic responses to disturbances, such as forest harvesting. This study suggests that population connectivity of aquatic insects in this region may not be as high as that proposed in the literature. In addition, the results of this study suggested that harvesting does not negatively affect adult aquatic insect dispersal. The life history traits, such as high temperature tolerance and long emergence timing, of many species in this region may have reduced the possible impact of harvesting. Furthermore, the lack of dispersal of mayfly or caddisfly adults away from their natal streams suggested that the terrestrial zone outside of the riparian zone is not frequently used as a dispersal route. Although many taxa were capable of flying distances of several hundred meters between sub-catchments, this route of dispersal was likely to be very rare. Instead, dispersal was likely to be along stream channels. Although it may not be sufficiently frequent to affect population dynamics in adjacent streams, it could maintain population connectivity and gene flow among nearby streams. Therefore, distance and direction of adult aquatic insect dispersal is relevant to population dynamics at the scale of single streams, and to the persistence of populations at the landscape scale.

Declaration

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

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Belinda Young

July 2012

Anisocentropus bicoloratus (Calamoceratidae). Photography by Belinda Young

Atalomicria banjdjalama (Leptophlebiidae). Photography by Belinda Young

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Young, B. A., Schmidt, D. J., and Sheldon, F. In press. Small-scale patterns of genetic variation in a headwater specialist mayfly: no influence of selective forest harvesting on diversity. *Austral Ecology*.

Acknowledgements

First I thank my supervisors Dr Fran Sheldon and Dr Dan Schmidt for their guidance and encouragement throughout the project. Thanks also to Dr Andrew Boulton, my associate supervisor, for many stimulating and enthusiastic discussions.

The PhD project was funded by an Australian Postgraduate Award (Industry) with an industry contribution from Forests NSW, and a Griffith School of Environment top-up scholarship. I also received funding support for conference attendance from the Australian Rivers Institute; the Australian Society for Limnology and the Griffith School of Environment.

I thank Dr Ashley Webb from Forestry NSW and Dr Kate Smolders for assistance with early field work and familiarising me with the Kangaroo River Catchment. I also thank Justin Black and Warren Taylor from Forestry NSW for their assistance in finding suitable sites in Wild Cattle Creek State Forest. Thanks to Amy Bond, Laurisse Frampton, Alisha Steward, Tim Page, Iris Tsoi, Anna Barnes, Tanya Elisson, Ceaira Cottle, Sarah Maunsell (and her sister Justine), and Annette Young for their fantastic fieldwork assistance trekking up and down mountains. Thanks also to Carolyn Polson, Wendy Neilan, and Iris Tsoi for keeping me sane near the end of the microscope work.

Many thanks to Dr Phil Suter, Dr John Dean and Michael Shakleton for their help identifying the tricky adult mayflies and caddisflies. I also thank Ros St Clair for her assistance in trying to identify a possibly undescribed caddisfly species!

Finally, thanks to my family, and to Nick for his support and encouragement through this rewarding, but often testing time. Completing this work wouldn't have been possible without it.

Included in this thesis is a published paper in *Chapter 3*, which is co-authored with other researchers. My contribution to the co-authored paper is outlined at the front of the relevant chapter. The bibliographic details for this paper are:

Chapter 3: Young, B. A., Schmidt, D. J., and Sheldon, F. In press. Small-scale patterns of genetic variation in a headwater specialist mayfly: no influence of selective forest harvesting on diversity. *Austral Ecology*.

Appropriate acknowledgements of those who contributed to the research but did not qualify as authors are included in the published paper.

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