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$^\circ$C, while the two day predicted lethal temperature values (48-h$_{dmax}$ LT$_{50}$) for the shorter-lived mayflies *Austrophlebioides* and *Koornonga* sp. and the caddisfly *A. bicoloratus* were slightly lower at around 31$^\circ$C. Peak day-time air temperatures rarely exceeded 30$^\circ$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 *Koornonga* 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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July 2012

*Anisocentropus bicoloratus* (Calamoceratidae). Photography by Belinda Young

*Atalomicria banjdjalama* (Leptophlebiidae). Photography by Belinda Young
Table of Contents

Abstract ............................................................................................................................. II
Declaration ...................................................................................................................... VI
List of tables .................................................................................................................. XI
List of figures .................................................................................................................. XIII
List of appendices .......................................................................................................... XVII
List of supplementary material ................................................................................... XVIII
Acknowledgements .................................................................................................... XIX

Chapter 1. Introduction .................................................................................................. 1
1.1 Ecological connectivity and aquatic insect dispersal in headwater streams .......... 1
1.2 Genetic consequences of dispersal ......................................................................... 3
   1.2.1 Effects of forest harvesting on aquatic insect dispersal .................................. 6
1.3 Broad research aims and predictions .................................................................... 10

Chapter 2. Study region and experimental design ................................................... 12
2.1 Study region .......................................................................................................... 12
   2.1.1 Stream gauging methods used by Forestry NSW ...................................... 13
   2.1.2 Catchments in the Kangaroo River State Forest and Wild Cattle Creek State
       Forest ................................................................................................................. 18
2.2 Harvesting in NSW ............................................................................................... 22
   2.2.1 Summary of timber harvesting operations in KCSF ................................... 22
   2.2.2 Summary of timber harvesting operations in WCCSF ............................. 24
   2.2.3 Sampling design and regime ..................................................................... 25

Chapter 3. Population genetics of an Australian mayfly Ulmerophlebia sp. AV2
           (Leptophlebiidae: Ephemeroptera) ....................................................................... 27
3.1 Introduction .......................................................................................................... 28
   3.1.1 Aims ............................................................................................................ 31
3.2 Methods ............................................................................................................... 32
   3.2.1 Study species ............................................................................................ 32
   3.2.2 Study area and sampling design ............................................................... 32
   3.2.3 DNA analysis .......................................................................................... 33
   3.2.4 Data analysis .......................................................................................... 34
3.3 Results .................................................................................................................. 36
   3.3.1 Genetic variation and structure within and between sub-catchments ....... 36
3.3.2 Genetic variation and structure within treatment and control sub-catchments............................................................................................................ 44

3.4 Discussion .......................................................................................................... 45
  3.4.1 Genetic and inferred dispersal patterns ....................................................... 45
  3.4.2 Genetic diversity in control and harvested catchments............................... 47
  3.4.3 Conclusion .................................................................................................. 49

Chapter 4.  Longitudinal and lateral movement of adult aquatic insects in headwater streams across a forest harvesting gradient ................................................................. 51
  4.1 Introduction ........................................................................................................ 51
    4.1.1 Aims ............................................................................................................ 56
  4.2 Methods .............................................................................................................. 56
    4.2.1 Lateral dispersal .......................................................................................... 56
    4.2.2 Longitudinal dispersal – 15N addition and analysis ................................... 57
    4.2.3 Data analysis ............................................................................................... 59
  4.3 Results ................................................................................................................ 60
    4.3.1 Lateral movement and distribution ............................................................. 60
    4.3.2 Influence of habitat structure ...................................................................... 64
    4.3.3 Longitudinal movement and distribution .................................................... 67
  4.4 Discussion .......................................................................................................... 69
    4.4.1 Adult aquatic insect dispersal in headwater streams: longitudinal and lateral movement ............................................................................................................. 69
    4.4.2 Effects of forest harvesting on adult dispersal ............................................ 72
    4.4.3 Conceptual model of adult aquatic insect dispersal in headwater streams . 73
    4.4.4 Conclusion .................................................................................................. 76

Chapter 5.  Can life histories of aquatic insects influence the degree to which forest harvesting affects their populations? ................................................................. 77
  5.1 Introduction ........................................................................................................ 77
    5.1.1 Aims ............................................................................................................ 79
  5.2 Methods .............................................................................................................. 80
    5.2.1 Physical parameters .................................................................................... 80
    5.2.2 Emergence traps .......................................................................................... 80
    5.2.3 Larval sampling .......................................................................................... 81
    5.2.4 Larval cohort analysis ................................................................................. 82
  5.3 Results ................................................................................................................ 82
List of tables

Table 2.1 Catchment areas and hectares harvested for Kangaroo River monitoring catchments.................................................................................................................................................. 23

Table 2.2 Outline of minimum filter strip, protection zone and operational zone widths for mapped and unmapped drainage lines, prescribed streams and watercourses in native forests in Inherent Hazard Levels 1 and 2 (metres are measured along the ground surface). .................................................................................................................................................. 23

Table 2.3 Outline of 5-metre zone and buffer zone widths for drainage features, (metres are measured along the ground surface). .................................................................................................................................................. 25

Table 3.1 Table of haplotype frequencies at each site of Ulmerophlebia sp. AV2. ............................................................................................................................. 37

Table 3.2 Sites, haplotype and nucleotide diversity indices of Ulmerophlebia sp. AV2.................................................................................................................................................. 39

Table 3.3 Analysis of Molecular Variance (AMOVA) results for populations of Ulmerophlebia sp. AV2 showing F-statistics and Φ-statistics. * p<0.05, ** p<0.01. ...................................................................... 42

Table 3.4 Ulmerophlebia sp. AV2 pair-wise comparisons using ΦST values with sequence divergence included. Figures above diagonal represent corresponding p-values and those below represent ΦST values. Bold p-values are significantly different (FDR correction p < 0.009). ........................................................................................................................................ 43

Table 3.5 Diversity indices of Ulmerophlebia sp. AV2 for 81 haplotypes across subcatchments.................................................................................................................................................. 44

Table 4.1 δ15N values (‰) of non-labelled caddisfly and mayfly larvae collected before 15N addition, and the threshold used to determine which individuals (larvae and adults) were labelled. .................................................................................................................................................. 58

Table 4.2 Percent abundance of individuals from families of adult mayflies and caddisflies caught in hanging traps across a harvesting intensity gradient (all traps and times combined). ........................................................................................................................................ 61

Table 4.3 Spatial distribution of the catch of adult mayflies and caddisflies with distance from stream edge (m) across a harvesting intensity gradient with sampling time combined. ........................................................................................................................................ 63

Table 4.4 Three-way ANOVA for differences in adult insect abundance within a harvesting gradient. Degrees of freedom are in parentheses. Significant p-values are in bold. ........................................................................................................................................ 64
Table 4.5  Direct oblimin rotated factor loadings for environmental variables at sites in Kangaroo and Wild Cattle Creek State Forests.  Magnitude and signs of loadings indicate strength and direction of each variables influence on a factor. Underlined loadings indicate strength and direction of each variables influence on a factor. Underlined loadings were used to characterise factors.

Table 4.6  Correlation Matrix of the five environmental variables used in the PCA.

Table 4.7  Species and sex (where known) of labelled caddisfly and mayfly adults caught along the stream channel.

Table 6.1  Microclimate conditions for air temperature regimes applied to adult insects.

Table 6.2  Forest air temperature analysis from loggers placed along 100-m transects perpendicular to the stream channel in sub-catchments with varying degrees of forest harvesting.  48 h and 96 h denote the number of consecutive days that the maximum day temperature was higher than the specified temperature.

Table 6.3  Longevity data for varying air temperature cycles applied to adult insects.

Table 6.4  $L_{T_{50}}$ values ($^\circ$C; 95% confidence intervals in parenthesis) for adult insects using maxima of four diurnally varying temperature cycles at 48 h for $A.~bicloratus$, Koornonga sp., Austrophlebioides sp. and 96 h for $A.~banjdjalama$, and $A.~bifasciata$.

Table 6.5  Number of times air temperature exceeded 48-h$_{d_{max}}$ $L_{T_{50}}$ and 96-h$_{d_{max}}$ $L_{T_{50}}$ values of adult aquatic insect taxa over 14 weeks.  R = riparian zone (0-10 m from stream channel); T = terrestrial zone (≥ 25 m).
List of figures

**Figure 1.1** Conceptual model of hypothesised effects of forest harvesting on adult aquatic insect dispersal in the Kangaroo River State Forest based on reviewed literature. Black, broken arrows indicate dispersal pathways of adult aquatic insects. 9

**Figure 2.1** Map of north east NSW and location of catchments within Kangaroo River State Forest and Wild Cattle Creek State Forest. Source: R. Lloyd, Forestry NSW 2007.................................................................14

**Figure 2.2** Minimum and maximum mean temperatures (°C) based on 66 years of record for Coffs Harbour. Source: Bureau of Meteorology 2009...............................15

**Figure 2.3** Mean annual rainfall (mm) based on 66 years of record for Coffs Harbour. Source: Bureau of Meteorology 2009. ..........................................................15

**Figure 2.4** Mean daily discharge (ML/d) for control catchments C1 and C2 from 2001-09. Source: Forests NSW 2011.............................................................................16

**Figure 2.5** Mean daily discharge (ML/d) for treatment catchments T1 and T2 from 2001-09. Source: Forests NSW 2011.............................................................................17

**Figure 2.6** Kangaroo River Catchments, with stream order, location of gauging stations (sites) and forest types. Refer to Appendix A for details of vegetation associated with these forest types. Source: R. Lloyd, Forests NSW, 2009.................19

**Figure 2.7** Wild Cattle Creek forestry compartments showing site locality (red dots) and plantation information. Source: J. Black, NSW Forestry, 2010............................20

**Figure 2.8** Morphology of study streams in KRSF showing typical pools, bedrock channels, steep banks and heavy shading. Photos: B. Young 2009...............................21

**Figure 3.1** Map of north-eastern NSW showing sampling sites for *Ulmerophlebia* sp. AV2 in Kangaroo River State Forest and Wild Cattle Creek State Forest. ...............33

**Figure 3.2** Geographical representation of haplotype frequencies for *Ulmerophlebia* mtDNA gene. Pies represent total individuals sampled at that site and different colours represent different haplotypes. Haplotype 1 is the dominant haplotype represented in red.................................................................40

**Figure 3.3** Haplotype network showing geographical distribution of haplotypes of *Ulmerophlebia*. Circle size indicates the frequency of each haplotype. Solid lines represent a single mutation and small white circles represent haplotypes that were not sampled. Haplotype 1 (labelled) was identified as the root for the entire network. ...41
Figure 3.4  Estimates of genetic diversity of Ulmerophlebia sp. AV2 in control = grey; and selectively logged = white; error bars = standard error. ........................................45

Figure 4.1  Conceptual models of potential dispersal patterns for flying adult aquatic insects. Circles represent the probability of an adult dispersing from the stream at the emergence site designated by the thinner horizontal black line with circle shades indicating probability of dispersal (black = high, dark grey = medium and light grey = low). Dispersal pattern of adults will differ with dispersal behaviour: a) dispersal ability is limited and restricted to the stream channel; b) dispersal ability is high and restricted along the stream channel; c) dispersal ability is low and not restricted to the stream channel; d) dispersal ability is high and not restricted to the stream channel. 54

Figure 4.2  Mean (± SE) δ¹⁵N values (%o) of larvae after ¹⁵N addition at seven sites below addition site (0 m). .........................................................................................................................59

Figure 4.3  Mean (± SE) adult insects caught at intervals from the stream channel across a harvesting intensity gradient. The lower graph focuses on the variation in the bottom half of the top graph..............................................................................................................62

Figure 4.4  Association of mayfly abundance and Factor 1 (considered to represent the vegetation gradient across a harvesting gradient). .................................................................66

Figure 4.5  Association of mayfly abundance and Factor 2 (considered to represent distance from the stream) across a harvesting gradient. ..........................................................66

Figure 4.6  Proportion of labelled adult individuals from total catch along the stream reach. Total number of individuals caught is above each sampling location. ............67

Figure 4.7  Distance upstream and downstream of ¹⁵N addition site (represented by 0 m) that individuals labelled with ¹⁵N were caught. Arrow indicates direction upstream of labelled section........................................................................................................68

Figure 4.8  Proposed conceptual model of dispersal patterns over one generation for mayflies and caddisflies in KRSF. Circle shades from emergence site (black line) represent the direction and likelihood of dispersal based on isotopic, adult trap data presented here and genetic data presented in Chapter 3. Dark shading represents a high probability of adult insect dispersal; medium grey shading represents possible direction and distance travelled; light grey shading represents low probability distances and direction travelled........................................................................................................74

Figure 5.1  Emergence trap placement at sub-catchments C2 and T1 in KRSF...........81

Figure 5.2  Average monthly rainfall at KRSF from 2001 - 2009..................................83

Figure 5.3  Daily discharge recorded at each sub-catchment during 2007 in KRSF..84
Figure 5.4 Monthly mean water temperature and range (min and max) at site T1 during 2007 in KRSF. All sites showed a similar pattern and temperature range. 85

Figure 5.5 Monthly emergence of adult aquatic insects from sites C2 and T1 at KRSF. 86

Figure 5.6 Size frequency (%) distributions (mm) of A. bicoloratus across all sites. The number of individuals measured is given across the top for each month. 87

Figure 5.7 Size frequency (%) distributions (mm) of Diplectrona sp. AV11 across all sites. The number of individuals measured is given across the top for each month. 87

Figure 5.8 Size (mm) frequency (%) distributions (mm) of Asmicridea sp. AV1 across all sites. The number of individuals measured is given across the top for each month. Short-dotted line arrows indicate possible emergence. 88

Figure 5.9 Size frequency (%) distributions (mm) of Hydrobiosella sp. across all sites. The number of individuals measured is given across the top for each month. Short-dotted line arrows indicate possible emergence. 89

Figure 5.10 Size frequency (%) distributions (mm) of Ulmerophlebia sp. AV2 across all sites. The number of individuals measured is given across the top for each month. 89

Figure 5.11 Size frequency (%) distributions (mm) of Koornonga sp. AV1 across all sites. The number of individuals measured is given across the top for each month. 90

Figure 6.1 Adult aquatic insects examined in lab experiment: a) Anisocentropus bicoloratus, b) Atalomicria banjdjalama, c) Atalomicria bifasciata, d) Koornonga sp., e) Austrophlebioides sp. 99

Figure 6.2 Diurnally varying air temperature cycles over 96 h (constant 18°C minimum with variable maximum) applied to macroinvertebrates to study thermal tolerances. 102

Figure 6.3 Box plot of temperature recorded by loggers along 100-m transects perpendicular to the stream channel in sub-catchments with varying degrees of forest harvesting. The horizontal lines in the box denote the 25th, 50th and 75th percentile values. Error bars denote the 5th and 95th percentile values. 103

Figure 6.4 Mortality rates for adult insects over 24, 48 and 96 h subjected to four air temperature cycles (°C) with different maxima (18-23, 18-27, 18-30 and 18-34). (A) A. bicoloratus, (B) A. banjdjalama, (C) A. bifasciata, (D) Koornonga sp., (E) Austrophlebioides sp. ND, no data. 107
Figure 7.1 Conceptual model of hypothesised effects of forest harvesting on adult aquatic insect dispersal in the Kangaroo River State Forest. Black, broken arrows indicate dispersal pathways of adult insects. Red solid lines indicate barrier to dispersal.
List of appendices

Appendix A. Forest types in Kangaroo River from map 2.6.................................123
Appendix B. Distribution of variable positions among 81 unique haplotypes of the
cytochrome c oxidase subunit 1 (COI) mtDNA fragment in the mayfly Ulmerophlebia
sp. AV2. Nucleotide positions for each haplotype correspond to the associated
sequence deposited in Genbank..................................................................................126
Appendix C. Tests of normality results of square root transformed adult abundance
data................................................................................................................................128
Appendix D. Normal Q-Q plot of square root transformed adult abundance data.....
.........................................................................................................................................128
Appendix E. Detrended normal Q-Q plot of square root transformed adult
abundance data.................................................................................................................129
Appendix F. Tests of normality results of fourth root transformed adult abundance
data. ..................................................................................................................................129
Appendix G. Normal Q-Q plot of fourth root transformed adult abundance data. 130
Appendix H. Detrended normal Q-Q plot of fourth root transformed adult
abundance data.................................................................................................................130
Appendix I. Tests of normality results of cube root transformed adult abundance
data. ..................................................................................................................................131
Appendix J. Normal Q-Q plot of cube root transformed adult abundance data. 131
Appendix K. Detrended normal Q-Q plot of cube root transformed adult abundance
data. ..................................................................................................................................132
Appendix L. Canopy density along transects at site C1.................................133
Appendix M. Canopy density along transects at site C2.................................133
Appendix N. Canopy density along transects at site T1.................................133
Appendix O. Canopy density along transects at site T2.................................133
Appendix P. Canopy density along transects at site WCC1 ......................134
Appendix Q. Canopy density along transects at site WCC2 ......................134
Appendix R. Number of dead subimagos for each air temperature regime ......135
List of supplementary material

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:


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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