The role of allochthonous dissolved organic carbon in supporting food webs in Australian lowland rivers

Matthew Balzer

A thesis in fulfilment of the requirements for the degree of

Doctor of Philosophy

August 2021

Freshwater Estuarine Research Group

School of Life Sciences

University of Technology Sydney

Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text. I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This research is supported by an Australian Government Research Training Program.

Production Note:
Signature removed prior to publication.

Signature Date 27/07/21

Acknowledgements

The list of people I need to thank for help, support and encouragement throughout this PhD is too long to put here, and words probably won't do it justice anyway. Nevertheless there are a number of people I really do owe a great deal of thanks to.

A massive debt of gratitude is owed to my supervisors Doug Westhorpe, Yoshi Kobayashi, Wade Hadwen, James Hitchcock and Simon Mitrovic whose patience and support has been nothing short of incredible. Their generous sharing of knowledge and encouragement for experimental ideas and writing has been a constant booster, particularly for the last year. Being able to have a group of supervisors that I can catch up with over a coffee or beer and talk about music, life and whatever else comes up has been amazing and made this entire PhD incomparably better. I owe particular thanks to Simon, taking a chance on a mug like me has been life changing, I used to work in factories and now I'm finishing a PhD. But more than that, your constant willingness to help and go far beyond the call of duty even when you are painfully overworked has been greatly appreciated and made this all possible, and I will always be incredibly grateful for that. Plus you're a great hang and have good taste in music.

I would also like to acknowledge all past and present members of the freshwater research group that I have been lucky enough to work with. From helping out in the field in the brutal heat to (even worse) counting algae in the lab everyone's help has always been brilliant. More importantly though I've loved working with everyone and its been a privilege to work with such a great group of friendly and genuine people, most of whom I consider either friends or very good friends. I would like to acknowledge special thanks for Laura and Lauren whose years (!) of help in the field made this PhD possible and enjoyable. And to Jordo for the last 6 wildly intense months, the work was good but the company was better, thanks for it all, I couldn't have picked a better mate to do it all with.

Finally, I simply could not have done any of this without my wife, Aleisha. I can't even put into words how grateful I am to have had you by my side for this, and everything else.

Dedicated to my mum and dad.

Preface

This thesis consists of six chapters. Chapters 2 to 5 have been written as separate articles that are in preparation for submission to peer reviewed scientific journals. These chapters are included in their pre-submission form, and as such use the terms we/our when discussing results and hypotheses. To prevent unnecessary duplication of references, a single reference list has been provided at the end of this thesis.

This thesis is a compilation of my own work, carried out with guidance from my supervisors and others. I conceptualized this research, conducted all data collection and analysis and wrote the manuscript. Contributions by supervisors and others are as follows:

Chapter 2: *Variable flow sizes and their effects on carbon, nutrients, phytoplankton and zooplankton in a highly regulated lowland river*

S. Mitrovic provided conceptual advice, guidance, reviewed manuscript and assisted with fieldwork

D. Westhorpe provided conceptual advice, reviewed manuscript and assisted with fieldwork

J. Hitchcock provided conceptual advice, guidance, reviewed manuscript

T. Kobayashi provided conceptual advice, reviewed manuscript

Chapter 3: *Hydrology controls of primary energy sources supporting zooplankton growth in a lowland river.*

W. Hadwen provided conceptual advice, reviewed manuscript

S. Mitrovic provided conceptual advice, reviewed manuscript and assisted with fieldwork

J. Hitchcock provided conceptual advice, reviewed manuscript

T. Kobayashi provided conceptual advice, reviewed manuscript

D. Westhorpe provided conceptual advice and assisted with fieldwork

Chapter 4: *Allochthonous dissolved organic matter support for freshwater zooplankton and mixotrophs in a mesocosm experiment*

S. Mitrovic provided conceptual advice, guidance, reviewed manuscript and assisted with fieldwork

J. Hitchcock provided conceptual advice, guidance, reviewed manuscript and assisted with fieldwork

T. Kobayashi provided conceptual advice and reviewed manuscript

C. Boys provided conceptual advice and assisted with fieldwork

W. Hadwen provided conceptual advice and reviewed manuscript

R. Delmas assisted in phytoplankton enumeration

Chapter 5: *Bioavailable DOC additions increase mixotroph and ciliate production in riverine microcosms.*

L. O'Brien provided conceptual advice and assisted with fieldwork

S. Mitrovic provided conceptual advice and reviewed manuscript

J. Hitchcock provided conceptual advice and reviewed manuscript

W. Hadwen provided conceptual advice

Table of Contents

Table of Figures

List of Tables

Abstract

The flow regime of a river plays a critical role in maintaining the health and processes within a river ecosystem. However, due to high water requirements for human needs such as agriculture, many rivers are regulated with dams and weirs. Regulation greatly reduces large flow events and in-channel flows resulting in a severe impact on the natural flow regime of a river, reducing allochthonous carbon loads otherwise mobilised during flows. Environmental flows are a key tool in mitigating the effects of regulation by reinstating a portion of the natural flow regime. However, there is still a knowledge gap between the role of these flows in mobilising allochthonous dissolved organic carbon (DOC) and the subsequent response of the lower food web.

Field monitoring on the Namoi River over 2.5 years revealed discharge was positively correlated with increases in nutrient and DOC concentrations with overbank flows mobilising very high levels of all measured nutrients. Phytoplankton and zooplankton also increased during and/or after flow events indicating flows increased food web production potentially via both heterotrophic and autotrophic production. Carbon stable isotope (^{13}C) analysis revealed allochthonous energy was supporting zooplankton communities even during small flow events which changed to autochthonous sources when the river ceased to flow.

Two manipulative studies were run using mesocosm and microcosm techniques. These studies showed pulses of DOC and dissolved organic matter (DOM) can greatly boost food web production with mixotrophic algae and zooplankton increasing significantly following terrestrial floodplain leachate additions in the mesocosm experiment. This was further seen in the phytoplankton communities of the microcosm experiment as mixotrophs and ciliates clearly increased following DOC (as glucose) +nutrient additions, making up for any autotrophic biovolume lost due to competition with bacteria.

This thesis contributes to the growing body of evidence suggesting allochthonous carbon may be an important energy source for riverine food webs. In particular, it suggests allochthonous organic matter may be considerably bioavailable and increase production via both heterotrophic and autotrophic production and greatly increase resources for higher consumers. Protecting flows that mobilise allochthonous DOM through environmental flows will be highly beneficial for riverine communities, particularly in highly regulated lowland rivers.