Freshwater inflows to estuaries: Terrestrial resource inputs and planktonic food web responses

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree or as part of the requirements for a degree. I also certify that this thesis has been written by me. Any help received throughout the research process and preparation of this thesis has been acknowledged. In, addition, I certify that all information sources and literature used are indicated in the thesis. This research was supported by the Australian Government Research Training Program.

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Place, people, and knowledge are inseparable. In listening we learn.

Preface

This thesis contains 6 chapters. Chapters 2-5 are written as self-contained journal articles in preparation for submission to peer reviewed journals. They are presented in a format similar to independent manuscripts and therefore some repetition may occur between chapters. Where these chapters do cross-reference each other relevant chapter numbers are provided. To reduce further unnecessary repetition a single reference list has been provided at the end of this thesis.

This thesis is a compilation of my own work. I conceptualised the research, obtained and processed samples, conducted data analysis and wrote the chapters contained in this thesis. While guidance, support and assistance were provided by supervisors and co-authors this thesis is written using the singular "I" rather than the plural "we". The titles of each chapter and the contributions of co-authors are listed below.

Chapter 2: Responses of estuarine zooplankton to freshwater inflows: a comparison between a regulated and unregulated estuary

Ellery B. Johnson, James N. Hitchcock, Wade L. Hadwen, Douglas P. Westhorpe and Simon M. Mitrovic

JH – conceptual advice and guidance Production Note: Signature removed prior to publication.

WH – conceptual advice and guidance Production Note: Signature removed prior to publication.

DW – conceptual advice, guidance, and field assistance Production Note: Signature removed prior to publication.

SM – conceptual advice, guidance, and field assistance Production Note: Signature removed prior to publication.

Chapter 3: Fine scale food web responses to a freshwater inflow event in a small regulated Australian estuary

Ellery B. Johnson, James N. Hitchcock, Terrence A. Rogers, Abeeha Khalil, Wade L. Hadwen, and Simon M. Mitrovic

JH – conceptual advice and guidance Production Note: Signature removed prior to publication.

TR – algal analysis and advice Production Note: Signature removed prior to publication.

AK – bacterial analysis and advice Production Note: Signature removed prior to publication.

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Chapter 4: Inflow events drive resource use changes for mesozooplankton in a regulated estuary

Ellery B. Johnson, Wade L. Hadwen, James N. Hitchcock, Jordan A. Facey, Tim Smith, Troy F. Gaston, and Simon M. Mitrovic

WH – conceptual advice, guidance, stable isotope assistance Production Note: Signature removed prior to publication.

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Chapter 5: Can zooplankton fed allochthonous carbon diets support and sustain juvenile fish?

Ellery B. Johnson, Craig A. Boys, D. Stewart Fielder, Wade L. Hadwen, Unnikrishnan Kuzhiumparambil, James N. Hitchcock, and Simon M. Mitrovic

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WH – conceptual advice, guidance, and stable isotope assistance Production Note: Signature removed prior to publication.

UK – essential fatty acid analysis and advice Production Note: Signature removed prior to publication.

JH – conceptual advice and guidance Production Note: Signature removed prior to publication.

SM – conceptual advice and guidance Production Note: Signature removed prior to publication.

Other papers and reports published during my candidature but not forming part of this thesis:

Hammill, E., Johnson, E., Atwood, T.B., Harianto, J., Hinchliffe, C., Calosi, P. and Byrne, M., 2018. Ocean acidification alters zooplankton communities and increases top-down pressure of a cubozoan predator. *Global Change Biology*, *24* (1), p. e128-e138.

O'Brien, L., Johnson, E., Balzer, M., Rogers, T., Michie, L., Hitchcock, J., Hadwen, W., Westhorpe, D., Mitrovic S., 2020. Carbon and nutrient transport, food webs and the effectiveness of high flow protection and end-of-system flow rules; An assessment of the current flow rules on the Gwydir, Macquarie, Williams and Wyong Rivers, NSW, Report to NSW DPIE. May 2020

Roberts, L., Kutay, C., Melbourne-Thomas, J., Petrou, K., Benson, T.M., Fiore, D., Fletcher, P., Johnson, E., Silk, M., Taberner, S. and Filgueira, V.V., 2021. Enabling enduring evidence-based policy for the Southern Ocean through cultural arts practices. *Frontiers in Ecology and Evolution*, *9*, p. 284

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List of Abbreviations

DOC	Dissolved organic carbon
FRP	Filtered reactive phosphorous
FWI	Freshwater inflow
OM	Organic Matter
NO_x	Nitrates and nitrites
NSW	New South Wales
Q30	30-day antecedent discharge
Q60	60-day antecedent discharge
tDOM	Terrestrial dissolved organic matter
tOM	Terrestrial organic matter
WSP	Water sharing plans

Ethics Statement

A study within this thesis involved the use of animals (Chapter 5). This research was approved by the University of Technology Sydney Animal Care and Ethics Committee under permit ETH19-3895. The research was conducted in accordance with the Australian Code for the Care and Use of Animals for Scientific Purposes (8th Edition 2013), the NSW Animal Research Act (1985) and Regulations (2010).

Abstract

Freshwater inflows are crucial to estuarine processes, regulating habitats and delivering important resources. However, river regulation has substantially reduced freshwater inflows to estuaries, affecting them negatively. This thesis aimed to enhance understanding of 1) how estuarine planktonic food webs responded to inflows in a regulated estuary; and 2) the importance of terrestrial carbon resources to estuarine food webs. These are important questions in estuarine flow-ecology and water resource management. To achieve this a suite of monitoring and manipulative studies were carried out in the Williams and Manning River estuaries.

A 4.5-year monitoring study comparing the unregulated Manning with the regulated Williams demonstrated the potential impacts of river regulation with results from the Williams contrasting strongly with the Manning. The Williams estuary was characterised by high concentrations of DOC and nutrient, regardless of flow conditions, with zooplankton communities consistently dominated by copepod nauplii, displaying no seasonal trends and responding positively to inflows and inputs of terrestrial DOC. Fine-scale monitoring of an inflow on the Williams estuary showed the importance of inflows in delivering terrestrial carbon and phosphorus resources and in stimulating bacterial and algal productivity. However, this did not translate to increased zooplankton production, relative to pre-flow periods.

Strong evidence was found for the importance of terrestrial carbon resources delivered to estuarine food webs by inflows. Analysis of zooplankton stable isotopes across a variable flow period showed that terrestrial carbon resources were being utilised by zooplankton following inflows, suggesting its importance in upper estuarine areas. Experimental results also indicated that terrestrial carbon in mesozooplankton food webs could contribute to the growth of juvenile fish of an endemic estuarine species. Together these results highlighted the importance and role of terrestrial carbon in estuarine food webs and productivity.

Individually my studies contribute new knowledge to important ecological and management questions in estuaries. Combined as a thesis they provide strong evidence for the importance of FWIs to estuaries and their food webs, highlighting the importance of terrestrial carbon as an energetic resource and contributor to estuarine productivity. This knowledge contributes to the wider literature recognising the importance of freshwater inflows to estuaries and supports their protection.