The ecology and evolution of invasive *Potamopyrgus antipodarum* in Australia

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Abstract

The spread of invasive organisms is one of the greatest threats to ecosystems and biodiversity worldwide. Understanding the evolutionary and ecological factors responsible for the transport, introduction, establishment and spread of invasive species will assist the development of control strategies.

The New Zealand mudsnail, *Potamopyrgus antipodarum* (Gray 1843) (Gastropoda: Hydrobiidae), is a global freshwater invader, with populations established in Europe, Asia, the Americas and Australia. While sexual and asexual *P. antipodarum* coexist in the native range, invasive populations reproduce by parthenogenesis, producing dense populations that compete for resources with native species. *Potamopyrgus antipodarum* is a natural model system for the study of evolutionary and ecological processes underlying invasion.

This thesis assesses the invasion history, genetic diversity and ecology of *P. antipodarum* in Australia, with particular focus on: a) potential source populations, b) distribution and structure of populations, and c) species traits related to the establishment, persistence and spread of invasive *P. antipodarum*. Genetic analyses were carried out on specimens collected for this study from New Zealand and Australia, along with existing museum samples. In combination with published data, the analyses revealed low genetic diversity among and within invasive populations in south-eastern Australia, relative to New Zealand populations. Phylogenetic relationships inferred from mitochondrial sequences indicated that the Australian populations belong to clades dominated by parthenogenetic haplotypes that are known to be present in Europe and

the US. These 'invasive clades' are likely to originate from the North Island of New Zealand, and suggest a role for selection in determining genetic composition of invasive populations.

The genotypic diversity of Australian *P. antipodarum* was low, with few, closely related clones distributed across south-eastern Australia. The pattern of clone distribution was not consistent with any assessed geographical or abiotic factors; instead a few, widely-distributed clones were present in high frequencies at most sites. Differences in clone frequencies were found, which may indicate differential success of clonal lineages.

A range of traits have been proposed as facilitators of invasion success, and within-species variation in these traits can promote differential success of genotypes. Using laboratory-based experiments, the performance of the three most common Australian clones was tested across a suite of invasion-relevant traits. Ecologically-relevant variation in traits was found among the clones. These differences may have determined the spatial distribution of clones, and may continue to do so into the future.

This thesis found that the *P. antipodarum* invasion of Australia is the result of few introductions of a small number of globally-invasive genotypes that vary in ecologically-relevant traits. From a source of considerable genetic diversity in the native range, very few genotypes have become invasive. Those that are invasive appear to be very successful at continental scales. These findings highlight a capacity in asexual invaders to successfully invade, and potentially adapt to, a broad range of ecosystems. The *P. antipodarum* invasion system is amenable to research using combinations of field-based studies, molecular and laboratory approaches, and is likely to yield significant, broadly-applicable insights into invasion.

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In the early stages of my PhD I spent considerable time examining the Hydrobiid specimens at the Museum Victoria and the Environment Protection Authority Victoria, I thank these institutions and their staff for accommodating me. Samples collected during my fieldwork were supplemented by contributions from the EPA and from Toni Furlonge, to whom I am very grateful. Many thanks to Dr. Dorota Paczesniak for generously contributing her data and expertise over numerous (doubtless inconvenient!) Skype calls.

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This thesis would not be possible without everyone mentioned above. My thanks again to all who have supported me, and in so doing endured my punny sense of humour. Hopefully it is some consolation that we have done our little bit to prevent *P. antipodarum* becoming simply another snail in the coffin of biodiversity.

Foreword

This thesis represents work carried out under the supervision of Professor Ross Thompson, Professor Paul Sunnucks and Associate Professor Dianne Gleeson. The thesis is composed of a series of connected but independent units, each of which is intended for publication. Each chapter is written as a separate entity, with a full complement of the sections required by a manuscript and there may be some overlap of material among chapters. Some chapters have used data published in previous studies and the authors contributing these data are acknowledged in-text. When such chapters come to be submitted as papers for publication, these collaborators will be recognised as co-authors, and are identified as such below.

Chapter 1. *General introduction*. This chapter provides a background on asexual reproduction in invasion and a summary of existing knowledge of the ecology of the clonal invader, *Potamopyrgus antipodarum*. It will be combined with components of my general discussion to be submitted as a co-authored paper with my supervisors.

Chapter 2. *Reconstructing the invasion history of Potamopyrgus antipodarum in Australia.* This chapter uses genetic markers to explore the global movement of *P. antipodarum* and infer potential source populations. This chapter will be submitted as a paper co-authored with Dr. Maurine Neiman (University of Iowa), Dr. Dorota Paczesniak (Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)), and my supervisors.

Chapter 3. *The distribution of invasive clones of Potamopyrgus antipodarum in south-eastern Australia.* This chapter identifies the distribution patterns of different *P. antipodarum* genotypes across south-eastern Australia. This chapter will be submitted as a paper co-authored with Dr. Maurine Neiman (University of Iowa), Dr. Dorota Paczesniak (IPK), and my supervisors.

Chapter 4. *Differential performance among genotypes in a clonal invader.* This chapter compares the performance of three *P. antipodarum* genotypes across a suite of invasion-relevant traits. This chapter will be submitted as a paper co-authored with my supervisors.

Chapter 5. *General discussion*. This chapter provides an overview and synthesis of my findings, and proposes future research directions.

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