PLANT LIFE HISTORY AND THE NATURALISATION TO INVASION PATHWAY

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DECLARATION

This is to certify that:

(i) 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.

(ii) I also certify that the thesis has been written by me.

(iii) Any help that I have received in my research work and the preparation of the thesis itself has been duly acknowledged.

(iv) In addition, I certify that all information sources and literature used are indicated in the thesis.

……………………………………… Megan L. Phillips

Thesis Abstract

Exotic plant species that become widespread and abundant in their new ranges are a worldwide environmental problem. Such invasive plant species are responsible for a growing number of ecological problems including biodiversity loss, disruptions in ecosystem function and species extinctions. Many exotic plant species introduced to new regions become naturalised, but only a small subset of these species transition from naturalisation to invasion. An important goal of invasion ecology is the identification of plant traits that enable exotic plant species to become invasive within their new ranges. The identification of such traits provides a better understanding of factors contributing to invasion success and contributes to the effective management of invasive plants. In Australia, exotic plant invasion is recognized as a serious and growing threat to native biodiversity. Yet, despite the recognition of the impacts of invasive exotic plant species, there is a paucity of information about the factors contributing to their success in Australia. Thus, identifying plant traits that promote the invasion success of exotic plant species in Australia is a research and management imperative.

This research thesis examined relationships between exotic plant species invasiveness and a range of plant life-history traits through the use of a continental-scale, target-area comparative approach. I compared plant traits between invasive and non-invasive species across multiple plant life-history stages, from seed traits in the seed bank to germination characteristics, seedling emergence and growth traits, as well as the attributes of mature plants. I first constructed a database of 468 naturalised exotic plant species in Australia, with data for four plant introduction traits. I found that residence time (the length of time an exotic plant species has been present in the introduced range) was a consistent predictor of invasion success, as was growth form with the introduction of vines significantly more likely to be linked with invasiveness within Australia. Continental origin was correlated with invasiveness, with invasive species in Australia significantly more likely to originate from North America or South America and less likely to originate from Europe or Australasia. There was no clear indication that exotic species introduced accidentally, as ornamentals or for agricultural purposes were significantly more likely to become invasive.

I then designed a novel species selection framework to closely examine life-history trait differences between invasive and non-invasive naturalised plant species.

Critical to this framework was the need to control for potentially confounding factors that might result in either the emergence of spurious life-history correlates of invasiveness or an inability to find important life-history trait relationships with invasiveness. The species selection framework controlled for the introduction traits residence time, growth form and continental origin, all found to be important correlates of invasiveness in my previous analysis, as well as geographic co-occurrence and range size differences. In the case of the latter two, it was essential to ensure that comparisons between invasive and non-invasive species involved pairs of species that occurred in the same habitats and to ensure that invasive species were substantially more widespread geographically than non-invasive species. Importantly, the framework used information about phylogenetic relationships to provide phylogenetically independent contrasts of life-history traits between invasive and non-invasive species. This species selection framework provided the foundation of all my database and experimental studies in the rest of this thesis.

Using the framework, I conducted an empirical desk-top study to analyse life-history trait relationships with species invasiveness using a complementary cross-species and phylogenetically-independent contrasts approach. The cross-species approach examined trait relationships with invasiveness without explicitly considering the phylogenetic relatedness of the study species. The contrasts approach complemented the cross-species approach by using phylogenetic information to examine patterns of correlated evolutionary divergences between life-history traits and invasiveness. Life-history traits examined in this study included seed mass, leaf size, maximum canopy height, number of dispersal mechanisms and types of dispersal mechanisms used by each species. This study detected two life-history traits linked significantly to invasiveness within the naturalised flora of Australia: an increased number of plant dispersal mechanisms and the use of water as a dispersal mechanism. Both of these traits are intimately connected with a species' capacity to spread across a landscape, which implies enhanced dispersal may be promoting exotic species invasiveness in Australia.

Using a subset of plant species from the desk-top dataset, I performed three separate experiments. In the first experiment, I found evidence on a local scale that the survival of seeds of invasive species in the soil seed bank was significantly higher than seed survival in non-invasive species (in six out of seven congeneric contrasts). I also found that the application of a fungicide treatment led to a larger increase in seed survival in the non-invasive compared with the invasive species, suggesting that poorer seed survival in the non-invasive species could be attributed to seed-deteriorating soil-borne pathogenic fungi present in the new range. In the second experiment, I compared a range of seed germination characteristics between invasive and non-invasive species. I found that the seeds of invasive species germinated significantly more rapidly (in five out of seven contrasts), but were also more likely to exhibit a 'bet-hedging' strategy by staggering seed germination over a longer period of time (in four out of seven contrasts), as well as retaining a higher proportion of dormant but viable seeds after a germination-triggering event occurred (in five out of seven contrasts). In the third experiment, I compared seedling traits between invasive and non-invasive plant species using four congeneric pairs to determine whether there were any consistent trait correlations with species invasiveness. The study explored five seedling traits including time to seedling emergence from the soil, seedling height, leaf production, specific leaf area and biomass. I found evidence that some invasive species differed from non-invasives during the seedling stage, but I found no consistent seedling trait explicitly linked to species invasiveness.

The work presented in this thesis contributes to the quest to identify plant traits facilitating the naturalisation to invasion transition. This thesis used a comparative approach to successfully link exotic plant species invasiveness within the introduced range to plant introduction and life-history traits across a range of plant life stages. The approach and findings of this thesis were built on an important historical and growing body of work examining plant species invasiveness. Given the relative paucity of work specifically focusing on the shift from naturalisation to invasion, this thesis provides information crucial for our understanding and management of the global problem of biological invasions.

Acknowledgements

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Preface

All research presented here was completed for my PhD thesis.

A version of Chapter 2 has been published in the journal *Austral Ecology*.

A version of Chapter 4 has been published in the journal *Evolutionary Ecology Research*.

A version of Chapter 7 has been published in the journal *Preslia*.

Versions of Chapters 3 and 4 have been presented as posters at the Ecological Society of Australia's annual national conference in 2010 and 2011 respectively.

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