Molecular phylogeography and climate change biology of the invasive green marine macroalgae Caulerpa taxifolia and Caulerpa cylindracea in Australia

Submitted by
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Thesis Summary

Populations of the green marine macroalgae *Caulerpa taxifolia* and *Caulerpa cylindracea* have invaded and spread throughout Mediterranean after they were introduced from Australia. In Australia, these tropical to subtropical species have established invasive populations in New South Wales, South Australia, and most recently, for *C. cylindracea,* in Victoria.

Significant efforts have been made to elucidate the invasion history and geographic source locations of Mediterranean populations. The same effort has been lacking in Australia. Both species have provided challenges for molecular ecologists because of their predominantly clonal reproduction and low genetic variation within invasive populations in the case of *C. taxifolia*, and very high intra-individual genetic variation in *C. cylindracea*.

In chapter 2, I present a detailed review of the literature about the molecular ecology of *C. taxifolia* and *C. cylindracea*. I outline the phylogenetic and phylogeographic research on both of these species. The methodology and analysis of each study is critiqued. From this analysis I identify the knowledge gaps about invasive *Caulerpa* spp., and how to approach further research given advances in technology and knowledge of the organisms.

In chapter 3, I present a modified Ion Torrent next generation sequencing protocol that was used to identify novel single nucleotide polymorphisms (SNPs) in *C. taxifolia*. This approach resulted in the successful identification of a suite of SNPs. Primer development and SNP validation was performed for the Sequenom MassArray, and 184 specimens from 10 Australian populations from Queensland, New South Wales, South Australia, and Western Australia, were genotyped. The data build on existing phylogeographic data for *C. taxifolia* in Australia, and support a model of anthropogenic distribution rather than natural dispersal. Anthropogenically mediated primary introductions may have been caused by aquarium releases, while secondary spread has been facilitated by heavy boat traffic in affected areas. Finally I discuss the evidence of the so called “invasive strain” of *C. taxifolia*, and conclude that there is no such thing, and that

the assumption that an “invasive strain” exists has undermined the scientific objectivity of 30 years of study of invasive *Caulerpa* species.

Chapter 4 represents the first phylogeographic study of invasive and native *C. cylindracea* populations in Australia. In this chapter I used variation in the *rpl*16-*rps*3 region of the chloroplast to test hypotheses about the origins and dispersal mechanisms responsible for the establishment of invasive populations of *C. cylindracea* in South Australia. Molecular data does not support natural dispersal of *C. cylindracea*, a finding that is supported by a lack of species records of *C. cylindracea* for 2600 km between southern Western Australia and the SouthAustralia.

In chapter 5, I determined if RNA:DNA, Protein:DNA, and Protein:RNA ratios can be used to quantify the effect of ocean warming and acidification on *C. taxifolia* and *C. trifaria*. Protein profiles were also examined for effects of ocean warming and acidification. While no significant effects were observed on the ratios, concentrations of DNA were positively affected by temperature, while negative impacts on protein were associated with decreasing pH. The protein profiles also allowed me to determine if the invasive tropical and subtropical *C. taxifolia* is likely to be impacted differently by ocean warming and acidification than the native temperate *C. trifaria*. Protein profile data revealed that *C. trifaria* specimens experience greater levels of metabolic stress than *C. taxifolia* at lower pH, and that the invasive *C. taxifolia* will continue to thrive in warmer and more acidic ocean conditions while the native temperate species will be impacted negatively, possibly resulting in localized extinctions.

In chapter 6, I discuss how new techniques and their application aid in understanding the phylogeogaphy of invasive *Caulerpa* spp. in Australia, paving the way for continued phylogeographic analyses of these problematic species. I have also shown that the response of native and invasive *Caulerpa* spp. to climate change scenarios indicates that invasive populations of *Caulerpa* may become more abundant and continue to expand their invasive range in the

future. I also identify the limitations of this body of work and the issues encountered in the program of research, and discuss future research possibilities for invasive *Caulerpa* species.

Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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