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Advancing systematic conservation planning for freshwater ecosystems

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To Chuck

Thank you for guiding me to this opportunity.
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Abstract

Freshwater ecosystems and their associated biota are among the most endangered in the world. Key disturbances, such as water extraction, dams, and modifications to riparian and in-stream habitats, invasive species, and impacts on water quality have heavily altered these ecosystems. Escalating human pressure on, and disturbances to, water resources requires well-informed decision making and effective on-ground management to conserve and restore freshwater ecosystems. Systematic conservation planning offers the tools needed to address these issues, providing a strategic and scientifically defensible framework. Systematic conservation planning was pioneered in the terrestrial realm and has, with time, become the most commonly recommended approach to marine planning and management because it can ensure the selection of multiple protected areas that together achieve explicit objectives. However, in comparison to the terrestrial and marine realms, the adoption of systematic methods to inform decision making for the protection and/or restoration of freshwater ecosystems remains in its infancy. The principal focus of this thesis is on spatial conservation prioritisation applied to both protected area and off-reserve management decision making. It focuses on two areas in the field of freshwater systematic conservation planning that have been identified as research priorities: 1) assessing the sensitivity of conservation planning outcomes to different surrogates and objectives; and 2) enhancing applicability of systematic conservation planning to inform on-ground management decisions.

The aim of this thesis is to advance the scientific basis and application of systematic conservation planning for fresh waters. I address key questions in the field of systematic conservation planning in freshwater ecosystems, which are both novel contributions to the field and influential in informing conservation decisions both on and off-reserves, using the Wet Tropics of Queensland bioregion as a case study. My objectives were to 1) determine the occurrence of disturbances, and the incidental protection of fresh waters in terrestrial protected areas; 2) identify the effectiveness of using coarse-filter surrogates for representing freshwater fish diversity in systematic conservation planning; 3) develop methods to evaluate the effectiveness of invasive species management; and 4) integrate management costs into systematic conservation planning for invasive species.
There is a need for assessments that quantify the effectiveness of terrestrial protected areas for representing freshwater ecosystems and their dependent species, and that determine areas of vulnerability from human-induced disturbances. In Chapter 3, I used data on the spatial distribution of freshwater ecosystems and fish, human-induced disturbances, and the Wet Tropics protected area network to assess how well freshwater ecosystems and fish species are protected within this network. I identified human-induced disturbances likely to influence the effectiveness of freshwater protection measures and I evaluated the vulnerability of these ecosystems to human-induced disturbances within and outside protected areas. The representation of freshwater ecosystems and species in the protected areas of the Wet Tropics is poor: 83% of streams, 75% of wetland types, and 89% of fish species have less than 20% of their total lengths and areas in IUCN category II protected areas. Higher-order streams and their associated wetlands are influenced by the greatest number of human-induced disturbances and are also the least protected. My results indicate poor representation of freshwater ecosystems and fish species in protected areas, and high numbers of human-induced disturbances impacting on these systems both within and outside of protected areas despite the high level of protection of terrestrial areas in the Wet Tropics. My findings demonstrate the need for greater consideration of protection status and off-reserve management of freshwater systems.

Abiotic and biologically informed classifications are often used in conservation planning as coarse-filter surrogates for species. The relationship between these surrogates and the distribution of species is commonly assumed, but rarely assessed by planners. In Chapter 4, I derived four abiotic and eight biologically informed classifications of stream reaches to serve as surrogates for biodiversity patterns in the Wet Tropics. I used stream reaches as planning units and, as conservation targets for each surrogate, I used two percentages – 10% and 30% – of the total number of stream reaches occupied by each class. I then derived minimum sets of planning units to meet targets for each surrogate and tested the effectiveness of the surrogates by calculating the average achievement of the same targets for predicted distributions of 28 fish species. My results showed that neither abiotic nor biologically informed classifications were good at representing freshwater fish species; in fact none of the surrogates led to average representation of species better than randomly selected planning units. There were two main reasons for this poor performance. First, none of the surrogates had high classification strength or informativeness about compositional change in fish species within the study region. Second, frequency distributions of probabilities of occurrence for
most fish species were strongly right-skewed, with few stream reaches having high probabilities. Combined, these results meant that selection of stream reaches to achieve surrogate targets were effectively random with respect to probabilities of fish species occurrence, leading to poor representation of fish species.

Often ecologists and natural resource managers can easily access data on invasive species occurrence across a region. Yet, collecting species abundance data over a large area is arguably more important for decision making, but inherently costly, so methods which can provide robust information at low-cost are particularly valuable. In Chapter 5, I tested the relationship of environmental suitability with local abundance of an aquatic invasive species, olive hymenachne (*Hymenachne amplexicaulis*) in the Wet Tropics. Least squares and quantile regressions revealed a positive relationship between environmental suitability and local abundance of olive hymenachne. I used the relationship between environmental suitability and local abundance to quantify the effectiveness of management (reduction in local abundance) under four different management investments. I showed that the upper limit of abundance can be used to evaluate management effectiveness based on varying investments, and that ongoing management is the most effective at reducing local abundance.

The successful management and eradication of invasive species is often constrained by insufficient or inconsistent funding. Consequently, managers are usually forced to select a subset of infested areas to manage. In Chapter 6, I present a spatially explicit decision method that can be used to identify actions to manage invasive species while minimizing costs and the likelihood of reinvasion. I apply the method to a real-world management scenario, aimed at managing an invasive aquatic macrophyte, olive hymenachne (*Hymenachne amplexicaulis*).

The approaches I developed in this thesis allowed me to overcome several challenges related to the conservation and management of fresh waters, advancing the field of freshwater systematic conservation planning by: 1) quantifying conservation gaps for fresh waters, 2) identifying the effectiveness of surrogate methods and invasive species management investments, and 3) advancing the application of systematic approaches to address resource allocation questions for invasive species management. I was able to achieve these outcomes by integrating systematic approaches and spatial models of native and invasive species distributions. The results of my work can be used to inform conservation decision makers...
about the limitations of 1) protection afforded to fresh waters and their dependent species and 2) surrogates for representing freshwater biodiversity in regional scale conservation plans. Further, using the method I developed for monitoring the effectiveness of invasive species management, and implementing actions at the sites that I identified as priorities for weed management, would provide more cost-effective solutions to managers in the region.
Table of Contents

List of Tables 11

List of Figures 13

Publications 17

Chapter 1 Introduction 20

Chapter 2 The Wet Tropics study area 35

Chapter 3 Fresh waters and fish diversity: distribution, protection and disturbance in tropical Australia 38

Chapter 4 Coarse-filter surrogates do not represent freshwater fish diversity at a regional scale in Queensland, Australia 60

Chapter 5 Effective control of an invasive aquatic species in tropical Australia 85

Chapter 6 A systematic approach for prioritizing multiple management actions for invasive species 101

Chapter 7 General discussion 122

Literature cited 137

Appendix A Chapter 3 supporting tables and figures 157

Appendix B Chapter 4 supporting table 161

Appendix C Characterizing surface model error and associated costs 163
List of Tables

Table 3.1  Environmental variables, human-induced disturbances and their attributed features used for fish species distribution modelling. 44

Table 3.2  The total stream reach length (km) and wetland area (km$^2$) protected in IUCN protected area management categories (IUCN category) and the State of Queensland’s protected area classification in the Wet Tropics. 50

Table 4.1  Environmental variables considered for species distribution modelling and derivation of coarse-filter surrogates. Also shown are attributed stream or catchment features. 66

Table 4.2  Environmental variables used to define classes of planning units with Discriminant Function Analysis and naïve Bayesian classification. 69

Table 4.3  Pearson’s correlation coefficients of selection frequencies based on selection of surrogates and species models, a) using a 10% surrogate target and b) using a 30% surrogate target. Numbers after classification and MARS methods indicate numbers of classes. MARS refers to species distribution models. 77

Table 5.1  Environmental descriptors and proxies of propagule pressure used to predict environmental suitability for olive hymenachne (Hymenachne amplexicaulis) using Maxent (Phillips et al. 2006). Also shown are the spatial data sources where the environmental descriptors and proxies for propagule pressure were derived. 91

Table 6.1  Variable descriptions for Equations 1 and 4. 111

Table 6.2  Descriptions of management scenarios and parameters. 114
Table S3.1  Wetland type and conservation status definitions from Queensland Department of Environmental Resource Management (DERM 2009).

Table S3.2  The Area Under the Receiver Operator Characteristic curve (AUC) for distribution models established for 45 freshwater fish species. * = species endemic to the Wet Tropics.

Table S4.1  The Area Under the Receiver Operator Characteristic curve (AUC) for distribution models established for 28 freshwater fish species.
List of Figures

**Figure 1.1** Conceptualization of the data and stages considered in a systematic conservation plan. Boxes with a black outline are data considerations, and boxes with a light grey outline are measures that can be considered for each component in systematic conservation planning (assets, spatial dependencies, management actions and constraints and opportunities).

**Figure 2.1** Map of the Wet Tropics study area in north-eastern Queensland, Australia.

**Figure 3.1** The Wet Tropics study area in north Queensland, Australia, showing the spatial distribution of: a) wetland types; b) stream reaches and sites sampled for fish; c) IUCN protected area categories; d) land uses and e) aquatic invasive species.

**Figure 3.2** Statistics for stream reaches, sub-catchments and wetlands in the Wet Tropics. The total: a) length (grey bars) and area (black bars) of each Strahler stream order and adjacent sub-catchment; b) area of each wetland type; c) area of the four wetland types in adjacent sub-catchments for each Strahler stream order; d) length of each Strahler stream order, with IUCN categories indicated; and e) area of each wetland type represented within IUCN categories II, III and VI.

**Figure 3.3** The percent representation of: a) sub-catchment area adjacent to streams in Strahler stream orders 1-6; b) wetland types; and c) each fish species distribution occurring completely within an IUCN category II protected area. * = species that are endemic to the Wet Tropics. The dashed lines indicate 20% representation.

**Figure 3.4** The percent of sub-catchment area adjacent to each Strahler stream order 1-6 (listed from bottom to top bars) that is: a) protected area;
unprotected remnant native vegetation; low disturbance; localized disturbances (mining, industry) which occupy a small proportion of the landscape (< 1%); urban/residential; grazing; intensive agriculture/horticulture; or b) is covered with an invasive macrophyte: olive hymenachne (*Hymenachne amplexicaulis*), pond apple (*Annona glabra*) and/or salvinia (*Salvinia molesta*).

**Figure 3.5** The percent of: a) sub-catchments adjacent to Strahler stream orders 1-6; b) sub-catchments supporting each of the four wetland types; and c) sub-catchments adjacent to each Strahler stream order 1-6 that support at least 10 fish species and that have 0, 1, 2, 3 or 4 human-induced disturbances present.

**Figure 3.6** The distribution and prevalence of human-induced disturbances upstream of protected areas by: a) the number of stream reaches with 0, 1, 2, 3 or 4 human-induced disturbances; b) the total stream length (grey bars) and sub-catchment area (black bars) with one or more human-induced disturbance; and c) the number of sub-catchments with one or more human-induced disturbance.

**Figure 4.1** Classification of coarse-filter surrogates used in this study (no attempt has been made to subdivide species surrogates). Shaded boxes indicate the two types of coarse-filter surrogates compared here.

**Figure 4.2** The inset shows an expanded view of part of the Russell catchment, stream reaches (planning units) are light grey and stream reach sub-catchments are darker grey.

**Figure 4.3** Frequency distributions of predicted probabilities of occurrence for the 28 fish species.

**Figure 4.4** Summed probabilities of predicted occurrence for the 28 fish species. For clarity, values are mapped for sub-catchments adjacent to each
of the 7,210 stream reaches. The maximum summed probability was 16 (shaded black).

**Figure 4.5** Plots of representation of the 28 fish species as percentages of total predicted occurrences for each of the 12 surrogates and two target levels: a) 10% and b) 30%. Each of the species is represented by a black dot. Average representations across species are shown with open circles. None of the average representations were significantly higher than the corresponding value from 4999 randomly generated solutions, based on the 95% confidence interval.

**Figure 4.6** Spatial distribution of absolute differences in planning unit selection frequency for 30% targets applied to the naïve Bayesian classification (8 classes) and 30% targets applied to the 28 modelled species distributions. For clarity, values are mapped for sub-catchments adjacent to each of the 7,210 stream reaches.

**Figure 4.7** Histograms of planning unit selection frequencies based on: a) naïve Bayesian classification (8 classes) and b) MARS predicted species distributions. Targets were 30% for both. Labels for bars are upper values of the categories and represent the number of times (out of 100 restarts) that planning units were selected.

**Figure 5.1** a) Location of the study area; b) Wet Tropics showing the distribution of environmental suitability, as determined by Maxent (Phillips et al. 2006), for olive hymenachne (*Hymenachne amplexicaulis*). The white boxes highlight areas of interest where environmental suitability for olive hymenachne is variable; and c) Tully-Murray (upper) and Herbert (lower) catchments with thresholds of environmental suitability, represented within individual stream reaches and wetlands: low (0 – 0.07), moderate (0.10 – 0.44) and high (0.44 – 0.76), for olive hymenachne (*Hymenachne amplexicaulis*).
**Figure 5.2** a) Relationship between predicted environmental suitability (X-axis) and olive hymenachne (*Hymenachne amplexicaulis*) local abundance (Y-axis) as a proportion of total stream or wetland area (ha) depicted for two percentiles (‘tau’), ordinary least squares (OLS – solid line) regression and the 95th percentile (dashed line) based on linear quantile regression, which represents the upper limit of local abundance; symbols represent amount of time managed; and b) relationship between management investment (X-axis) and the reduction in local olive hymenachne abundance as a proportion of the upper limit of abundance (±standard error), represented here by the 95th percentile (Y-axis).

**Figure 6.1** Location of the Tully-Murray study area in north-eastern Queensland, Australia. Across the 1353 planning units, values of zero indicate that olive hymenachne (*Hymenachne amplexicaulis*) is not predicted to be present. Areas mapped with a value of 1 are those where the species currently occurs or is predicted to occur by the Maxent model. Presence is defined by a threshold probability of occurrence, $P \geq 0.30$.

**Figure 6.2** Solutions for five management scenarios established to prioritize management actions aimed at reducing olive hymenachne (*Hymenachne amplexicaulis*) in the Tully-Murray study area. Each scenario is presented sequentially from one a) to five e). Areas not selected were not part of the prioritization solution.

**Figure S3.1** Distribution of a) Strahler stream orders 1-6 and b) fish species richness by stream reach ($n = 7210$), based on modelled distributions for 45 fish species.
Publications produced during my PhD Candidature

*indicates those publications that are derived wholly or in part from this thesis

**Peer-reviewed literature**


**Reports**

*Januchowski, S. R.* and Visconti, P. 2009. Identifying on-ground management priorities for the control of hymenachne (*Hymenachne amplexicaulis*): A pilot study with Cassowary Coast Regional Council, Tully, Queensland, Australia

**Peer-reviewed conference proceedings**


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