REEF FISHES ON ISOLATED ISLANDS:

COMMUNITY STRUCTURE, ENDEMISM AND

EXTINCTION

PhD thesis submitted by

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DECLARATION ON ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human (*1999*),* the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number A976), Parks Australia North, and the Western Australia Department of Fisheries.

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STATEMENT ON THE CONTRIBUTIONS OF OTHERS

The chapters of this thesis are also manuscripts that have been published, submitted or are in preparation for submission. Several researchers have made contributions to these manuscripts and it is necessary to recognise their contributions.

Chapter 2 is a manuscript currently in review at Journal of Biogeography and is co-authored by G.P. Jones, P.L. Munday, S.R. Connolly and M. Srinivasan. Field data for this manuscript came from surveys performed by GPJ, PLM and MS. The construction, description and implementation of the null model analyses in this manuscript were done by SRC. G.R. Allen kindly provided the Indonesia species list used in the analyses. All authors provided intellectual input into this manuscript.

Chapter 3 is now published as: Hobbs, J-P.A., Frisch A.J., Allen, G.R., and van Herwerden, L. (2009) Marine hybrid hotspot at Indo-Pacific biogeographic border. *Biology Letters* 5:258-261. For this publication, AJF provided funding and helped design the study. GRA provided information on hybrids from previous field surveys and LvH provided molecular data. All authors provided intellectual input.

Chapter 4 involves regression tree analysis, which I learnt through the assistance of Maya Srinivasan. This manuscript is being prepared for journal submission and GPJ, PLM and MS have provided comments.

Chapter 5 has been published as: Hobbs, J-P.A., Jones, G.P. and Munday P.L. (2010) Rarity and extinction risk in coral reef angelfishes on isolated islands: interrelationships among abundance, geographic range size and specialization. *Coral Reefs* 29:1-11. All authors provided intellectual input.

Chapter 6 is a molecular study and the manuscript is nearing submission. Adrian McMahon and Stephen Kolomyjec were employed to do some laboratory work and obtain DNA sequences for some of the samples used in this study. Comments have been provided by D. Jerry, LvH, GPJ and PLM.

I was supported by an Australian Postgraduate Award Scholarship and a Nancy Vernon Rankine write-up award from James Cook University (JCU). Funding for this study came from a JCU Competitive Research Incentive Grant to GPJ, PLM and DJ and an Envirofund Australia Natural Heritage Trust grant to J-PAH. Significant in-kind and logistical support was provided by Parks Australia. Fieldwork assistance was provided by J. Gilligan, J. Hender, J. Neilson and C. McDonald.

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ABSTRACT

Ecology strives to identify the processes determining species diversity, species composition and population abundance. Island communities have served as the natural laboratories for the development and testing of ecological theories. Islands also provide the opportunity to determine whether there are differences in the ecological processes that structure mainland and isolated communities. To date, most of the theory and empirical studies of island communities have focused on terrestrial organisms. However, islands can be equally instructive about the mechanisms favouring the presence, absence and abundance of marine species. Therefore, the aim of this thesis is to determine whether the processes structuring terrestrial island communities apply in the marine environment. Ecological hypotheses spanning the fields of biogeography through to conservation biology are tested using reef fish communities at the remote Christmas Island and the Cocos (Keeling) Islands in the tropical eastern Indian Ocean.

Like small isolated terrestrial communities, the reef fish communities at Christmas and Cocos Islands were found to be species poor and contained a distinct taxonomic composition with an over-representation of species with high dispersal potential. Despite low species richness, there was no evidence of density compensation, with population densities on the islands similar to species-rich neighbouring mainland assemblages. In contrast to terrestrial communities, species at the edge of their range did not have lower abundance than species at the centre of their range, and endemic species had substantially higher abundance than widespread species. Overall, the observed patterns conform to predictions from terrestrial ecological hypotheses, indicating that similar processes are important in determining species richness and community

composition in marine and terrestrial communities on isolated islands. However, observed patterns in abundance did not conform to expectations from terrestrial theory, and this appears to be due to the different life histories of marine and terrestrial species.

Local environmental factors can also be important in structuring reef fish communities; however, few studies have examined their role on oceanic reefs. Regression tree analysis of angelfish and butterflyfish communities revealed that large physical gradients (island location, exposure, depth, habitat complexity) are more important than small-scale biotic factors (live coral cover, algal cover and habitat diversity) in determining the community structure of reef fishes at these oceanic islands.

Christmas and Cocos Islands are also situated on the Indo-Pacific biogeographic border, and in the terrestrial environment, biogeographic borders represent important areas for hybridisation. Eleven hybrid coral-reef fishes (across six families) were identified at the islands: the most recorded hybrids of any marine location. In most cases, at least one of the parent species is rare (< 3 individuals per 3000 m^2), suggesting that hybridisation has occurred due to a scarcity of conspecific partners. The Islands also represent a marine suture zone because many of the hybrids have arisen through interbreeding between Indian and Pacific Ocean species. For these species, it appears that past climate changes allowed species to diverge in allopatry, while recent conditions have facilitated contact and subsequent hybridisation at this biogeographic border.

Isolated islands often contain a high proportion of endemic species, which suffer high rates of extinction because of an association among three traits that threaten species persistence: small geographic range size, low abundance and ecological specialisation. This study found that endemic angelfishes at Christmas and Cocos Islands did not

conform to these interrelationships. Endemic angelfishes were 50-80 times more abundant than widespread species and were not more specialised than widespread congeners. High abundance and lack of specialisation by endemic reef fishes may compensate for the extinction risk posed by having an extremely small geographic range.

Endemic species, and isolated populations of widespread species, are also at risk of extinction because they tend to have low genetic diversity. Examination of angelfish mtDNA revealed that the endemic *C. joculator* exhibit high haplotype (h > 0.98) and nucleotide diversity (Christmas π% = 3.63, Cocos π% = 9.99). The isolated populations of widespread angelfishes (*C. bispinosa* and *C. flavicauda*) present at Christmas Island also had high haplotype (h > 0.99) and nucleotide diversity (π% = 2.81 and π% = 5.78%, respectively). The genetic diversity of all three study species are among the highest reported for marine fishes and may have been caused by high abundance, relict populations, multiple clades and rapid mutation rate. High genetic diversity should reduce extinction risk in these species because it increases their evolutionary potential to adapt to the changing environmental conditions that are forecasted for coral reefs.

In summary, this study tested the generality of terrestrially-derived ecological relationships related to island communities. Some of these ecological hypotheses were found to apply to marine communities, whereas others did not. New hypotheses have been proposed to explain why marine communities do not always conform to these ecological generalisations. By combining field, laboratory and molecular studies with datasets constructed from the literature, this study has provided a thorough examination of the ecology of reef fishes on isolated islands and advances our understanding of marine ecology.

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