Habitat associations of tropical fishes across latitudes: Implications for ocean warming and species range expansion

Thesis submitted by

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February 2018

For The degree of Doctor of Philosophy

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree at this or any other university, nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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This research is supported by an Australian Government Research Training Program Scholarship.

Acknowledgments

This thesis could not have been possible without the guidance, assistance and support of many people.

Firstly, I would like to thank my supervisors David Booth and Andrew Hoey. I am extremely grateful for your support, expert knowledge and guidance throughout my project. Many thanks to Dave for giving me the freedom to explore my ideas, your positivity, enthusiasm and continued support through the many obstacles I faced along the way. Thank you to Andy for giving up many hours of your time over skype and visits to Sydney to facilitate my progress, and for providing valuable advice and constructive feedback on my writing, which greatly improved this thesis.

I would also like to thank my collaborators for their contributions to this thesis. In particular, thank you to Brigitte Sommer who taught me an incredible amount on how to carry out fieldwork in high latitude reef environments, identify benthic assemblages and about the analysis and interpretation of ecological data. Many thanks to Stephen Bush, for providing his valuable expertise and assistance in predictive modelling. I am also very grateful to Jennifer Donelson and Rebecca Fox for facilitating fieldwork in Cairns, helping with the design and interpretation of behavioural experiments and providing endless advice and support.

This thesis involved extensive fieldwork and laboratory experiments which could not have been possible without the help and commitment of amazing volunteers including Jack Adriaans, Frederic Cadera, Maddy Combe, Holly Gunton, Jacqueline Herman, Ellery Johnson, James Laolada, James O'Brien, Davina Poulos, Vicky Von Bernard, Andrew Wang and Bevan Yiu. I am grateful to Joshua Madin, Andrew Baird, and Toni Mizerek for facilitating the logistics of research at the Solitary Islands as well as the research station managers at One Tree Island Research Station. Thank you also to Belinda Dechnik for lending her expertise in coral ID.

Thanks to my fellow fish lab members; Hayden Beck, Nikki Bramwell, Gwenael Cadiou, Jennifer Donelson, Ash Fowler and Selma Klanten for stimulating discussions,

valuable feedback, support and friendship. Special thanks to David Feary, for his early support of my ideas and recommendation to get out there and give things a try. I greatly appreciate the feedback from my writing group friends; Maria Palacios, Lauren Nadler and Steve Doo who greatly improved the quality of drafts from my thesis, manuscripts, conference abstracts and grant applications. I also extend my gratitude to our diving office Rochelle Johnston, and the technical staff at UTS, in particular Gemma Armstrong, Paul Brooks, Susan Fenech, Graeme Poleweski and Kerryn Parkinson who have always been so willing to help.

I would like to thank the funding sources that have made this work possible: the Great Barrier Reef Foundation, The New South Wales Environmental Trust (through Joshua Madin, David Booth and Andrew Baird) and UTS Faculty of Science. I am also very grateful to the Australian Coral Reef Society, ARC Centre of Excellence for Coral Reef Studies, Australian Society for Fish Biology, UTS Faculty of Science and UTS Vice-Chancellor's Conference Fund for funding travel to various national and international conferences to present my work. Also, to the Australian Government for the support of an Australian Government Research Training Program Scholarship.

Finally, I thank my family and friends for their unconditional support and encouragement. I have appreciated the genuine interest and enthusiasm you have shown throughout this journey. To my amazing parents Andrea and Antony Matis, who instilled in me a love of the ocean and always encouraged me to pursue my dreams. Thank you for always believing in me and supporting all that I do.

Ethics approval and collection permit

Animal ethics approval for this research was granted by the University of Technology Sydney (UTS) Animal Care and Ethics Committee (ACEC) (Permit 2011 - 036A). Collection of fishes and coral for this project was permitted by the Great Barrier Reef Marine Park Authority (Permit G11/34452.1, G11/34670.1, G12/35118.1, G14/37177.1).

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Abstract

Climate change is fundamentally altering the structure and functioning of terrestrial and marine ecosystems globally. In coral reefs, fishes are under increasing pressure from elevated temperatures and habitat degradation associated with climatic warming. Their ability to cope with these changing conditions will be key to species persistence and population sustainability into the future. The poleward shift in the geographic distribution of tropical fishes has also been documented in response to the warming and intensification of poleward boundary ocean currents, which strongly influence dispersal of fishes. However, high latitude reefs present novel conditions (e.g. temperature, resource availability, species interactions) which influence the ability of species to successfully colonise these areas. This thesis examines how habitat associations of tropical fishes may vary with latitude and temperature, in light of dynamic climate change impacts, including ocean warming and the poleward range expansion in species distributions. Such knowledge will be critical in managing coastal and coral reefs under pressing climate change scenarios.

Firstly, this thesis examined habitat associations of reef fishes, with particular focus on tropical species, across a latitudinal gradient. Fish assemblages were compared across four reef locations spanning 17 degrees of latitude along the east coast of Australia to determine the role that benthic complexity and composition of the receiving environment have in structuring the distribution of reef fish assemblages from tropical to temperate reef environments (Chapter 2). Total fish density was highest at the temperate location followed by the subtropical and two tropical locations. Overall, the densities of adult fishes were greater than juvenile fishes across all locations and among latitudinal affinities (i.e. tropical, subtropical and temperate fishes). The only exception was the greater abundance of tropical juvenile fishes than adults at the temperate location. There was also a clear difference in the functional groups driving the separation of fish assemblages among the temperate, subtropical and tropical locations. Benthic composition, compared to habitat complexity, best predicted differences in the distribution of total fish assemblages, and specifically tropical fish assemblages, among latitudinal locations. These results suggest species that rely on particular corals or have highly specialised habitat and/or trophic requirements (e.g. obligate corallivores) are

unlikely to successfully establish populations in temperate environments. Overall, local benthic composition is likely to play a role in determining which tropical fish species successfully colonise temperate reefs in the future.

Building on this foundation, behavioural time budgets, social group structure, feeding patterns and movement were quantified for three common tropical fishes (*Chaetodon auriga, Abudefduf sexfasciatus* and *Pomacentrus coelestis*), across three locations, spanning tropical to temperate reefs (Chapter 3). Species behavioural time budgets and social group structure varied both among latitudes and among species. Species were only observed to aggregate with conspecifics at the tropical location; however, mixed species aggregations were more common at subtropical and temperate locations. A reduction in movement and feeding at the higher latitudes may indicate the physiological constraints of temperature and/or impact of predation risk for tropical species in these locations. Resource availability (e.g. food, habitat, conspecifics) is also likely to have caused variation in the patterns of behaviour observed at the higher latitudes.

Following these latitudinal surveys, the influence of water temperature associated with ocean warming events on species habitat preferences were investigated (Chapter 5). Habitat choice experiments were conducted in the laboratory to isolate the effect of temperature on habitat preference. Prior to this, however, a suitable method needed to be established for detecting habitat preferences in species with varying levels of habitat association (*C. auriga, C. flavirostris, P. coelestis and A. sexfasciatus*) (Chapter 4). This study revealed that a commonly used observation interval (10 min) was not suitable, and that hourly measurements were better at detecting habitat preferences of species known to use a range of habitats (*C. flavirostris, P. coelestis and A. sexfasciatus*). The application of discrete choice modelling in understanding these habitat preferences was also found to be useful. Hourly measurements were then utilised to determine the influence of water temperatures (22˚C, 28°C and 31˚C) on habitat preferences of three common damselfishes (*P. moluccensis, P. coelestis* and *A. sexfasciatus*) selected for their range of habitat preferences (Chapter 5). Results showed *P. moluccensis* consistently selected its preferred complex coral habitat across all temperatures. Unexpectedly, however, *A. sexfasciatus* and *P. coelestis* who usually associate with a

range of habitats, developed strong habitat preferences (respectively for complex coral and boulder, and complex coral) as temperature increased from ambient levels. Therefore, we may be currently underestimating the impact of climate change on species that are known to associate with a range of habitats.

Overall, the findings of this thesis highlight that, in addition to temperature and larval supply, benthic composition likely plays a role in structuring the availability of suitable habitat and trophic resources, and thus may constrain the establishment of some tropical fishes while promoting others within high latitude reef environments. These results also provide evidence of differences in species behaviour across latitudes, giving us greater insight into the novel constraints of temperate environments, as well as which species are likely or unlikely to shift with ongoing climate change. Furthermore, within tropical reefs there are potential cumulative impacts of global warming, with risks associated both directly with habitat degradation (e.g. loss of complex coral) and possibly increasing resource overlap and competition between species in ways that have not previously been accounted for in climate prediction models. The shifts in habitat preferences observed in this study suggest we may also see increased pressure on species that do not currently rely on a particular habitat, indicating that climatic warming could affect ecological relationships in subtle and unexpected ways, prompting new lines of inquiry.