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

Thesis submitted by

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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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# Contents

Certificate of original authorship ................................................................................................... ii  
Acknowledgments ......................................................................................................................... iii  
Ethics approval and collection permit ........................................................................................... v  
Table of Figures ........................................................................................................................... viii  
Table of Tables ............................................................................................................................... x  
Abstract ......................................................................................................................................... xi  

Chapter 1: General Introduction ................................................................................................... 1  

Chapter 2: Habitat predicts the distribution of tropical fishes across a tropical to temperate gradient ....................................................................................................................................... 12  
  Abstract ................................................................................................................................... 12  
  2.1 Introduction ...................................................................................................................... 12  
  2.2 Methods ............................................................................................................................ 16  
  2.3 Results ............................................................................................................................... 20  
  2.4 Discussion .......................................................................................................................... 30  

Chapter 3: Latitudinal variation in behavioural patterns and social group structure of coral reef fishes ........................................................................................................................................... 36  
  Abstract ................................................................................................................................... 36  
  3.1 Introduction ...................................................................................................................... 37  
  3.2 Methods ............................................................................................................................ 39  
  3.3 Results ............................................................................................................................... 44  
  3.4 Discussion .......................................................................................................................... 55  

Chapter 4: Applying discrete choice models to habitat preference studies of coral reef fishes 60  
  Abstract ................................................................................................................................... 60  
  4.1 Introduction ...................................................................................................................... 60  
  4.2 Methods ............................................................................................................................ 63  
  4.3 Results ............................................................................................................................... 67  
  4.4 Discussion .......................................................................................................................... 74  

Chapter 5: Temperature influences habitat preference of coral reef fishes: Will generalists become more specialised in a warming ocean? ......................................................................... 77  
  Abstract ................................................................................................................................... 77  
  5.1 Introduction ...................................................................................................................... 77  
  5.2 Methods ............................................................................................................................ 80  
  5.3 Results ............................................................................................................................... 84
5.4 Discussion .......................................................................................................................... 89
Chapter 6: General Discussion ............................................................................................... 93
References ............................................................................................................................... 100
Appendix A: Supplemental information for Chapter 5 .......................................................... 114
Table of Figures

Figure 1.1. Map of eastern Australia showing the four study locations where research for this thesis was undertaken, spanning ~ 2400 km from Cairns (16°39'26.58"S, 145°59'26.09"E) in the north to Sydney (33°48'2.26"S, 151°17'49.84"E) in the south. Images show the typical reef environments at the locations of Cairns (tropical reef), One Tree Island (tropical reef), Solitary Islands (subtropical reef) and Sydney (temperate reef). ........................................................................................................ 9

Figure 2.1. Map of eastern Australia showing locations of the four study sites spanning ~ 2400 km from Cairns (16°39'26.58"S, 145°59'26.09"E) in the north to Sydney (33°48'2.26"S, 151°17'49.84"E) in the south. Surveys were conducted at three to four sites selected within each location. .................................................................. 17

Figure 2.2. Mean (±SE) (a) species richness (b) density of adults and (c) density of juveniles, for tropical, subtropical and temperate fishes recorded across locations (Cairns, One Tree Island (OTI), Solitary Islands (SI) and Sydney). .................................................. 22

Figure 2.3. Principle coordinated ordination of total fish assemblages at each site within reef locations (Cairns, One Tree Island (OTI), Solitary Islands (SI) and Sydney). Vectors summarising the main trophic groups (apex predator, mesopredator, planktivore, obligate corallivore, benthic herbivore, omnivore, detritivore) indicate direction of the parameter effect in the ordination plot. ............................................................ 24

Figure 2.4. Principle coordinates analysis of benthic assemblages (detailed original ID’s) at each site within reef locations (Cairns, One Tree Island (OTI), Solitary Islands (SI) and Sydney). Vectors summarising the main benthic groups (summarised at the family level) indicate direction of the parameter effect in the ordination plot. ................. 26

Figure 2.5. Distance-based redundancy analysis (dbRDA) plot of the DistLM based on the predictor variables (habitat complexity, benthic PCO axes 1 and 2) fitted to the variation in total fish assemblages (Table 2.1 DistLM results) at each site within reef locations (Cairns, One Tree Island (OTI), Solitary Islands (SI) and Sydney). Vectors indicate direction of the parameter effect in the ordination plot. ........................... 28

Figure 2.6. Distance-based redundancy analysis (dbRDA) plot of the DistLM based on the predictor variables (habitat complexity, benthic PCO axes 1 and 2) fitted to the variation in tropical fish assemblages (Table 2.2 DistLM results) at each site within reef locations (Cairns, One Tree Island (OTI), Solitary Islands (SI) and Sydney). Vectors indicate direction of the parameter effect in the ordination plot. ........................... 30

Figure 3.1. Map of eastern Australia showing (a) the geographic position of the three study locations: One Tree Island, Coffs Harbour and Sydney, and (b - d) the position of sites within each location. Focal observations of *Chaetodon auriga* (triangle), *Abudefduf sexfasciatus* (circle) and *Pomacentrus coelestis* (star) were conducted at three sites selected within each location. ................................................................. 41

Figure 3.2. Canonical discriminant analysis (CDA) of the behaviour of *Chaetodon auriga*, *Abudefduf sexfasciatus* and *Pomacentrus coelestis* among the three reef locations (One Tree Island, Coffs Harbour and Sydney). Ordination plots on CV1 and CV2 of group centroids for (a) *C. auriga*, (c) *A. sexfasciatus* and (e) *P. coelestis* with 95% confidence ellipses at the locations of One Tree Island (red), Coffs Harbour (green)
and Sydney (blue) and vector plots for (b) C. auriga, (d) A. sexfasciatus and (f) P. coelestis based on full correlations between the behavioural variables and CV1 and CV2. n = 20 per species, per location.

Figure 3.3. Mean (±SE) number of antagonistic interactions observed (per 3 min observation) for juvenile (a) Chaetodon auriga, (b) Abudefduf sexfasciatus and (c) Pomacentrus coelestis at One Tree Island (OTI), Coffs Harbour (Coffs) and Sydney. Note: differences among locations were determined using a rank test and no significant differences were observed in (b). n = 20 per species, per location.

Figure 3.4. Mean (±SE) group size, including the proportion of conspecific and heterospecific groups, of juvenile (a) Chaetodon auriga, (b) Abudefduf sexfasciatus and (c) Pomacentrus coelestis at One Tree Island (OTI), Coffs Harbour (Coffs) and Sydney. Note: differences among locations were determined using a rank test. n = 20 per species, per location.

Figure 3.5. Mean (±SE) (a) bite rate (number of bites in 3 min) and (b) feeding rate (time spent foraging in a 3 min bout/number of bites taken in 3 min) of Chaetodon auriga at One Tree Island (OTI), Coffs Harbour (Coffs) and Sydney (n = 20 per location). Note: differences among locations were determined using a rank test.

Figure 3.6. Mean (±SE) maximum linear distance moved (to the nearest 5 cm) of (a) Chaetodon auriga, (c) Abudefduf sexfasciatus and (e) Pomacentrus coelestis, and distance above substrate (to the nearest 5 cm) of (b) C. auriga, (d) A. sexfasciatus and (f) P. coelestis among locations (One Tree Island (OTI), Coffs Harbour (Coffs) and Sydney). Note: differences among locations were determined using a rank test. n = 20 per species, per location.

Figure 4.1. Mean (± SE) proportion of habitat preferences (based on equal availability of coral and rock) observed in the (a) first 10 min and across (b) hourly observations for Abudefduf sexfasciatus, Chaetodon auriga, Chaetodon flavirostris, and Pomacentrus coelestis.

Figure 5.1. Example experimental tank set up prior to the start of a habitat-choice trial (a). Habitat preferences were assessed for juvenile Pomacentrus moluccensis, Pomacentrus coelestis and Abudefduf sexfasciatus at 22°C, 28°C and 31°C for all possible combinations using paired combinations of the following: (b) complex coral, (c) noncomplex coral, (d) coral rubble and (e) rocky boulder.

Figure 5.2. Percentage of time (mean ± SE) spent at each of four experimental habitat types, (based on the option of no selection and equal availability of habitat types) for juvenile individuals of the species (a) Pomacentrus moluccensis (b) Pomacentrus coelestis and (c) Abudefduf sexfasciatus observed at 22°C, 28°C and 31°C.
Table 2.1. Results of the distance-based linear model (DistLM) for total fish assemblages against explanatory variables including habitat complexity, benthic PCO axes 1 (Benthic 1) and 2 (Benthic 2). The proportion of variance in fish assemblages was explained by explanatory variables in stepwise sequential tests following AICc selection criterion. Prop. = proportion of variance explained by each single variable; res.df = residual degrees of freedom. ................................................................. 27

Table 2.2. Results of the distance-based linear model (DistLM) for tropical fish assemblages against explanatory variables including habitat complexity, benthic PCO axes 1 (Benthic 1) and 2 (Benthic 2). The proportion of variance in fish assemblages was explained by explanatory variables in stepwise sequential tests following AICc selection criterion. Prop. = proportion of variance explained by each single variable; res.df = residual degrees of freedom. ................................................................. 29

Table 3.1. Behaviours recorded by the observer and definitions/interpretation for focal individuals of juvenile *Chaetodon auriga*, *Abudefduf sexfasciatus* and *Pomacentrus coelestis*. ...................................................................................................................... 43

Table 3.2. Other species observed in social groups with focal individuals of juvenile *Chaetodon auriga*, *Abudefduf sexfasciatus* and *Pomacentrus coelestis* at Coffs Harbour and Sydney. Latitudinal affiliation (Lat) classified as tropical (Trop), subtropical (Sub) or temperate (Temp) (determined from Randall *et al.*, 1997, Kuiter, 2000, Malcolm *et al.*, 2010). ..................................................................................................................... 51

Table 4.1. Model estimates for three multinomial logistic regression models of *Abudefduf sexfasciatus*, *Chaetodon flavirostris*, and *Pomacentrus coelestis* hourly location based on data collected in first 10 min. Model 1 contains only intercept terms (hourly observations) and Model 2 contains intercept terms as well as the proportion of time spent at both locations in the first 10 min. Since there are three outcomes, each factor has a parameter describing the effect of the factor on the likelihood that a fish chooses coral rather than making no selection and another describing the effect of the factor on the likelihood that the fish chooses rock instead of making no selection, denoted by “:Coral” and “:Rock” respectively. The models for each species with the lowest Akaike Information Criterion (AIC) scores are indicated in bold. .................... 71

Table 4.2. Comparison of the predicted locations based on the multinomial logit model with the lowest Akaike Information Criterion (AIC) scores to the observed locations for *Abudefduf sexfasciatus*, *Chaetodon flavirostris*, and *Pomacentrus coelestis*. These proportions may overestimate for the ability of the model to predict behaviour after 10 min, as these proportions are calculated from predictions for the data that was also used to construct the model.................................................................. 73

Table 5.1. Comparisons of habitat preferences (p-values) of juvenile *Pomacentrus moluccensis*, *Pomacentrus coelestis* and *Abudefduf sexfasciatus* between (a) habitats (rubble, boulder, complex coral, non-complex coral and no selection) (b) temperatures (22°C, 28°C, 31°C) and (c) species. ................................................................. 86
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.