Recruitment in time and space: the dynamics and distributions of reef fish populations on a low latitude coral reef

Thesis submitted by

Maya Srinivasan, BSc (Hons) Qld

in November 2006

for the degree of Doctor of Philosophy
in the School of Marine and Tropical Biology
James Cook University

ELECTRONIC COPY

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library, is an accurate copy of the print thesis submitted, within the limits of the technology available.

_____ _____

Signature Date

STATEMENT OF ACCESS

I, the undersigned, the author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and I do not wish to place any further restriction to access on this work.

.....	.....
Signature	Date

STATEMENT ON SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

....

Signature Date

STATEMENT OF CONTRIBUTION OF OTHERS

This project was funded by Walindi Plantation Resort, JCU's Doctoral Merit Research Scheme and an ARC Discovery Grant to GP Jones. Mahonia Na Dari Research and Conservation Centre provided accommodation as well as use of their boats and laboratory. I was supported by International Postgraduate Research, James Cook University Postgraduate Research, and JCU Doctoral Completion scholarships during my PhD. In Chapter 2, I use rainfall data provided by Walindi Plantation Resort, and wind speed data provided by the Dami Research Facility of New Britain Palm Oil Ltd. In Chapter 3, habitat availability data for four reefs were provided by GP Jones and MI McCormick. Chapter 5 is a collaboration with GP Jones and MI McCormick, who made available their long-term data set on adult fish.

ACKNOWLEDGEMENTS

There are many people I wish to thank for various reasons, including:

Traditional land/reef owners (Thomas Koi in particular) and residents of Tamare and Kilu villages for allowing me to work on their reefs, and for their friendship and support;

My supervisors, Julian Caley, Howard Choat and Mark McCormick, for advice, comments on manuscripts and many helpful discussions;

Lars Gamfeldt, Joanne Harris, Lisa Iwahara, Sarah Kistle, Joe 'Mismin' Loga, Margit Luscombe, Will Robbins, Michelle Rutten, Marie-Lise Schläppy, Craig Syms, Mahonia Na Dari boating staff (Joe 'Mismin' Loga, Andrew 'Digger', Ambrose and Dominic), Walindi Diving staff (Sebastian, Blasius, Henry, Martin 1, Martin 2, Joe 'Muscles' Loga) for assistance with fieldwork;

Glenn Almany, Ken Clifton, Peter Doherty, Jeff Leis, and Philip Munday for advice and encouragement;

Glenn De'Ath, Steven Delean, Philip Munday, Marcus Sheaves, Craig Syms, Gerry Quinn and Renae Tobin for providing advice and/or assistance with statistical analyses;

Peter Mumby and two anonymous reviewers for providing useful comments on Chapter 2 (published in Coral Reefs);

Craig Osenberg and two anonymous reviewers for providing useful comments on Chapter 4 (published in Oecologia);

Max and Cecilie Benjamin, and everyone at Walindi Plantation Resort for their support and friendship;

Simon Lord and Ruth Jordansom of New Britain Palm Oil for sending the wind speed data used in Chapter 2;

Shane Ritchie for providing technical assistance during field trips, and for building me a work desk;

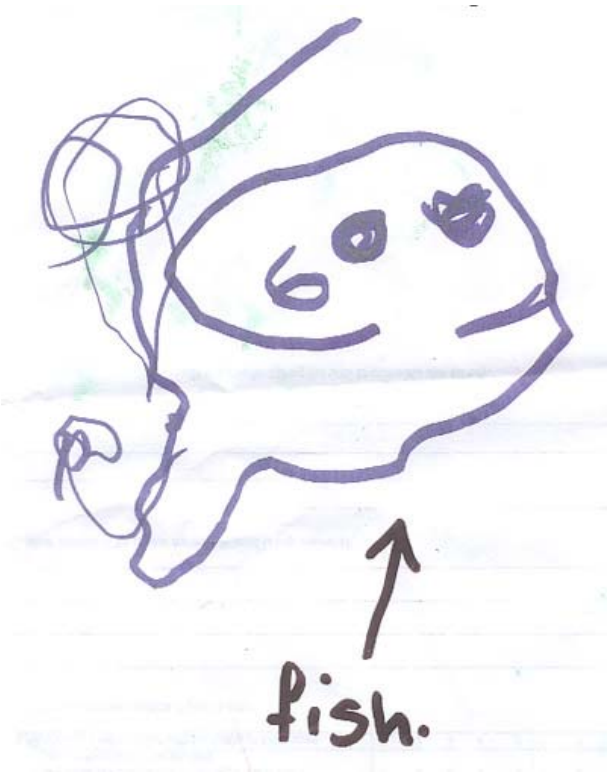
Vince Pullella and Gordon Bailey for computing support; Janis Nugent and Jenny MacGregor for their assistance with administrative matters;

Margit Luscombe for being a fantastic housemate during field trips, and to Dokas and Karo for being faithful bodyguards;

My parents, Rosemary and Srini, for their encouragement and for supporting my education in distant lands;

My friends in Kimbe and Townsville (sorry I do not have the space to mention you all);

Most of all, I thank my partner Geoff Jones for his help and support, and our daughter, Nina and dog, Liila for their unconditional love. I also wish to apologise to Nina for spending time on this thesis while she had more important things for me to do.



GENERAL ABSTRACT

Most benthic marine fishes have a pelagic larval stage, which after metamorphosis, recruits into adult habitat. Recruitment is known to play a major role in determining the dynamics and spatial distribution of coral reef fish populations. Temporal and spatial patterns in recruitment can arise through variation in larval supply, habitat selection and/or the availability of suitable recruitment habitat. Most of the work demonstrating the importance of recruitment on coral reefs has been carried out at high-latitude, seasonal locations, where reproduction and subsequent recruitment occur over a restricted period. Theory predicts a more continuous larval supply near the equator, and because of greater fish species diversity, a higher level of specialisation and dependence on habitat characteristics. However, very few studies have examined recruitment patterns, habitat degradation and the consequences for reef populations at low latitudes.

The primary goal of this thesis was to extend our knowledge of the causes and consequences of temporal and spatial patterns in reef fish recruitment to a low latitude coral reef in the Indo-Pacific (Kimbe Bay, Papua New Guinea, 5°30'S; 150°05'E). Specifically, the chapters set out to examine: (1) temporal patterns in recruitment, with particular emphasis on describing extended recruitment periods and underlying processes affecting recruitment periodicity; (2) spatial patterns in recruitment, with particular emphasis on microhabitat specialisation and the role of microhabitat availability in determining reef-wide patterns in recruitment; (3) the underlying mechanisms responsible for establishing and reinforcing distinct narrow depth distributions in the recruitment of reef fishes in this region; and (4) the influence of recruitment patterns on the temporal dynamics and spatial distributions of adult fish populations against a background of declining coral reef health.

Coral reefs in Kimbe Bay are subject to a monsoon climate, with distinct wet (November-February) and windy (April-June) seasons, and annual temperature deviations of just 1-2°C. Due to the lack of variation in temperature, I predicted that most fish species would reproduce and recruit year-round (Chapter 2). To

test this I carried out quantitative surveys of new recruits of all abundant, non-cryptic reef fishes every 1-2 months on inshore reefs over a 2.5-year period (December 1998 to April 2001). For the vast majority of species, new recruits were present during most months of the year, with damselfishes (Pomacentridae) and wrasses (Labridae) accounting for 90% of all new recruits observed. The majority of wrasse species exhibited year-round recruitment with broad peaks from November to May, while most damselfish species had negligible recruitment during the wet season (December-February), followed by one or two broad recruitment peaks between May and November. Species with year-round recruitment exhibited the highest cumulative recruit abundances. The reproductive output of three damselfish species was monitored for just over a year, and it was found that reproduction occurred throughout the year, even during the wet season. Although reproductive output decreased during the wet season, this was not considered sufficient to explain the lower recruitment of these species during this time. I argue that the lack of damselfish recruitment during the wet season is due to both decreased reproductive output and increased mortality of larvae, possibly due to hypo-saline conditions in surface waters. These results indicate that consistent family-wide recruitment strategies that may play a significant role in the dynamics of populations at low latitudes.

As a consequence of high fish diversity and steep reef profiles in Kimbe Bay, I predicted a high level of specialisation on settlement substrata that would be a major determinant of the spatial distribution and abundance of recruits (Chapter 3). Recruitment surveys were carried out using a spatially structured sampling design to determine differences in abundance among reefs located different distances from shore, among depths and reef zones within reefs (macrohabitats), as well as among different recruitment substrata (microhabitats). The microhabitats used by new recruits were recorded and compared with microhabitat availability from annual benthic surveys carried out at the same sites and depths. Over half the common species (23 out of 38) occupied corals in the family Acroporidae in proportions greater than expected based on their availability, and 12 species preferentially occupied non-living substrata (i.e. bare rock, rubble and sand). There were only five species, two damselfishes and three wrasses, which used all 13 microhabitat categories. At both the family-level (for

damselfishes and wrasses) and the species-level, depth explained the greatest percentage of the variance in the spatial recruitment data (just under 50% on average) and microhabitat availability explained the lowest. Therefore, although the level of microhabitat specialisation suggests that microhabitat availability might be an important factor in determining recruitment patterns, in terms of spatial patterns, the region is primarily characterised by a strong depth gradient.

A number of potentially important factors co-vary down a depth gradient. To determine whether the narrow depth range of new recruits was determined by the depth distribution of preferred microhabitats or depth itself, I conducted further surveys at additional depths on two reefs, in combination with a field experiment, using patch reefs composed of identical coral substrata at the same five depths (3, 6, 10, 15 and 20 m). Settlement patterns from the patch reef experiment were compared to those on un-manipulated reef habitat (i.e. patterns from surveys), to determine whether new settlers have preferences for particular depths, independent of microhabitat structure. For all species, settlement on patch reefs differed significantly among depths despite uniform substratum composition, indicating that depth preferences are largely independent of microhabitat structure. For four of the six species tested, depth-related settlement patterns on un-manipulated habitat and on patch reefs did not differ. For the other two species, depth ranges were greater on the patch reefs than on un-manipulated habitat. A second experiment examined whether depth preferences reflected variation in growth and survival when microhabitat was similar. Newly settled individuals of *Chrysiptera parasema* and *Dascyllus melanurus* were placed, separately, on patch reefs at five depths (as above) and their survival and growth monitored. For *D. melanurus*, which is restricted to shallow depths, both survival and growth were highest at the shallowest depth. Depth did not affect either survival or growth of *C. parasema*, which has a broader depth range than *D. melanurus* (between 6 and 15 m). This suggests that the stronger the depth preference, the greater the fitness costs incurred by settling at the extremes of, or outside, a preferred depth range.

The final aim of this project was to determine how temporal and spatial recruitment patterns influence adult fish populations. The temporal surveys of

new recruits were conducted during a time of a dramatic decline in coral cover caused by a series of bleaching events and change in fish communities. Associated with this, 75% of the common reef fish species declined in abundance, with 50% declining to less than half their original numbers. Wrasses exhibited the greatest range of responses, including species that increased, species that declined and others that remained stable. The majority of damselfish species declined and the magnitude of declines were greater than for most wrasses. The magnitude and direction of the long-term change in fish abundance was inversely correlated with the degree of association between recruits and live branching corals. Species that did not recruit into live coral tended to increase in abundance, while the greater the dependence of recruits on live coral, the greater the adult decline. For many species, long-term trends in adult numbers were interrupted by a spike of increased abundance in 2001, which was associated with high recruitment the previous year. Spatial patterns in the abundance of adults across reefs and depths were positively correlated with recruitment levels for 80% of the species examined. For some species, adult distributions tended to be more even than recruit distributions, indicating post-settlement expansion in distributions. A comparison of recruit-adult relationships among species and families established that a given average density of recruits resulted in greater average densities of adult damselfishes, compared with wrasses. Within each family, species with higher recruitment exhibited higher adult densities, but the magnitude of the increase in adult numbers declined as a function of increasing recruitment. I suggest that short-term fluctuations in adult abundance arise through fluctuations in larval supply, while longer-term trends reflect a combination of changes in habitat availability, habitat-limited recruitment and adult survival. In contrast, adult spatial distributions are primarily explained by strong habitat-specific settlement preferences.

This first study of coral reef fish recruitment in Papua New Guinea confirms that recruitment is a major determinant of the dynamics and spatial distribution of adult fishes in this high diversity region. While extended recruitment seasons clearly influence short-term population dynamics, longer-term trends in population size appear to be driven by habitat-limited recruitment and habitat change. Spatial gradients indicate a high level of specialisation with regard to

depth and dependence on live coral as recruitment microhabitat. Documenting variation in spatial and temporal dynamics has also revealed a number of previously unknown family-wide and species-specific themes. The family-level differences between damselfish and wrasses may reflect fundamental differences in their life history traits, reliance on living corals and the carrying capacities of their habitats. Greater attention to variation in recruitment dynamics along biodiversity and biogeographic gradients will be required to understand and respond to the impacts of global change on coral reef fish populations.

TABLE OF CONTENTS