Dynamics of outbreak populations of crown-of-thorns starfish (*Acanthaster planci* L.), and their effects on coral reef ecosystems.

Thesis submitted by

Morgan S. Pratchett B.Sc. (HONS I) JCU

in October, 2001

for the degree of Doctor of Philosophy in Marine Ecology, within the School of Marine Biology and Aquaculture, James Cook University.

Statement of Access

I, the undersigned author of this thesis, understand that James Cook University will make it available for use within the University Library and, by microfilm or other photographic means, allow access to users in other approved libraries. All users consulting this thesis will have to sign the following statement:

> "In consulting this thesis I agree not to copy or closely paraphrase it in whole or in part without the written consent of the author; and to make proper written acknowledgment for any assistance which I have obtained from it."

Beyond this I do not wish to place any restriction on access to this thesis.

31 October, 2001

Morgan S. Pratchett

Abstract

Population outbreaks of crown-of-thorns starfish (*Acanthaster planci* L.) represent one of the most significant, but also least understood processes affecting coral reef communities. Limited understanding of crown-of-thorns outbreaks is due, at least in part, to a critical lack of data on the structure and dynamics of *A. planci* populations. Therefore, this study examined fine-scale (within reef) patterns in the size structure, distribution, and abundance of starfish populations, during an outbreak of *A. planci* in the northern Great Barrier Reef. The outbreak resulted from steady and prolonged increase in starfish densities, over a three year period. Furthermore, starfish populations comprised individuals from at least four different year classes, suggesting that the outbreak was caused by progressive accumulation of starfish from multiple recruitment events. Overall densities of *A. planci* increased to 1.0 starfish per $200m^2$ (±0.1 SE), in January 1997, and then remained fairly constant until June 1998, after which time starfish densities declined rapidly. During the outbreak, densities of *A. planci* varied greatly among locations (separated by 0.5-8km), and also between reef zones (<5m apart). Densities of *A. planci* were consistently highest at locations in sheltered back reef habitats, but considerable numbers of starfish were also recorded at depth (>7 metres) in some exposed locations. Fine-scale patterns in the distribution and abundance of *A. planci* were partly attributable to spatial variation in wave exposure (whereby starfish avoid turbulent environments), but also resulted from spatial patterns established at settlement.

Outbreak populations of *A. planci* caused substantial coral mortality, and also significantly altered the structure of coral communities. Scleractinian coral cover declined by 32%, from a mean of 32.2% cover (± 1.1SE) in October 1996 down to 21.9% cover (± 1.2SE) in January 1999. The impacts of *A. planci* were however, very patchy. At the most

severely affected locations (in sheltered back reef habitats) coral cover declined by 72% between 1996 and 1999, whereas at several other locations (e.g., lagoonal habitats) there was no observable change in scleractinian coral cover. Crown-of-thorns starfish also had varying impacts among different coral species, caused by significant selectivity in their patterns of feeding. In general, starfish had a disproportionate impact on fast growing branching corals (e.g. *Acropora* spp. and pocilloporids), tending to avoid slow growing massive corals (e.g., *Diploastrea* spp., *Porites* spp.).

Crown-of-thorns starfish are well adapted to feed on a wide range of different coral prey, and it is not known why they consistently target a restricted suite of different coral species. Herein, I tested the role of coral symbionts in structuring the feeding preferences of *A. planci*, for common branching coral species (*Acropora* spp. and pocilloporids). To test the role of coral symbionts, this study compared feeding preferences of *A. planci* for six different coral species, with and without their usual complement of coral symbionts. Crown-of-thorns starfish had a clearly defined hierarchy of preference for the six different corals when they contained symbionts (*Acropora gemmifera* > *A. nasuta* = *A. loripes* > *Seriatopora hystrix* > *Pocillopora damicornis* > *Stylophora pistillata*). In contrast, when coral symbionts were removed, starfish readily consumed all six corals and did not exhibit any significant selectivity. For the six coral species tested, it is clear that coral symbionts (and particularly trapeziid crabs) do have a marked influence on the feeding preferences of crown-of-thorns starfish. However, despite the protection provided by coral symbionts, *Acropora* and pocilloporid corals were among the first corals eaten by field populations of *A. planci*. Therefore, other factors (e.g., the size, morphology, chemical defence and/ or nutritional value of corals) may be more important in determining overall feeding preferences of *A. planci* (across a broader range of different coral species).

Clearly, crown-of-thorns starfish have a major impact on coral communities, but impacts of starfish outbreaks may also extend to a wider range of reef associated organisms, such as coral reef fishes. Despite a close association between reef fishes and benthic habitats, there has been little consideration for how disturbances to benthic reef habitats (particularly, extensive reductions in coral cover) affect coral reef fishes. It is likely that impacts will be most pronounced in those fish species which exhibit a direct reliance on scleractinian corals, such as coral feeding butterflyfishes. This study examined long-term changes in the distribution and abundance of butterflyfishes throughout the course of a crown-of-thorns outbreak. Depletion of scleractinian corals resulted in significant reductions in the abundance of seven butterflyfish species (*Chaetodon auriga*, *C. citrinellus*, *C. kleinii*, *C. plebius*, *C. rainfordi*, C. *trifascialis*, and *C. unimaculatus*), whereas there was no change in the abundance of *C. aureofasciatus*, C. *baronessa*, *C. ephippium*, *C. lunulatus*, *C. melannotus* or *C. vagabundus*. *Chaetodon* species affected by coral depletion mostly had a high dependence on live coral for food. However, at least on non-coral feeding butterflyfish, *C. auriga*, was also affected. Among corallivorous butterflyfish, impacts of coral depletion varied in accordance with their degree of feeding specialisation. For example, declines in the abundance of the coral-feeding specialist, *C. trifascialis* were much more pronounced than declines in the abundance of the generalist coral feeding species *C. baronessa*. *Chaetodon baronessa* responded to the depletion of prey resource by expanding both the range of prey it consumed and also its depth distribution, thereby mediating impacts of resource depletion on its population size. This study demonstrates that major disturbances to coral reef habitats can have significant follow-on affects for coral feeding butterflyfishes. However, the specific responses of individual species vary in accordance with their diet, distribution and ecological versatility (specialist versus generalist).

In addition to feeding on scleractinian coral, many reef fish species also rely on scleractinian corals for shelter. Therefore, declines in coral cover may lead to a reduction in habitat availability, and corresponding declines in the local abundance of coral reef fishes. This study explores changes in the abundance and habitat associations of six coral-dwelling damselfish species, during extensive and wide-spread reductions in the availability of suitable host corals, caused by outbreak populations of *A. planci*. Coral-dwelling damselfishes occupied a very limited suite of available habitat categories, showing strong preference for only a limited range of habitat types (mostly specific coral species). Patterns of habitat use by coral-dwelling damselfish were also very consistent among locations and between years, despite significant variation in both the total abundance of corals and the relative abundance of different coral species. Live coral cover declined by 16-59% at locations affected by *A. planci*, causing declines in the abundance of *Chromis viridis*, *Dascyllus aruanus*, *D. reticulatus* and *Pomacentrus moluccensis*, but not *C. atripectoralis* or *P. amboinensis*. Species not affected (*C. atripectoralis* and *P. amboinensis*) often inhabited skeletons of dead corals, whereas all other species were strongly dependent on live coral as shelter. Variation in the abundance of obligate coral-dwelling species (*C. viridis*, *D. aruanus*, *D. reticulatus* and *P.moluccensis*) was strongly associated with variation in the abundance of corals that they most frequently occupied. This study demonstrates that infestations of *A. planci* can significantly effect the distributions and abundances of reef fishes with strong dependence on live corals.

Acknowledgments

Foremost, I would like to thank my two supervisors Prof. Terry Hughes and Dr. Geoff Jones for their expertise and guidance throughout the years. I also wish to acknowledge the large group of people, including Dr. David Williams, Dr. John Brodie, Assoc. Prof. John Lucas, Dr. David Bellwood, Dr. Garry Russ, Dr. Hugh Sweatman, Dr. Craig Syms, Dr. Jason Tanner, Dr. Phillip Munday, and Andrew Baird, with whom I discussed the findings of this research, and all of whom provided extremely valuable advice and feedback. Moreover, I'd like to thank Prof. Peter Glynn, Prof. Charles Birkeland and Dr. Hugh Sweatman whose comments, during the review process, greatly improved this thesis.

Funding for the project was provided by Australian Geographic, the Australian Coral Reef Society, the Australian Marine Sciences Association, CSIRO, the Great Barrier Reef Marine Park Authority , the Project AWARE Foundation, and the James Cook University Marine Biology Department (through the Doctoral Merit Research Scheme). Thankyou to everyone associated with these organisations who recognised the value of this research and awarded funds accordingly.

This project would not have been possible without the assistance of the numerous volunteers, to all of whom I am sincerely grateful; Stuart Watson, Andrew Baird, Elizabeth Dinsdale, Jackie Wolstenhome, Mathew Gordon, Melissa Shultz, Kerry Neil, David Pratchett, Jason Pratchett, Janelle Eagle, Shaun Wilson, Ross Thomas, Deborah Gibson, Nick Gust, and Gill Goby. Moreover, I would like to thank Gordon Bailey and Vince Pullella, and all the administrative staff (especially, Jan Nugent and Ann Sharp) at James Cook University, as well as staff at Lizard Island Research Station for their logistic support.

Finally, I would like express sincere thanks to my parents as well as whose constant love and support greatly assisted me through the course of the project.

Statement on Sources

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.

31 October, 2001

Morgán S. Pratchett

Table of Contents

List of Tables

Chapter 2: Fine scale variation in the population dynamics and impacts of *Acanthaster planci*

Chapter 4: Variable responses to resource depletion in a guild of corallivores

Chapter 5: Effects of coral depletion on coral-dwelling fishes

List of Figures

Chapter 5: Effects of coral depletion on coral-dwelling fishes