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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

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

Morgan S. Pratchett
# Table of Contents

Statement on Access.............................................................. i
Abstract............................................................................. ii
Acknowledgments................................................................. vi
Statement on Sources.............................................................. vii
Table of Contents................................................................. viii
List of Tables........................................................................ x
List of Figures........................................................................ xii

## Chapter 1: General Introduction

1.1 Effects of disturbance on ecological communities.................. 1
1.2 "The *Acanthaster* phenomenon" .................................. 7
1.3 Direct effects of *Acanthaster planci* .................................. 12
1.4 Indirect effects of *Acanthaster planci* .............................. 15
1.5 Thesis outline................................................................. 17

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

2.1 Abstract........................................................................ 22
2.2 Introduction.................................................................... 23
2.3 Methods......................................................................... 27
2.4 Results.......................................................................... 34
2.5 Discussion....................................................................... 52

## Chapter 3: Influence of coral symbionts on feeding preferences of crown-of-thorns starfish

3.1 Abstract........................................................................ 62
3.2 Introduction.................................................................... 63
3.3 Methods......................................................................... 65
3.4 Results.......................................................................... 69
3.5 Discussion....................................................................... 79
Chapter 4: Variable responses to resource depletion in a guild of corallivores

4.1 Abstract ................................................................. 84
4.2 Introduction ........................................................... 85
4.3 Methods ................................................................. 91
4.4 Results ................................................................. 97
4.5 Discussion ............................................................. 122

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

5.1 Abstract ................................................................. 131
5.2 Introduction ........................................................... 132
5.3 Methods ................................................................. 136
5.4 Results ................................................................. 143
5.5 Discussion ............................................................. 159

Chapter 6: General Conclusions

6.1 Population outbreaks of A. planci ...................................... 166
6.2 Impacts of A. planci on coral reef communities ...................... 168
6.3 Future directions ....................................................... 170

References ........................................................................ 172

Appendix 1 - Pratchett (1999) Coral Reefs 18: 272 ....................... i
Appendix 3 - Pratchett et al. (2000) Coral Reefs 19: 36 ............... vii
Appendix 8 - Hughes et al. (In press) Ecology ............................. xxx
List of Tables

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

Table 2.1 Taxonomic groupings of sessile invertebrates used to assess impacts of *A. planci* on benthic reef assemblages ........................................ 33
Table 2.2 Three-way ANOVA to explore variation in abundance of *A. planci* ...... 38
Table 2.3 Three-way ANOVA to explore variation in the body size (total body diameter) of *A. planci* ................................................................. 42
Table 2.4 Three-way ANOVA to explore variation in live cover of scleractinian corals ...................................................................................... 44
Table 2.5 Three-way MANOVA to explore variation in the community structure of benthic assemblages ......................................................... 46
Table 2.6 Structure coefficients for taxonomic groups of sessile invertebrates used in CDA of benthic assemblages ........................................... 48
Table 2.7 Temporal variation in the abundance of sessile invertebrates at both severely affected and relatively unaffected locations .................. 49

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

Table 4.1 Three-way ANOVA to explore variation in availability of live coral cover .............................................................................................. 98
Table 4.2 Three-way MANOVA to explore variation in the species composition of scleractinian coral prey ................................................................. 100
Table 4.3 Structure coefficients for species groups used in CDA of benthic communities .................................................................................. 102
Table 4.4 Three-way ANOVA to explore variation in the overall abundance of *Chaetodon* butterflyfish ................................................................. 103
Table 4.5 Three-way MANOVA to explore variation in the relative abundance of 13 butterflyfish species .............................................................. 106
Table 4.6 Structure coefficients for species groups used in CDA of butterflyfish assemblages .................................................................................. 108
Table 4.7 Three-way ANOVAs to explore variation in the abundance of each butterflyfish ..................................................................................... 110
Table 4.8 Range of prey categories used by each of eight species of *Chaetodon* butterflyfish .............................................................................. 114
Table 4.9 Temporal variation in the dietary composition of each of eight *Chaetodon* butterflyfish ................................................................. 117
Table 4.10 Patterns of feeding selectivity for each of eight butterflyfish species .... 119
Table 4.11 Multiple linear regression of butterflyfish abundance and prey availability ......................................................... 121

Table 4.12 Contrasting results from four different studies exploring changes in the abundance Chaetodon butterflyfish ......................................................... 123

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

Table 5.1 Log-linear models used to test patterns of habitat use ......................................................... 129

Table 5.2 Occupation of different coral species by coral-dwelling damselfish ......................................................... 135

Table 5.3 Log-linear analysis of habitat use by coral-dwelling damselfish ......................................................... 137

Table 5.4 Patterns of habitat use by coral-dwelling damselfish ......................................................... 138

Table 5.5 Three-way ANOVA to explore variation in the abundance of host corals used by coral-dwelling damselfish ......................................................... 139

Table 5.6 Three-way MANOVA to explore variation in the relative abundance of different host corals ......................................................... 141

Table 5.7 Temporal variation in the mean area cover of each habitat category ......................................................... 142

Table 5.8 Three-way ANOVAs to explore variation in the abundance of each of six coral-dwelling damselfish ......................................................... 144

Table 5.9 Habitat associations of coral-dwelling damselfish ......................................................... 147
List of Figures

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

**Figure 2.1** Map of Lizard Island showing the sampling locations used to assess populations dynamics and impacts of *A. planci* .......................... 29

**Figure 2.2** Temporal variation in the overall abundance of *A. planci* at Lizard Island from October 1994 to January 1999 .............................................. 35

**Figure 2.3** Temporal variation in the mean abundance of *A. planci* at each depth, in each location ................................................................. 37

**Figure 2.4** Temporal variation in the size-structure of starfish populations .......... 39

**Figure 2.5** Spatial variation in the size-structure of starfish populations .......... 41

**Figure 2.6** Temporal variation in the mean cover of scleractinian corals at each depth, in each location ........................................................................... 43

**Figure 2.7** Relationship between densities of crown-of-thorns starfish and the extent of coral decline observed at each location ........................................ 45

**Figure 2.8** Temporal variation in the community structure of benthic assemblages at each depth, in each location ................................................................. 47

Chapter 3: Influence of coral symbionts on feeding preferences of crown-of-thorns starfish

**Figure 3.1** Variation in the distribution of coral symbionts among six different coral species .................................................................................................. 70

**Figure 3.2** CDA of the community structure of symbiont assemblages from three *Acropora* species and three pocilloporid corals .................................. 71

**Figure 3.3** Variation in the average rank score for different corals species showing the relative avoidance by *A. planci* in controlled feeding trials ........................................................................................................ 76

**Figure 3.4** Variation in the average rank score for colonies of coral species which contained different symbiont assemblages ........................................... 78

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

**Figure 4.1** Map of Lizard Island showing reef profiles at each of four locations used to assess abundance of *Chaetodon* butterflyfish ........................................ 92

**Figure 4.2** Temporal variation in live coral cover at each, at each location .......... 99

**Figure 4.3** Canonical discriminant analysis showing temporal variation in the structure of coral communities ................................................................. 101
Figure 4.4 Temporal variation in the mean abundance *Chaetodon* butterflyfish, compared to overall declines in live coral cover ........................................... 104

Figure 4.5 Relationship between mean area cover of scleractinian corals and average densities of *Chaetodon* butterflyfish .................................................. 105

Figure 4.6 Canonical discriminant analysis showing temporal variation in the structure of butterflyfish assemblages .................................................. 107

Figure 4.7 Temporal variation in the mean abundance of butterflyfish, associated with impacts of outbreak populations of A. planci .......... 112

Figure 4.8 Variation in dietary composition among eight butterflyfish species .... 116

Figure 4.7 Temporal variation in the dietary composition of *C. baronessa* ........ 118

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

Figure 5.1 Map of Lizard Island showing locations used to assess abundance of coral-dwelling damselfish ................................................................. 126

Figure 5.2 Temporal variation in the distribution of damselfish among ten different habitat categories .......................................................... 134

Figure 5.3 Temporal and spatial variation in habitat availability for coral-dwelling damselfish .......................................................... 140

Figure 5.4 Variation in densities of coral-dwelling damselfish species between zones, between years and among sites ........................................ 145