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**Age determination and life-history characteristics of
Acanthaster planci (L.) (Echinodermata: Asteroidea).**

Thesis submitted by Richard Julian Witherington Stump

October 1994

**for the degree of Doctor of Philosophy in the Department of Zoology
at James Cook University of North Queensland**

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The following publication has been derived from work connected with the production of this thesis, and a copy of the publication is included in the back of this thesis:

Stump, R.J.W. and J.S. Lucas, 1990

Linear growth in spines from *A canthaster planci* (L.) involving growth lines and periodic pigment bands. Coral Reefs 9:149-154.

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Abstract

In the past, age classes in *Acanthaster planci* (L.) populations have been interpreted from modes in size frequency distributions. The relationship between size and age has continued to be used in studies despite increasing evidence of growth characteristics which are inconsistent with inherent assumptions. This approach was rationalised because the ability to determine age is fundamental to understanding the ecology and life history of this unique species, capable of developing massive outbreak populations and incurring widespread mortality of hard coral species. Therefore, the aims of the project were to develop a valid method of age determination and employ it to investigate the population dynamics, the morphometry of individual and skeletal growth and other life-history characteristics of several populations from the Western Pacific region.

Valid age determination in echinoderms has been achieved almost exclusively with echinoid species through skeletochronometric techniques. Periodic growth rings are generally found in larger skeletal elements such as test plates, since the echinoderm skeleton consists of an open tridimensional network, the calcitic stereom. However, the Asteroidea characteristically develop a skeleton of smaller ossicles which allows for a wide range of flexible movement, for locomotion, climbing and food handling. An exception is *A. planci* which has large spines that rest on pedicels, rooted in the aboral body wall, that do not restrict its habits.

The aboral spine ossicles of adult *A. planci* have a linear growth pattern unlike the mode of development previously reported for echinoids. Numerous growth lines, perpendicular to the long axis were evident in spine sections and confirmed with tetracycline staining, apparently caused by frequent growth episodes. Spine growth in adults is by elongation with addition of new stereom at the base, preserving the entire growth history. Broad pigment bands develop parallel to the growth lines and are visible on the ossicle surface after the removal of soft tissues. Therefore, it was hypothesised that spine pigment band counts (SPBC) can be used to determine age in *A. planci*, commencing after sexual maturity, in the third (2+) year. At this time,

body growth slows and spine ossicle growth changes from enlargement in three dimensions to a mode primarily of elongation. Therefore, one SPBC (light and dark band pair) = 3+ years, two SPBC = 4+ years, etc.. A biosynthetic mechanism was proposed to explain the functional role of the pigment banding process.

Field studies were conducted on Davies Reef, Central GBR, to validate the SPBC method. They consisted of mark-recapture exercises and collections of morphometric data for seasonal and longer-term growth analyses. The recapture rate for marked individuals was 3.5%. Twelve of thirteen recaptured individuals whose release periods were at least twelve months supported the validation of age classes 3+, 4+ and 5+ years. A further ten recaptures were obtained with release periods of less than twelve months, with incomplete band pair formation, also supporting the method. Further independent evidence comes from morphometric results, including: annual incremental growth in the SPBC classes; a significant increase in mean spine ossicle length over the 38 month study period; consistent estimates of the growth constant ($K = 0.039\text{mo.}^{-1}$) between the recapture and morphometric analyses; and the coincidence of the timing of the outbreak from survey results with the estimated age of the first outbreak cohort.

The outbreak population density on Davies Reef was approximately 420ha.^{-1} . This is at the lower end of the scale of outbreak sizes, and consisted of four principal cohorts, estimated to have settled between 1983 and 1986. A significant reduction in population size over the study period, following a profound decline in coral cover, was caused by high mortality rates in the post-outbreak cohorts. Lower mean asymptotic body sizes in each successive cohort occurred as a response to the increasingly limited resources.

A. planci can grow to well over 60cm in diameter and 4kg in wet weight, but more often exhibits lower ranges, well below maximum attainable size. The mode of growth varies between habitat-dependent, asymptotic growth (determinate) and plastic asymptotic growth (indeterminate). Therefore, determinate growth occurs when constraints are imposed on an underlying potential for indeterminate growth. Further

physiological studies are required to describe precisely how *A. planci* reach very large body sizes under solely intrinsic resource limitation.

Sexually dimorphic characteristics were found in the Davies Reef outbreak population, where male starfish had lower gonad weights, and longer lifespans, promoting high fertilization rates during the decline phase of outbreaks. Higher estimated reproductive effort and a seasonal oscillation in whole body diameter of 2 to 3 cm occurred in the post-outbreak cohorts. Therefore, larger body sizes in the pre-outbreak cohorts allowed for storage of relatively greater energy reserves to offset fluctuations in body size and the energetic demands of reproduction, promoting iteroparity and longevity. When resources became limited in higher densities, body reserves were drawn upon more heavily in order to support the increased reproductive effort causing resorption of body wall and skeletal tissues, resulting in shrinkage and presumably reduced lifespan.

Among the Western Pacific populations studied (Suva Reef, Guam and Davies Reef) reproductive tactics were described as "big-bang iteroparity" (Davies Reef and Suva Reef), approaching semelparity in higher density outbreaks, and iteroparous with a lower reproductive output (Guam). A life-history strategy of phenotypically polymorphic bet-hedging is proposed for *A. planci*, which varies according to sex, population density, the pattern of mortality from *stress* (decreased production), and *disturbance* (loss of biomass). Therefore, *A. planci* owes its success to the ability to vary its channelling of resources into the various functions of growth, somatic maintenance, protection and reproduction. To maintain this variable strategy between iteroparity and semelparity implies that periodic outbreaks of *A. planci* occur within regions under natural conditions. The immediate concerns of management agencies regarding the prediction of outbreaks should focus on the dynamics of expanding populations i.e. those leading to primary outbreaks. These issues can only be addressed through the implementation of long-term population studies, including the assessment of age structure, particularly in areas where primary outbreaks are suspected to occur.

TABLE OF CONTENTS

Acknowledgments

| | |
|-------------------|-------|
| Abstract | vii |
| Table of contents | x |
| List of tables | xviii |
| List of figures | xxvi |

CHAPTER 1

GENERAL INTRODUCTION

| | |
|--|----|
| 1.1. Introduction | 1 |
| 1.2. Ecology of populations in the Indo-Pacific region | 5 |
| 1.3. Characteristics of growth in Asteroidea | 8 |
| 1.4. Longevity in Asteroidea | 11 |
| 1.5. The study of life history in <i>A. planci</i> | 13 |
| 1.5.1. Evaluation of life-history theory | 13 |
| 1.5.2. Age and life histories | 18 |
| 1.5.3. Assessment of life histories | 19 |

CHAPTER 2

VALIDATION STUDY OF THE SPINE PIGMENT BAND COUNT (SPBC) METHOD OF AGE DETERMINATION FOR *A. planci*.

| | |
|---|----|
| 2.1. Introduction | 23 |
| 2.1.1. Morphological characteristics, growth and age | 23 |
| 2.1.2. Marking and identification in the field | 25 |
| 2.1.3. The SPBC method of age determination | 26 |
| 2.2. Methods | 27 |
| 2.2.1. Davies Reef recapture study | 27 |
| 2.2.2. Site selection | 28 |
| 2.2.3. Morphometry in other populations | 29 |
| 2.2.4. Experimental methods | 29 |
| 2.2.4.1. Use of tetracycline as a permanent skeletal marker | 29 |
| 2.2.4.2. Effects of starvation on morphometric variables | 30 |
| 2.2.5. Field collections | 31 |
| 2.2.6. Morphometry and age determination procedures | 33 |
| 2.2.7. Population size and density | 34 |
| 2.2.8. Spine growth in the Western Pacific populations | 35 |
| 2.3. Results | 36 |
| 2.3.1. The aboral spine appendage | 36 |
| 2.3.1.1. Structure and growth of aboral spines | 36 |
| 2.3.2. Skeletal ossicle and whole body morphometry | 38 |
| 2.3.2.1. Effect of concentrations of the tetracycline marker | 38 |
| 2.3.3. Validation of the age determination method | 39 |
| 2.3.4. Assessment of the SPBC method | 42 |
| 2.3.4.1. Recapture analyses | 42 |
| 2.3.4.2. Spine ossicle length and whole body diameter morphometry | 44 |
| 2.3.4.3. Estimated population size and density | 45 |
| 2.3.5. Analyses of the morphometric variables | 45 |
| 2.3.5.1. Assessment of pigment band readability | 45 |

| | | |
|----------|--|----|
| 2.3.5.2. | Sample sizes of variables within individuals | 46 |
| 2.3.5.3. | Morphometry of unfed <i>A. planci</i> | 47 |
| 2.3.5.4. | Population allometry in the Western Pacific region | 49 |
| 2.4. | Discussion | 54 |
| 2.4.1. | Validity of the method of age determination | 54 |
| 2.4.2. | Growth lines and pigment bands | 55 |
| 2.4.3. | Spine growth in echinoderms | 57 |
| 2.4.4. | Growth and age estimation in <i>A. planci</i> | 58 |
| 2.4.5. | Regeneration of amputated arms | 59 |
| 2.4.6. | Optimum dosage of tetracycline | 59 |
| 2.4.7. | Spine growth and life history of <i>A. planci</i> | 60 |
| 2.4.8 | Population allometry of body size and spine ossicle length | 61 |

CHAPTER 3

THE DAVIES REEF POPULATION STUDY OF *A. planci*.

| | | |
|----------|---|----|
| 3.1. | Introduction | 77 |
| 3.1.1. | <i>A. planci</i> population studies | 77 |
| 3.1.2. | Recent history of populations in the Central GBR | 78 |
| 3.1.3. | Life-history characteristics of <i>A. planci</i> | 79 |
| 3.1.3.1. | Life history information from experimental <i>A. planci</i> | 79 |
| 3.1.3.2. | The mode of growth in <i>A. planci</i> | 80 |
| 3.1.4. | The principle of symmetry in life histories | 84 |
| 3.2. | Methods | 86 |
| 3.2.1. | Davies Reef collections | 86 |
| 3.2.2. | Other populations from the GBR region | 87 |
| 3.2.3. | Population morphometric analyses | 88 |
| 3.2.3.1. | Analyses for seasonal variation and asymptotic growth | 88 |
| 3.2.3.2. | Mortality rate | 89 |
| 3.2.3.3. | Curve fitting | 89 |

| | |
|---|-----|
| 3.3. Results | 90 |
| 3.3.1. Population dynamics | 90 |
| 3.3.1.1. Changes in population density | 90 |
| 3.3.1.2. Timing of settlement of the outbreak cohorts | 91 |
| 3.3.2. Population morphometric analyses | 91 |
| 3.3.2.1. Analyses of size frequency distributions | 91 |
| 3.3.2.2. Analyses of growth in morphometric variables | 92 |
| 3.3.3. Allometry in pre and post-outbreak groups | 94 |
| 3.3.4. Cohort morphometric analyses | 99 |
| 3.3.4.1. Whole body diameter growth in cohorts | 99 |
| 3.3.4.2. Growth of spine ossicle and whole spine appendage growth in cohorts | 101 |
| 3.3.4.3. Primary and secondary oral ossicle growth in cohorts | 105 |
| 3.3.5. Morphometric analyses among three GBR populations | 107 |
| 3.3.6. Life-history constants | 110 |
| 3.4. Discussion | 113 |
| 3.4.1. Further support for the SPBC method | 113 |
| 3.4.2. Time series morphometric study | 115 |
| 3.4.2.1. Population dynamics in the Central GBR | 115 |
| 3.4.2.2. Assessment of the Davies Reef population estimates | 116 |
| 3.4.2.3. Davies Reef population characteristics | 117 |
| 3.4.2.4. Seasonal and long term variability in cohorts | 119 |
| 3.4.2.5. Mortality in cohorts | 121 |
| 3.4.3. Life-history characteristics in the Davies Reef population | 122 |
| 3.4.4. Mode of body growth in <i>A. planci</i> | 126 |
| 3.4.5. An alternative assessment of body growth | 129 |
| 3.4.6. Longevity in populations from the GBR | 131 |

CHAPTER 4

COMPARATIVE MORPHOMETRIC STUDY OF *A. planci* POPULATIONS FROM THE WESTERN PACIFIC REGION

| | |
|---|-----|
| 4.1. Introduction | 158 |
| 4.2. Methods | 159 |
| 4.2.1. Description of regions and population histories | 159 |
| 4.2.1.1. Davies Reef, Central GBR | 159 |
| 4.2.1.2. Guam, USA | 160 |
| 4.2.1.3. Suva Reef, Fiji | 160 |
| 4.2.2. Collection methods for each location | 161 |
| 4.2.2.1. Davies Reef | 161 |
| 4.2.2.2. Guam | 161 |
| 4.2.2.3. Suva Reef | 161 |
| 4.2.3. Sample preparation | 162 |
| 4.2.4. Age determination and morphometry | 162 |
| 4.2.5. Morphometric analyses | 163 |
| 4.3. Results | 165 |
| 4.3.1. Populations and habitats | 165 |
| 4.3.1.1. Davies Reef | 165 |
| 4.3.1.2. Guam | 165 |
| 4.3.1.3. Suva Reef | 166 |
| 4.3.2. Frequency distribution analyses | 167 |
| 4.3.3. Sexual dimorphism | 170 |
| 4.3.4. Allometry of body size and skeletal ossicles | 171 |
| 4.3.5. Influence of estimated age on population morphometry | 174 |
| 4.3.6. Adult population morphometric analyses | 178 |
| 4.3.6.1. Underwater weight and whole body diameter | 179 |
| 4.3.6.2. Whole wet weight and whole body diameter | 180 |
| 4.3.6.3. Underwater weight and whole wet weight | 182 |
| 4.3.6.4. Spine ossicle length and estimated age | 184 |

| | | |
|----------|---|-----|
| 4.3.7. | Adult body growth in populations | 186 |
| 4.3.8. | Multiple regression models for skeletal ossicle variables | 187 |
| 4.3.8.1. | Minimal model analysis for spine ossicle length | 188 |
| 4.3.8.2. | Minimal model analysis for whole spine appendage length | 189 |
| 4.3.8.3. | Minimal model analysis for adjusted primary oral ossicle weight | 190 |
| 4.3.8.4. | Minimal model analysis for adjusted secondary oral ossicle weight | 191 |
| 4.3.8.5. | Minimal model analysis for adjusted interbrachial ossicle weight | 192 |
| 4.3.8.6. | Minimal model analysis for adjusted madreporite ossicle weight | 193 |
| 4.3.8.7. | Summary of principal dependent variables used in the multiple regression modelling analyses of the skeletal ossicle variables | 194 |
| 4.3.9. | Life-history characteristics among populations | 194 |
| 4.4. | Discussion | 199 |
| 4.4.1. | Morphometric characteristics of the populations | 199 |
| 4.4.1.1. | Morphometric characteristics in the lower density populations | 199 |
| 4.4.1.2. | Morphometric characteristics in a higher density population | 200 |
| 4.4.2. | Allometric relationships for body size | 201 |
| 4.4.3. | Morphometry and estimated longevity | 204 |
| 4.4.4. | Multiple regression models | 207 |
| 4.4.5. | Life-history characteristics | 209 |
| 4.4.5.1. | Variation in life-history constants | 209 |
| 4.4.5.2. | Life-history characteristics of populations | 212 |

CHAPTER 5

REPRODUCTIVE MORPHOMETRY OF *A. planci* FROM THE WESTERN PACIFIC REGION

| | |
|--|-----|
| 5.1. Introduction | 247 |
| 5.1.1. Reproduction as the foundation of life histories | 247 |
| 5.1.2. Physiological trade offs involving reproduction | 248 |
| 5.1.3. Reproductive characteristics in populations | 251 |
| 5.2. Methods | 253 |
| 5.2.1. Population sample collections | 253 |
| 5.2.1.1. Davies Reef | 253 |
| 5.2.1.2. Fiji and Guam | 254 |
| 5.2.2. Morphometric analyses of reproduction | 254 |
| 5.2.2.1. Analyses of Covariance (ANCOVA) | 254 |
| 5.3. Results | 255 |
| 5.3.1. Sexual dimorphism | 255 |
| 5.3.2. Allometry of gonad weight and whole wet weight | 258 |
| 5.3.2.1. Power analyses for whole testes weight and whole wet weight | 258 |
| 5.3.2.2. Power analyses for whole ovary weight and whole wet weight | 259 |
| 5.3.2.3. Linear regression analyses for whole testes weight and whole wet weight | 260 |
| 5.3.2.4. Linear regression analyses of whole ovary weight and whole wet weight | 261 |
| 5.3.2.5. Summary of allometric relationships for gonad weights and whole wet weight | 263 |
| 5.3.3. Analyses for gonad weights and estimated age | 264 |
| 5.3.4. Analyses of size-adjusted gonad weights and estimated age | 265 |
| 5.3.4.1. Analyses of size-adjusted gonad weights in three populations | 267 |
| 5.3.4.2. Analyses of size adjusted gonad weights between sexes | 268 |
| 5.3.5. Analyses of somatic weights in five populations | 269 |

| | | |
|------------------|---|-----|
| 5.3.6. | Analyses for the Davies pre and post-outbreak groups | 272 |
| 5.3.7. | Summary of reproductive characteristics in the five populations from the Western Pacific region | 279 |
| 5.4. | Discussion | 280 |
| 5.4.1. | General reproductive characteristics | 280 |
| 5.4.2. | Body growth and fecundity | 281 |
| 5.4.3. | Reproductive allometry | 283 |
| 5.4.4. | Population reproductive characteristics | 284 |
| 5.4.5. | Characteristics of sex | 287 |
| 5.4.6. | Resource demand in high density populations | 288 |
| 5.4.7. | Reproduction and life-history characteristics | 289 |
| | | |
| CHAPTER 6 | | |
| | | |
| | A LIFE-HISTORY STRATEGY FOR <i>A. planci</i> | 300 |
| 6.1. | The development of a life-history strategy for <i>A. planci</i> | 300 |
| 6.2. | A summary of the principal results from this study | 302 |
| 6.4. | A specific life-history strategy for <i>A. planci</i> | 309 |
| 6.5. | Life-history variation and fitness | 315 |
| | | |
| | REFERENCES | 319 |
| | | |
| | APPENDICES | 341 |

List of Tables

CHAPTER 1.

Table 1.1. The primary life history strategies in species, *sensu stricto* Grime (1977), determined by factors limiting biomass, i.e. environmentally determined combinations of characteristics for habitat-determined strategies. 17

CHAPTER 2. Validation of the SPBC method of age determination.

Table 2.1 Location and dates of population collection of *A. planci* from the Western Pacific region. 35

Table 2.2 Analyses of changes in whole body morphometry in unfed *A. planci* over six months (where a = start; b = 3 months; c = 6 months): (i) Paired t test; (ii) ANOVA; (iii) Curve fitting analyses, using $y = a \cdot e^{-bx}$ 39

Table 2.3. Replicated madreporite patterns from the Davies Reef *A. planci* population. 40

Table 2.4a. Summary of results from the mark and recapture exercise for *A. planci* on Davies Reef (October, 1988 to December, 1991). Recapture results (mm) for validation of the method where individuals were released and recaptured for more than 12 months. b. Recapture results (mm) for validation of the method where individuals were released and recaptured within 12 months. 41

Table 2.5 Results of assessment of readability of spine pigment band counts, for between and within readers. 46

Table 2.6 Analyses of changes in whole body morphometry in unfed *A. planci* over 6 months (where: a = start; b = 3 months; c = 6 months); (i) paired t test; (ii) ANOVA; (iii) curve fitting analyses, using: $y = e^{-b \cdot x}$. 48

| | |
|--|----|
| Table 2.7 Summary of regression analyses of the relationship between spine ossicle length and whole body diameter in eight populations from the Western Pacific region (DA Davies Reef; HI Hook Island; KI Kiribati; GU Guam; TO Tonga; LH Lord Howe Island; SU Suva Reef; LM Lady Musgrave Reef). | 49 |
|--|----|

CHAPTER 3

| | |
|---|----|
| Table 3.1. Estimates of collection rates (CR, person ⁻¹ .hr ⁻¹) on Davies Reef between October 1988 and December 1991. | 90 |
|---|----|

| | |
|--|----|
| Table 3.2. Linear regression analyses of five variables using whole samples (* except for the relationship between (S) and (BD) where individuals < 3 years were omitted) from Davies Reef, between October 1988 to December 1991. | 92 |
|--|----|

| | |
|---|----|
| Table 3.3 Linear regression analyses of five morphometric variables and estimated age (AGE) using all data from the Davies Reef <i>A. planici</i> population. | 93 |
|---|----|

| | |
|--|----|
| Table 3.4. Multiple regression analyses for the dependent variable spine ossicle length from the Davies Reef <i>A. planici</i> population. | 95 |
|--|----|

| | |
|--|----|
| Table 3.5. Multiple regression analyses for the dependent variable whole spine appendage length from the Davies Reef <i>A. planici</i> population. | 96 |
|--|----|

| | |
|---|----|
| Table 3.6. Multiple regression analyses for the dependent variable primary oral ossicle weight from the Davies Reef <i>A. planici</i> population. | 97 |
|---|----|

| | |
|---|----|
| Table 3.7. Multiple regression analyses for the dependent variable secondary oral ossicle weight from the Davies Reef <i>A. planici</i> population. | 98 |
|---|----|

| | |
|--|-----|
| Table 3.8. Summary of curve analyses of spine ossicle length (S) for <i>A. planici</i> cohorts from Davies Reef which settled between 1982 and 1987 (Figure 3.11; Appendix 3.1). | 102 |
|--|-----|

| | |
|--|-----|
| Table 3.9. Summary of curve analyses of whole spine appendage length (WS) for <i>A. planci</i> cohorts from Davies Reef which settled between 1982 and 1987 (Figure 3.17; Appendix 3.3). | 104 |
| Table 3.10. Mean whole spine appendage length and SE of <i>A. planci</i> in the early summer spawning season (samples from 3 consecutive seasons) at (AGE) 2+, 3+ and 4+ years from Davies Reef. | 104 |
| Table 3.11. Summary of curve analyses of primary and secondary oral ossicle weight for <i>A. planci</i> cohorts which settled between 1982 and 1987 from Davies Reef ((PO); Figure 3.16; Appendix 3.4) and ((SO); Figure 3.18; Appendix 3.5). | 106 |
| Table 3.12. Mean whole body diameter and estimated population density in four <i>A. planci</i> populations from the GBR Region. | 107 |
| Table 3.13. Summary of life history coefficients calculated for four cohorts (1983-1986) from the <i>A. planci</i> population on Davies Reef. | 110 |
| Table 3.14. Life-history constants calculated for the four principal cohorts (1983 to 1986) in the <i>A. planci</i> population from Davies Reef. | 111 |
| Table 3.15. Linear regression analyses for: growth rate using ($K_{(S)}$, $K_{(BD)}$) and mortality rate M and, estimated maximum size using (BD), (S) and mortality rate M for the four principal cohorts (1983 to 1986) of <i>A. planci</i> from Davies Reef. | 112 |

CHAPTER 4.

| | |
|---|-----|
| Table 4.1. Ranked <i>A. planci</i> population characteristics according to mean adult body diameter (MA(BD)) in five populations from the Western Pacific region. | 168 |
|---|-----|

Table 4.2. Summary of non parametric size frequency analyses (Appendix 4.1) to group five *A. planci* populations from the Western Pacific region using ANOVA where no significant differences was found among the frequency distributions in each of the morphometric variables. 169

Table 4.3a, b, c. Allometric power coefficients for five *A. planci* populations from the Western Pacific region derived from analyses between skeletal ossicle variables and whole body size variables (BD, WET, UW). 172

Table 4.4. Five *A. planci* populations from the Western Pacific region ranked using the size of exponents from the power equation ($y = b \cdot X^n$) for three variables measuring whole body size (UW, WET and BD). 173

Table 4.5a. Summary of Bartlett's test of equal variances between estimated age classes in five *A. planci* populations from the Western Pacific region (including all age classes); where H_0 = there is no significant difference in variances of the variable between estimated age groups. 175

Table 4.5b. Summary of Bartlett's test of equal variances between estimated age classes in five *A. planci* populations from the Western Pacific region (selected individuals which were sexed); H_0 = there was no significant difference in variances of the variable between estimated age groups (i.e. $P > 0.01$). Where: NA = not tested due to single value for one age class. 176

Table 4.6a. Summary of results of the replication tests-of-fit analyses for all age groups in five *A. planci* populations from the Western Pacific region. Full results are presented in Appendix 4.3A. H_0 = there was a linear trend with estimated age. 176

Table 4.6b. Summary of results of the replication tests-of-fit analyses in five *A. planci* populations from the Western Pacific region, omitting starfish which were not sexed. Full results are presented in Appendix 4.4B. H_0 = there was a linear trend with estimated age. 177

| | |
|---|-----|
| Table 4.7. Ranked mean standard error of estimates for each morphometric variable for five <i>A. planci</i> populations from the Western Pacific region. | 178 |
| Table 4.8. Summary of linear regression analyses of adult growth (where (AGE) > 3 years) in five <i>A. planci</i> populations from the Western Pacific region, using log normal transformed dependent variables; whole body diameter, underwater weight and whole wet weight. | 186 |
| Table 4.9. Summary of principal dependent variables used to explain ossicle length (S) or (WS), or weight (POA), (SOA), (IBA) and (MA) among five <i>A. planci</i> populations of the Western Pacific region. | 194 |
| Table 4.10. Summary of life-history characteristics in five <i>A. planci</i> populations from the Western Pacific region predicted from analyses using the von Bertalanffy growth equation (where coefficients significance is $P < 0.01$). | 195 |
| Table 4.11. Life-history constants and mortality rates calculated for five <i>A. planci</i> populations from the Western Pacific region. | 196 |
| Table 4.12. Pearson correlation coefficient analyses for life-history constants: the growth constant using ($K_{(S)}$, $K_{(BD)}$) and mortality rate M and, estimated maximum size using (BD), (S) for the five <i>A. planci</i> populations from the Western Pacific region. | 198 |
| Table 4.13. Summary of population and morphometric characteristics of <i>A. planci</i> from five populations in the Western Pacific region. | 213 |

CHAPTER 5

- Table 5.1. The morphometric characteristics of reproduction; mean body size and mean gonad weight in five *A. planci* populations. 256
- Table 5.2. The morphometric characteristics of reproduction at sexual maturity; mean body size and gonad weight at maturity (α) in five *A. planci* populations, (α) = estimated age at first spawning, i.e. 3 years). 257
- Table 5.3. Regression analyses and Student' t test for isometry of whole testes weight and whole wet weight among five *A. planci* populations from the Western Pacific region. 258
- Table 5.4. Regression analyses and Student' t test for isometry of whole ovary weight and whole wet weight among five *A. planci* populations from the Western Pacific region. 259
- Table 5.5. Population samples which gonad growth demonstrated positive allometry ($a > 1$) in *A. planci* populations from the Western Pacific region. 263
- Table 5.6. Regression analyses of testes weight and estimated age in five *A. planci* populations from the Western Pacific region. 264
- Table 5.7. Linear regression analyses between whole ovary weight and estimated age in five *A. planci* populations from the Western Pacific region. 265
- Table 5.8. Linear regression analyses for adjusted testes weight and estimated age in three *A. planci* populations from the Western Pacific region. 266
- Table 5.9. Linear regression analyses for adjusted ovary weight and estimated age ((AGE) = 3 to 7 years) in three *A. planci* populations from the Western Pacific region. 267

| | |
|--|-----|
| Table 5.10. Summary of mean adjusted gonad weights (adjusted for whole wet weight = 1636g) in three <i>A. planci</i> populations from the Western Pacific region; (a) adjusted testes weight (AGWT), (b) adjusted ovary weight (AGWO). | 269 |
| Table 5.11. ANOVA of adjusted gonad weights between sexes in three <i>A. planci</i> populations from the Western Pacific region. | 270 |
| Table 5.12. Summary of mean adjusted male somatic weights in five <i>A. planci</i> populations from the Western Pacific region. | 271 |
| Table 5.13. Summary of mean adjusted female somatic weights in five <i>A. planci</i> populations from the Western Pacific region. | 272 |
| Table 5.14. Summary of analyses of adjusted somatic weights between sexes in five <i>A. planci</i> populations from the Western Pacific region. | 273 |
| Table 5.15. Summary of mean whole wet weights for PRE and PST groups in (a) male starfish and, (b) female starfish from the Davies Reef <i>A. planci</i> population. | 274 |
| Table 5.16. Summary of mean gonad weights and ANOVA between sexes in the Davies Reef PRE group, (a) unadjusted and, (b) adjusted for mean whole wet weight = 2208g. | 275 |
| Table 5.17. Summary of mean gonad weights and ANOVA between sexes in the Davies Reef PST group, (a) unadjusted and, (b) adjusted for mean whole wet weight = 2208g. | 276 |
| Table 5.18. Regression analysis for whole testes weight and whole wet weight between the PRE and PST groups. | 277 |

Table 5.19. Regression analysis for whole ovary weight and whole wet weight between the PRE and PST groups. 278

Table 5.20. Summary of mean adjusted ovary weights (adjusted for whole wet weight = 2208g) between Davies Reef PRE and PST groups. 279

Table 5.21. Summary of reproductive characteristics of *A. planici* developed under various conditions. 289

List of Figures

CHAPTER 2. Validation of the SPBC method of age determination

Figure 2.1. Map of the Western Pacific Region with location of seven populations used in the comparative morphometric study between spine ossicle length and whole body diameter.

Figure 2.2(a-h).

(a) Aboral spine ossicle and pedicel from the aboral arm of *A. planci*. The spine ossicle shows 6 pigment bands on its shaft and a pigment capped spine apex (a). The pedicel has a flanged root (r) at its base and pigment bands occur toward the tip (t). The base of the spine ossicle (b) rests on the tip of the pedicel (t), where the whole spine articulates. (bar = 10mm)

(b) Section of the base of an aboral spine ossicle, showing stereom growth stained with tetracycline. The stained region lies parallel to the basal surface (b). (bar = 0.5mm)

(c) Section of the tip of an aboral spine pedicel showing stereom growth stained with tetracycline. The stained region lies parallel to the surface of the pedicel tip. (bar = 0.7mm)

(d) Longitudinal thin-section of an aboral spine ossicle demonstrating numerous growth lines parallel to the spine base (b) in both the medulla (m) and outer cortex (c). (bar = 0.3mm)

(e) Longitudinal thin-section of aboral spine ossicle from *A. planci* raised in the laboratory (20 months). The developing structure of the medulla with linear arrangement of trabeculae (lt) is distinct from the rest of the juvenile spine stereom. (bar = 0.5mm)

(f) Adult aboral spine ossicle in longitudinal section showing detail of the intersection between the spine apex and shaft. The medulla (m) develops from the spine apex. The cortex (c) develops and expands from the remanent juvenile spine margins. (bar = 0.5mm)

(g) Spine and pedicel ossicles from a juvenile *A. planici* reared in the laboratory (BD = 12cm) and an adult *A. planici* (BD = cm) collected from Davies Reef, Central GBR. The spear-like spine apex has developed prior to the spine shaft in the older specimen. (bar = 10mm)

(h) Aboral spines from one *A. planici* recaptured after 6 months on Davies Reef, Central GBR (October, 1988 to April, 1989 (A)). Pigment bands are matched between the two sets of spines revealing the new spine growth and banding in the lower group of 3 spines. (bar = 10mm)

Figure 2.3a-c. Spine ossicle samples from 3 marked and recaptured individuals which demonstrate the growth and banding pattern developed over 12 to 14 months; arrowheads indicate light bands (L) developed between dark bands (D) on the shaft after spine apex (scale approx. bar = 0.7mm):

(a) Released 10/89, for 14 months (growth = D + L)

(b) Released 10/89, for 18 months (growth D + L + D)

(c) Released 3/90, for 14 months (growth L + D)

(d) Recapture after identification in the field using two adjacent regenerated arms (arrows) which are smaller than neighbouring arms and the spines are commensurately short (body diameter = 37cm).

Figure 2.4. Plot of linear regression for spine ossicle growth increment and spine ossicle length (at 0.5 x duration of the interim period) in 23 recaptured *A. planci* from Davies Reef (October, 1988 to December, 1991). Where the interim period is the time between release and recapture.

Figure 2.5. (a) Relationship between spine ossicle length and estimated age (month) from the Davies Reef population, using samples October, 1988 and April, 1989; (b) Relationship between whole body diameter and estimated age (month) from the Davies Reef population, using samples October, 1988 and April, 1989.

Figure 2.6. The effect of sample size on the coefficient of variation (CV %) for: (a) Spine ossicle length (mm); (b) Whole spine appendage (mm).

Figure 2.7. The effect of sample size on the coefficient of variation (CV %) for: (a) Primary oral ossicle weight (g); (b) Secondary oral ossicle weight (g).

Figure 2.8. The influence of starvation over six months on three morphometric variables: (a) Whole wet weight (g); (b) Whole body diameter (cm); (c) Underwater weight (g).

Figure 2.9. (a) Plot of standardised residuals for multiple regression model demonstrating a lack of residual trend in data after model has been fitted. (b) Plot of log transformed spine ossicle length (mm) and whole body diameter (cm) for seven populations sampled from the Western Pacific Region: Davies Reef, Central GBR (DA); Hook Island, Whitsunday Group GBR (HI); Lady Musgrave Reef (LM), Southern GBR; Tonga (TO), Central Pacific; Guam (GU) North West Pacific; Kiribati (KI) Central Pacific Lord Howe Island (LH), NSW; and Suva Reef, Fiji (SU), Central Pacific.

CHAPTER 3. The Davies Reef population study

Figure 3.1 Serial map of the Central Section (GBR) showing the annual distribution of outbreaks of *A. planci* between 1983 and 1988. The position of the reef used for the population study is indicated: Davies Reef (October, 1988 to December, 1991).

Figure 3.2 Size/frequency distributions of whole body diameter (BD) cm from Davies Reef (October 1988 to December 1991).

Figure 3.3 Size/frequency distributions of whole spine ossicle length (S) mm from Davies Reef (October 1988 to December 1991).

Figure 3.4 Size/frequency distributions of whole spine appendage length (WS) mm from Davies Reef (October 1988 to December 1991).

Figure 3.5 Size/frequency distributions of spine pigment band counts (SPBC) from Davies Reef (October 1988 to December 1991).

Figure 3.6 Size/frequency distributions of estimated age (AGE) from Davies Reef (October 1988 to December 1991).

Figure 3.7 Size/frequency distributions of primary oral ossicle weight (PO) g estimated age (AGE) from Davies Reef (October 1988 to December 1991).

Figure 3.8 Size/frequency distributions of secondary oral ossicle weight (PO) g estimated age (AGE) from Davies Reef (October 1988 to December 1991).

Figure 3.9 Plot of fitted cubic spline curves (dotted) for whole body diameter (BD) and (T) in the principal cohorts (1984 to 1987) and overlay of combined mean plot (solid) with SE, over the 38 month study on Davies Reef (October, 1988 to December, 1990)

Figure 3.10 Plot of mean and SE of whole body diameter (BD) in each sample and (T) joined by straight lines in each cohort (1983 to 1988) over the study period on Davies Reef (October, 1988 to December, 1990).

Figure 3.11 Plot of linear regressions (dotted) for spine ossicle length (S) and (T) in the principal cohorts (1984 to 1987) and overlay of combined means and SE with a cubic spline fit (dashed) and linear regression fit (solid), over the 38 month study on Davies Reef (October, 1988 to December, 1990)

Figure 3.12 Plot of mean and SE of spine ossicle length (S) in each sample and (T) joined by straight lines in each cohort (1982 to 1988) over the study period on Davies Reef (October, 1988 to December, 1990).

Figure 3.13 Plot of linear regressions (dotted) for whole spine appendage length (WS) and (T) in the principal cohorts (1984 to 1987) and overlay of combined means and SE with a cubic spline fit (dashed) and linear regression fit (solid), over the 38 month study on Davies Reef (October, 1988 to December, 1990)

Figure 3.14 Plot of mean and SE of whole spine appendage length (S) in each sample and (T) joined by straight lines in each cohort (1982 to 1988) over the study period on Davies Reef (October, 1988 to December, 1990).

Figure 3.15 Plot of linear regressions (dotted) for primary oral ossicle weight (PO) and (T) in the principal cohorts (1984 to 1987) and overlay of combined means and SE with a cubic spline fit (dashed) and linear regression fit (solid), over the 38 month study on Davies Reef (October, 1988 to December, 1990).

Figure 3.16 Plot of mean and SE of primary oral ossicle weight (PO) in each sample and (T) joined by straight lines in each cohort (1982 to 1987) over the study period on Davies Reef (October, 1988 to December, 1990).

Figure 3.17 Plot of linear regressions (dotted) for secondary oral ossicle weight (SO) and (T) in the principal cohorts (1984 to 1986) and overlay of combined means and SE with a cubic spline fit (dashed) and linear regression fit (solid), over the 38 month study on Davies Reef (October, 1988 to December, 1990).

Figure 3.18 Plot of mean and SE of secondary oral ossicle weight (PO) in each sample and (T) joined by straight lines in each cohort (1983 to 1987) over the study period on Davies Reef (October, 1988 to December, 1990).

Figure 3.19. Linear regression analysis of mean whole body diameter (cm) and estimated population density (ha^{-1}) in four populations from the GBR region: Helix Reef (from Kettle, 1990); Davies Reef; Butterfly Bay, Hook Island; and Lady Musgrave Reef.

Figure 3.20 Linear regression analyses of spine ossicle length (S) and estimated age (AGE) in three populations: Davies Reef ($n = 1549$); Butterfly Bay, Hook Island ($n = 68$); and Lady Musgrave Reef ($n = 9$).

CHAPTER 4.

Figure 4.1. Regional map of the Indo-Pacific with inset detail of the 5 study areas: Davies Reef (GBR), Suva Reef (Fiji) and the north western side of Guam with the positions of Hospital Point, South Tumon Bay and Double Reef.

Figure 4.2. Size frequency distributions of whole body diameter (cm) for *A. planici* in five populations.

Figure 4.3. Size frequency distributions of underwater weight (g) for *A. planici* in five populations.

Figure 4.4. Size frequency distributions of whole wet weight (g) for *A. planici* in 5 populations.

Figure 4.5. Size frequency distributions of spine ossicle length (mm) for *A. planci* in five populations.

Figure 4.6. Size frequency distributions of whole spine length (mm) for *A. planci* in five populations.

Figure 4.7. Size frequency distributions of spine pigment band counts for *A. planci* in five populations.

Figure 4.8. Size frequency distributions of estimated age (year) determined by spine pigment band counts for *A. planci* in five populations.

Figure 4.9. Size frequency distributions of primary oral ossicle weight (g) (adjusted for number of arms per individual) for *A. planci* in five populations.

Figure 4.10. Size frequency distributions of secondary oral ossicle weight (g) (adjusted for number of arms per individual) for *A. planci* in five populations.

Figure 4.11. Size frequency distributions of inter brachial ossicle weight (g) (adjusted for number of arms per individual) for *A. planci* in five populations.

Figure 4.12. Size frequency distributions of madreporite ossicle weight (g) (adjusted for number of madreporites per individual) for *A. planci* in five populations.

Figure 4.13a-i. Plots of standardised residuals derived from ANOVA for nine variables in five populations of *A. planci*.

Figure 4.14. Allometric relationships between whole body diameter (cm) and eight morphometric variables (two whole body and six skeletal ossicle variables) for *A. planci* in five populations.

Figure 4.15. Allometric relationships between underwater weight (g) and eight morphometric variables (two whole body and six skeletal ossicle variables) for *A. planci* in five populations.

Figure 4.16. Allometric relationships between whole wet weight (g) and eight morphometric variables (two whole body and six skeletal ossicle variables) for *A. planci* in five populations.

Figure 4.17. Relationships between all estimated age groups using spine pigment band counts (year) and nine morphometric variables (three whole body and six skeletal ossicle variables) for *A. planci* in five populations.

Figure 4.18. Relationships between estimated age groups > three years using spine pigment band counts and nine morphometric variables (three whole body and six skeletal ossicle variables) for *A. planci* in five populations.

Figure 4.19a. Plot of standardised residuals of underwater weight (g) and whole body diameter (cm) for *A. planci* in five populations.

Figure 4.19B. Linear regressions of ln (underwater weight) (g) and ln (whole body diameter) (cm) for *A. planci* in five populations omitting estimated age < three years.

Figure 4.20a. Plot of standardised residuals of whole wet weight (g) and whole body diameter (cm) for *A. planci* in five populations.

Figure 4.20b. Linear regressions of ln (whole wet weight) (g) and ln (whole body diameter) (cm) for *A. planci* in five populations omitting estimated age < three years.

Figure 4.21a. Plot of standardised residuals of whole wet weight (g) and underwater weight (cm) for *A. planci* in five populations. 4.21b. Linear regressions of ln (whole wet weight) (g) and ln (whole body diameter) (cm) for 5 populations omitting estimated age < three years.

Figure 4.22. Linear regressions of \ln (spine ossicle length) (mm) and age (month) estimated by spine ossicle pigment band counts for *A. planci* in five populations omitting estimated age < three years.

Figure 4.23a-d. Growth curves derived from; (a) whole body diameter (cm) and estimated age (month), (b) spine ossicle length (mm) and estimated age, (c) whole wet weight (g) and estimated age (month), and (d) underwater weight and estimated age (month) using spine ossicle pigment band counts in three Western Pacific *A. planci* populations; Davies Reef (GBR), Double Reef (Guam) and Suva Reef (Fiji) populations.

Figure 4.24a-f. Standardised residual plots for final models estimated for six skeletal ossicle types for *A. planci* in five populations

CHAPTER 5

Figure 5.1. Percentage frequency histograms of gonad weights (g) in five *A. planci* populations from the Western Pacific region; (a) Davies Reef PRE group, (b) Davies Reef PST group, (c) Suva Reef, (d) Hospital Point, Guam, (e) South Tumon Bay, Guam, (f) Double Reef, Guam.

Figure 5.2. Relationship between (GW) (g) and (WET) (g) for five *A. planci* populations from the Western Pacific region using the power equation, $(GW) = a \cdot (WET)^b$; for (a) testes weight, and (b) ovary weight; where (GW) = gonad weight (g); (WET) = whole wet weight; a and b are constants.

Figure 5.3. Linear regression analyses of \ln (GWT) and \ln (WET) for male starfish in five *A. planci* populations from the Western Pacific region; where (a) is the residual plot for fitted values, and (b) is the regression plot.

Figure 5.4. Linear regression analyses of \ln (GWO) and \ln (WET) for female starfish in five *A. planici* populations from the Western Pacific region; where (a) is the residual plot for fitted values, and (b) is the regression plot.

Figure 5.5. Relationships between \ln (GW) and estimated age (AGE) in five *A. planici* populations from the Western Pacific region; where (a) testis weight, and (b) ovary weight.

Figure 5.6. Relationships between \ln (AGWO) (ovary weight, adjusted for mean whole wet weight = 1636 g) and estimated age (AGE) in five *A. planici* populations from the Western Pacific region.

CHAPTER 6

Figure 6.1. A putative life-history strategy for *A. planici*; a phenotypically polymorphic bet-hedging strategy is determined by the post-settlement density, the levels of *stress* experienced, the reproductive schedule and various forces of mortality resulting in a continuum developed between the semelparous outbreaking pattern and the iteroparous long-lived pattern.