AGE-BASED DEMOGRAPHY AND REPRODUCTIVE ONTOGENY OF ANGELFISHES BELONGING TO THE FAMILY POMACANTHIDAE

Thesis submitted by
Tebaua Sapolu BSc *Qld*
In July 2005

for the research degree of Master of Science
in Marine Biology
within the School of Marine Biology and Aquaculture
at James Cook University

STATEMENT OF ACCESS

I, Tebaua Sapolu, the author of this thesis, understand that James Cook University will make this thesis available for use within University Library and, via the Australian Digital Theses network (unless granted an exemption), 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I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and;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 on access to this work.

---------- ----------

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 Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

---------- ----------

Acknowledgements

I wish to thank AUSAID in giving me an opportunity to undertake the masters degree at James Cook University, which has been an amazing experience.

My greatest gratitude goes to my supervisor, Professor J. Howard Choat, for his consistent guidance and support throughout the whole project. This thesis wouldn't have been possible without his encouragement during the difficult times of the degree. I also want to thank Phusit Horpet and Alison for their friendship, Elizabeth Laman Trip, John Ackerman, Stefan Walker for the valuable assistance in the growth analysis, and Phillip Munday for his guidance in gonad morphology. I wish to personally thank Adella Edwards for helping me with the contour maps and Gordon Bailey and Vincent Pulella for keeping my computer running.

My warmest gratitude goes to my husband, Mark Sapolu and my baby Elijah Donall Sapolu, and my parents and family for their patience and support especially during the hardest part of this degree. And lastly my deepest thanks to Him who gave me the strength and wisdom to do something I never thought I could accomplish.

General Abstract

There is an urgent need to understand population dynamics and life history characteristics of reef fishes that are highly exploited and limited in distribution to facilitate effective management and make predictions of potential impact. This is important within the pomacanthids family in which no demographic studies has been done. This study aims to explore the demographic features and reproductive ontogeny of a group of pomacanthids species, *Pomacanthus sexstriatus, Centropyge bicolor* and *C. loricul. P. sexstriatu* and *C. bicolor* were collected from the Great Barrier Reef and *C. loricul.* two species are in the first two species and from Kiritimati, Kiribati in the Central Pacific. An age-based approach combined with gonad histology was used in this thesis to examine the growth and longevity, reproductive ontogeny and the mechanism underlying larger male size in the study species.

Table of Contents

Statement of access i

Statement of sources - declaration ii

Acknowledgement iii

General Abstract iv

Table of Contents v

List of Figures and Tables vii

Chapter 1

General Introduction 1

Chapter 2

Review of the biogeography, life history and demography of Angelfishes (Pomacanthidae) with emphasis on endemics in the Pacific Ocean 5

2.1 Introduction 5

2.2 The Structure of Pomacanthid Faunas 6

2.3 Biogeography of Pomacanthids 8

2.4 Pacific Endemic Pomacanthids in the Global Marine Aquarium Trade (GMAT) 13

2.5 Abundance and Distribution, Life History and Demography of Pomacanthidae 14

2.6 Conclusion 18

2.7 Predictions for Patterns in the Pacific Ocean 18

2.8 Research needed on Endemic Pomacanthids in the Pacific 19

Chapter 3

Growth and Longevity in Three Angelfish Species 40

3.1 Introduction 40

3.2 Materials and Methods 41

3.3 Results 46

3.4 Discussion 50

Chapter 4

Reproductive Ontogeny of Three Pomacanthid Species 54

4.1 Introduction 54

4.2 Materials and Methods 58

4.3 Results 66

4.4 Discussion 73

Chapter 5

Otolith Dynamics of Pomacanthus Sexstriatus and Centropyge Bicolor 96

5.1 Introduction 96

5.2 Methods 98

5.3 Results 100

5.4 Discussion 104

Chapter 6

General Conclusions 107

References 112

List of Figures and Tables

Chapter 2

Table 2.1 Classification and regional distribution within the Pomacanthidae family....20
Table 2.2 Pomacanthid species according to distribution types....21
Table 2.3 Number of pomacanthid species within distribution range categories according to genus (km.sq) 22
Table 2.4 Definition of Endemism for the purpose of this review 22
Table 2.5 Type a Endemism with respective geographic distribution and range 23
Table 2.6 Type b Endemic species with respective geographic distribution and range 24
Table 2.7 Type c Endemic species with respective geographic distributions and range 25
Table 2.8 Harvested endemic species belonging to the Pomacanthidae family....26
Table 2.9 Spawning seasonality and lunar periodicity in pomacanthids....27
Figure 2.1 Maximum size range of Pomacanthidae according to genera showing lower, upper and middle quartiles and outliers (o and *)...28
Figure 2.2 Box plot showing median depth ranges of pomacanthids according to genus, showing lower, upper and middle quartiles and outliers (o and *)....28
Figure 2.3 Phylogenetic tree of 24 chosen species of Family Pomacathidae relative to the Family Chaetodontidae 29
Figure 2.4 Species density contour map of the family Pomacanthidae. Coloured lines represent level of species diversity....30
Figure 2.5 Geotectonic features of the world 31
Figure 2.6 Frequency distribution of pomacanthid species according to distribution range categories....32
Figure 2.7 Distribution of type a Endemic pomacanthid species 33
Figure 2.8 Distribution of type b Endemic pomacanthid species....34
Figure 2.9 Distribution of type c Endemic pomacanthid species 35
Figure 2.10 Histogram of total area of shallow water substrate (SWS) moving longitudinally away from the centre of diversity within the Pacific Ocean 36
Figure 2.11 Frequency distribution of pomacanthid species moving longitudinally away from the centre of diversity in the Pacific Ocean 37
Figure 2.12 Number of pomacanthid species per unit area of shallow water substrate (SWS) moving longitudinally away from the East Indies in the Pacific Ocean 37
Figure 2.13 Relative % of endemism (combined) in Pomacanthid fauna within each island moving longitudinally away from the East Indies in the Pacific Ocean 38
Figure 2.14 Total harvest of Pomacanthid endemics in the GMAT between 1988 to 2001 39

Chapter 3

Figure 3.1 Size at age plots with fitted von Bertalanffy growth function (VBGF) curves for study species: *P. sexstriatus, C. bicolor* and *C. loricula* 48
Table 3.1 Von Bertalanffy parameter estimates of size at age data for study species 48
Figure 3.2 Sex-specific size at age plots with fitted von Bertalanffy growth function (VBGF) curves for *P. sexstriatus* (A), *C. bicolor* (B) and *C. loricula* (C) 49
Figure 3.3 Bootstrapped estimates of sex-specific mean maximum longevity and body length of oldest individuals in *P. sexstriatus* (A & I), *C. bicolor* (B & II) and *C. loricula* (C & III) 50

Chapter 4

Table 4.1 Gonad developmental stages in *Pomacanthus sexstriatus* 63
Table 4.2 Gonad development stages in *Centropyge bicolor* 64
Table 4.3 Gonad development stages in *Centropyge loricula* 65
Table 4.4 Sex specific size and age of first sexual maturity in *P. sexstriatus, C. bicolor* and *C. loricula* 68
Figure 4.1 Forms of reproductive ontogeny in reef fishes 82
Figure 4.2 Aims of Chapter 4 83
Figure 4.3 *P. sexstriatus*. Histological transverse section of immature individuals 84
Figure 4.4 *P. sexstriatus*. Mature individuals 85
Figure 4.5 *C. bicolor*. Histological section of female gonads 86
Figure 4.6 *C. bicolor*. A-C Stage 3 transitional gonads contain previtellogenic oocytes and proliferating sperm tissue 87
Figure 4.7 *C. loricula*. A-B Immature bisexual gonad containing previtellogenic oocytes intermixed with early spermatogenic tissue 88
Figure 4.8 *C. loricula*. A Active mature male: testis in partial lamellar form showing an ex-ovarian lumen (EOL) 89
Figure 4.9 Size frequency distribution by reproductive category for *P. sexstriatus* (A), *C. bicolor* (B) and *C. loricula* (C) 90
Figure 4.10 Age frequency distribution by reproductive categories for *P. sexstriatus* (A), *C. bicolor* (B) and *C. loricula* (C) 91
Figure 4.11 Possible sexual differentiation pathways for *P. sexstriatus* 92
Figure 4.12 Possible sexual differentiation pathways for *C. bicolor* 93
Figure 4.13 Possible sexual differentiation pathways for *C. loricula* 94
Figure 4.14 Phylogenetic tree of 24 chosen species of Family Pomacathidae relative to the Family Chaetodontidae 95

Chapter 5

Figure 5.1 Diagram illustrating expected relationship between size at age and cumulative otolith radius at age plots with a sex-specific age and growth effect 100

Figure 5.2 Sex-specific von Bertalanffy growth function (VBGF) for (A) *P. sexstriatus* and (B) *C. bicolor*.....102
Figure 5.3 Sex-specific mean (+/- s.error) cumulative otolith radius (OR) with age for (A) *P. sexstriatus*, showing maximum OR for oldest male and female, and for (B) *C. bicolor* 103
Table 5.1 Results of repeated-measures analysis of variance (RM-ANOVA) comparing cumulative otolith radius between males and females for *P. sexstriatus* (0-31 years) and *C. bicolor* (0-9 years).....104

Chapter 6

Figure 6.1 Findings on reproductive ontogeny, longevity and otolith dynamics with respect to the phylogeny of 24 chosen species of Family Pomacathidae.....108