

**Stock structure of a coral reef fish, *Plectropomus leopardus*:  
identification and implications for harvest strategy  
evaluation**

**PhD thesis submitted by  
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in March 2007**

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 Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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## STATEMENT OF CONTRIBUTION OF OTHERS

This thesis includes some collaborative work with my supervisors Dr Gavin Begg, Prof. Bruce Mapstone, Prof. Garry Russ and Dr Rich Little, as well as with Dr Dong C. Lou, Mr Cameron Murchie and Dr André Punt. For all the project components in this thesis I was responsible for the concept and aims, carrying out the laboratory work, the statistical analysis, results interpretation and synthesis, and the writing of all text in the thesis and publications. My supervisors assisted with their advice on these issues, with their contributions reflected by the order of the co-authors for each paper. Rich Little (CSIRO) also assisted with the coding of ELFSim for the purpose of this project. CSIRO Marine and Atmospheric Research assisted with in-kind contribution during a one month stay at the laboratory in Hobart. André Punt assisted with technical and editorial advice for the ELFSim paper. Gavin Begg and Bruce Mapstone also assisted financially towards the Otolith Chemistry paper and with in-kind contributions for the production of this thesis. The samples from which this thesis was derived were provided by Bruce Mapstone and others from the Effects of Line Fishing Experiment done over 11 years on the Great Barrier Reef. Dong C. Lou aged most of the *P. leopardus* samples used in this thesis and assisted with minor editorial advice on the Life History paper. Cameron Murchie assisted with some of the laboratory work for the Otolith Chemistry paper. CRC Reef assisted with financial support towards my stipend, research funds and conference travel support. The School of Marine Biology and Aquaculture assisted with in-kind contribution, research funds and conference travel support. The Great Barrier Reef Marine Park Authority assisted with research funds towards the Otolith Chemistry analysis.

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**ABSTRACT**

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The recognition of stocks, or spatially separate groups of individuals with persistent differences in biological characteristics, is important for the sustainable and optimised use of fisheries resources. Stocks with different biological characteristics may respond differently to harvest and therefore have different vulnerabilities to over-exploitation. Recent research suggests that spatial variation in biological characteristics at a range of scales is a feature of many coral reef fishes. An investigation of the temporal stability of spatial differences and the identification of stocks that may require separate management strategies, however, has rarely been undertaken for such fish. Moreover, little is known about the implications of spatial differences in biological characteristics for spatially separate components as well as entire populations of coral reef fishes when subject to various levels of harvest.

This thesis has four primary aims: 1) to investigate the use of otolith chemistry as an indirect indicator of stock structure of three exploited epinepheline serranid coral reef fishes, *Plectropomus leopardus*, *Cephalopholis cyanostigma* and *Epinephelus fasciatus*, on the Great Barrier Reef (GBR), Australia; 2) to investigate the use of otolith morphology as an indirect indicator of stock structure of *P. leopardus*; 3) to investigate the spatial and temporal patterns in life history characteristics of *P. leopardus* as direct manifestations of stock structure; and 4) to examine the implications of spatial variability in life history characteristics of *P. leopardus* for harvest strategy evaluation.

The first two aims were achieved by comparing otolith chemistry (Mn, Sr, Ba) and otolith morphology (otolith length, width, area, perimeter, circularity, rectangularity and Fourier Harmonics) variables among four regions of the GBR,

separated by 100s of kilometres, as well as among three reefs 100s – 1000s of meters apart within each region. The temporal stability in otolith chemistry and morphology signals was also examined by comparing two cohorts of *P. leopardus* and individuals of *C. cyanostigma* and *E. fasciatus* from the same cohorts that were collected two years before and two years after a significant weather disturbance (Tropical Cyclone Justin) in March 1997. Persistent differences in otolith chemistry were found at both broad and fine spatial scales, and differences in otolith morphology were seen at mainly broad spatial scales. Moreover, some aspects of chemical and morphological signals differed between cohorts and individuals collected before and after the Cyclone. The results highlight the need to incorporate data from several years in studies using these techniques to discriminate temporary and possibly misleading signals from those that indicate persistent spatial structure in stocks. These results provide a good starting point for future research on groups of individuals that have lived at least part of their lives in different environments and therefore may have different biological characteristics, although otolith chemistry and morphology should not be used in isolation to determine stock structure.

The third aim was achieved by comparing vital life history characteristics of *P. leopardus* at the same broad regional and finer reef scale as the otolith chemistry and morphology. Temporal stability in stock structure was examined by comparing biological parameters among five consecutive years, from 1995 to 1999. The results matched the patterns indicated by otolith chemistry and morphology and emphasised that the stock structure of *P. leopardus* is far more complex than assumed previously. Mortality, growth, age richness and longevity of *P. leopardus* varied among reefs within regions and some estimates of growth and longevity also varied at the larger regional spatial scale. Several of the spatial patterns in these biological parameters

were complicated by inter-annual variation. Similar to the use of otolith chemistry and morphology, the life history results emphasised the importance of a multi-scaled sampling design, including a temporal component, when using biological characteristics to investigate the stock structure of tropical reef fishes. I proposed a theoretical model for conceptualising the stock identification and management challenge for *P. leopardus* that may be composed of a complex network of reef subpopulations, groups of subpopulations (i.e., regions), and potential stocks with persistent differences in biology.

The fourth aim was achieved using a spatially-structured management strategy evaluation model developed for *P. leopardus* harvested by the GBR line fishery. Relative spawning biomass of the population was estimated from simulations of four hypothetical scenarios of spatial variation in life history characteristics under each of five hypothetical effort scenarios. The life history scenarios involved simulating the *P. leopardus* population with or without differences in a) individual growth and b) mortality rates among four regions of the GBR. The different effort scenarios involved shifting fishing effort among the four regions. The effects of regional closures (no effort) were also examined. Trajectories of mean relative spawning biomass were compared among the different combinations of spatial and effort scenarios. Relative mean spawning biomass trajectories were also compared between two analytical approaches involving aggregating results over regions, as is usually done in fisheries assessments, or treating results separately for each region. The latter comparison directly assessed the impacts of erroneously assuming an homogeneous stock despite regional variation in life history parameters.

Including spatial variation in growth and mortality resulted in greater depletions of relative spawning biomass and longer times to recover relative to pre-

exploitation levels for the population as a whole, as well as for several regions. Aggregating results across regions masked important region-specific patterns in the relative spawning biomass trajectories arising from spatial variation in biology, and so resulted in the wrong conclusions about whether particular management objectives were likely to be realised. These results suggest that spatial variation in growth, in particular, mortality and potentially other life history characteristics should be incorporated in future harvest strategy evaluations for *P. leopardus*. Further, the results suggest that the single management unit currently in place for *P. leopardus* on the GBR may need to be divided into finer spatial units to closer reflect biological stock units to deliver prudent biologically optimal harvests.

The results clearly have some important implications for the management and harvest of *P. leopardus* on the GBR. *P. leopardus*, and probably many other exploited coral reef fishes, should not be viewed or managed as single homogenous populations. Instead these populations should be considered as complex networks of spatially and temporally varying components which although interlinked, may require separate management strategies to assure their long-term sustainability and optimal harvest.

## TABLE OF CONTENTS

<b>Statement of Access .....</b>	<b>i</b>
<b>Statement of Sources .....</b>	<b>ii</b>
<b>Declaration .....</b>	<b>ii</b>
<b>Statement of contribution of others .....</b>	<b>iii</b>
<b>Acknowledgements .....</b>	<b>v</b>
<b>Abstract.....</b>	<b>vii</b>
<b>List of figures.....</b>	<b>xv</b>
<b>List of tables .....</b>	<b>xvii</b>
<b>Chapter 1. General Introduction.....</b>	<b>1</b>
<b>1.1. Definition of ‘Stock’ .....</b>	<b>2</b>
<b>1.2. Importance of stock structure .....</b>	<b>4</b>
<b>1.3. Stock identification techniques .....</b>	<b>6</b>
<b>1.4. Theory and simulation modelling.....</b>	<b>7</b>
<b>1.5. Population structure of coral reef fishes.....</b>	<b>8</b>
<b>1.6. Common Coral Trout, <i>Plectropomus leopardus</i> .....</b>	<b>10</b>
<b>1.7. Thesis objectives.....</b>	<b>11</b>
<b>Chapter 2. The use of otolith chemistry to determine stock structure of three epinepheline serranids.....</b>	<b>14</b>
<b>2.1. Introduction.....</b>	<b>14</b>
<b>2.2. Methods.....</b>	<b>16</b>
2.2.1. Background and sample collection .....	16
2.2.2. <i>Plectropomus leopardus</i> .....	18
2.2.3. <i>Cephalopholis cyanostigma</i> .....	21
2.2.4. <i>Epinephelus fasciatus</i> .....	22
2.2.5. Otolith and sample preparation.....	22
2.2.6. ICP-MS analysis .....	23
2.2.7. Statistical methods .....	25
<b>2.3. Results .....</b>	<b>29</b>
2.3.1. <i>Plectropomus leopardus</i> .....	29
2.3.2. <i>Cephalopholis cyanostigma</i> .....	33

2.3.3. <i>Epinephelus fasciatus</i> .....	37
<b>2.4. Discussion</b> .....	<b>38</b>
2.4.1. Spatial and temporal variation in chemical signatures .....	38
2.4.2. Reasons for temporal and spatial variation in otolith chemistry .....	41
2.4.3. Conclusion and future directions. ....	46
<b>Chapter 3. The use of otolith morphology to determine stock structure of <i>Plectropomus leopardus</i>.</b> .....	<b>47</b>
<b>3.1. Introduction</b> .....	<b>47</b>
<b>3.2. Methods and data analysis</b> .....	<b>49</b>
3.2.1. Sample collection .....	49
3.2.2. Morphological analysis .....	50
3.2.3. Statistical methods.....	52
<b>3.3. Results</b> .....	<b>57</b>
3.3.1. Principal Component Analysis .....	57
3.3.2. Discriminant analyses.....	64
<b>3.4. Discussion</b> .....	<b>69</b>
3.4.1. Spatial and temporal variation in otolith morphology.....	69
3.4.2. Reasons for temporal and spatial variation in otolith morphology .....	71
3.4.3. Conclusion and future directions.....	73
<b>Chapter 4. The use of vital life history characteristics for the identification of appropriate management units of <i>Plectropomus leopardus</i>.</b> .....	<b>75</b>
<b>4.1. Introduction</b> .....	<b>75</b>
<b>4.2. Methods</b> .....	<b>76</b>
4.2.1. Sample collection .....	76
4.2.2. Spatial and temporal patterns of life history characteristics.....	79
4.2.2.1. Growth.....	79
4.2.2.2. Longevity and age distribution.....	80
4.2.2.3. Mortality .....	80
<b>4.3. Results</b> .....	<b>82</b>
4.3.1. Spatial and temporal patterns of growth.....	82
4.3.1.1. Weight-length relationships.....	82
4.3.1.2. Length of 4-year old fish .....	85
4.3.1.3. Von Bertalanffy growth parameters .....	89

4.3.2. Longevity and age richness.....	91
4.3.3. Patterns of mortality.....	94
<b>4.4. Discussion .....</b>	<b>97</b>
4.4.1. Patterns in life history characteristics as an indication of stock structure.....	97
4.4.2. Potential processes causing spatial and temporal patterns in life history characteristics.....	99
4.4.3. Conclusion and future directions .....	101
<b>Chapter 5. Implications of spatial variability in life history characteristics for harvest strategy evaluations.....</b>	<b>103</b>
<b>5.1. Introduction.....</b>	<b>103</b>
<b>5.2. Materials and methods .....</b>	<b>106</b>
5.2.1. ELFSim overview .....	106
5.2.2. Model specifications .....	107
5.2.2.2. Biological parameters .....	112
<b>5.3. Results .....</b>	<b>115</b>
5.3.1. Growth and mortality input parameters.....	115
5.3.2. Depletions and recoveries.....	116
5.3.3. Effort scenarios .....	119
5.3.3.1. Patterns in RSB trajectories .....	119
5.3.3.2. Patterns in mean RSB over the last five years of the projection period relative to mean RSB at status quo effort levels.....	123
5.3.3.3. RSB status relative to management objectives .....	126
<b>5.4. Discussion .....</b>	<b>128</b>
5.4.1. Consequences of ignoring spatial variability in biology .....	128
5.4.2. Consequences of aggregating data across biological units.....	129
5.4.3. Consequences of different effort levels .....	130
5.4.4. The importance of growth versus mortality.....	132
5.4.5. Other model considerations .....	134
5.4.6. Conclusion and future directions .....	136
<b>Chapter 6. General Discussion .....</b>	<b>138</b>
<b>6.1. The utility of phenotypic stock identification techniques for coral reef fishes.....</b>	<b>139</b>
<b>6.2. Stock structure of <i>P. leopardus</i> .....</b>	<b>142</b>

6.2.1. A theoretical model of stock structure of <i>P. leopardus</i> .....	144
<b>6.3. Implications of spatial structure in life history characteristics. ....</b>	<b>148</b>
<b>6.4. Management implications:.....</b>	<b>150</b>
<b>6.5. Conclusion .....</b>	<b>152</b>
<b>Chapter 7. References .....</b>	<b>154</b>



## LIST OF FIGURES

## Chapter 1.

**Figure 1.1** Schematic illustrating the terms used to discuss population structure. 4

## Chapter 2.

**Figure 2.1** Great Barrier Reef , Australia, showing sample regions and reefs. ... 18

**Figure 2.2** Ba concentrations in otoliths of 4-year-old *P. leopardus*..... 31

**Figure 2.3** Mn concentrations in otoliths of 4-year-old *P. leopardus* per cohort. ...  
..... 32

**Figure 2.4** Mn concentrations in otoliths of 4-year-old *P. leopardus* per region.  
..... 32

**Figure 2.5** Sr concentrations in otoliths of 4-year-old *P. leopardus* per cohort and  
region. .... 33

**Figure 2.6** Ba concentrations in otoliths of *C. cyanostigma* per region..... 35

**Figure 2.7** Mn concentrations in otoliths of *C. cyanostigma* per region..... 36

**Figure 2.8** Ba concentrations in otoliths of *C. cyanostigma* per period..... 36

## Chapter 3.

**Figure 3.1** *P. leopardus* otolith reconstructed using a) 128 Fourier descriptors  
and b) the first and last 14 descriptors. .... 52

**Figure 3.2** Mean scores of a) PC II per region and cohort, and b) PC IV per reef  
within region and cohort of 4-year old *P. leopardus*. .... 63

**Figure 3.3** Frequencies of DF I scores from otolith morphological variables per  
cohort for four regions of 4-year old *P. leopardus*. .... 66

**Figure 3.4** Mean DF I scores from otolith morphological variables per region for  
a) Cohort 1995, and b) Cohort 1999 in 4-year old *P. leopardus*. .... 67

## Chapter 4.

**Figure 4.1** Regression relationships between weight and fork length of *P.*  
*leopardus* from a reef in each of the four regions..... 83

**Figure 4.2** Average FL of 4-year old *P. leopardus* per region. .... 87

**Figure 4.3** Average FL of 4-year old *P. leopardus* per reef in the a) Lizard Island  
and b) Mackay Regions. .... 88

**Figure 4.4** Average FL of 4-year old *P. leopardus* per reef in the Storm Cay  
Region. .... 89

**Figure 4.5** VBGF fitted to *P. leopardus* length-at-age data per region per year. 90

<b>Figure 4.6</b> Average $L_{\infty}$ of <i>P. leopardus</i> per year . . . . .	91
<b>Figure 4.7</b> Average 90 <sup>th</sup> percentiles of age of <i>P. leopardus</i> a) per region and year and b) per reef. . . . .	93
<b>Figure 4.8</b> Average age richness of <i>P. leopardus</i> per reef within four regions. . . . .	94
<b>Figure 4.9</b> Cohort-specific mortality rates for three cohorts of <i>P. leopardus</i> . . . . .	95
<b>Figure 4.10</b> Cohort-specific mortality rates of <i>P. leopardus</i> for reefs in the (a) Townsville Region, (b) Mackay and (c) Storm Cay Regions. . . . .	96
<b>Chapter 5.</b>	
<b>Figure 5.1</b> a) Proportion of total effort under the status quo effort scenario per fishing sector and region; b) Proportion of effort density under the EPE, InEPE and UE scenarios compared to proportions of total effort per region. . . . .	111
<b>Figure 5.2</b> Mean relative spawning biomass of <i>P. leopardus</i> for the a) results aggregated across regions, b) Lizard Island, c) Townsville, d) Mackay and e) Swains Regions for life history scenarios with no fishing effort. . . . .	118
<b>Figure 5.3</b> Mean relative spawning biomass for the overall <i>P. leopardus</i> population under different life history and effort scenarios. . . . .	119
<b>Figure 5.4</b> Mean relative spawning biomass for <i>P. leopardus</i> in the Lizard (A) and Townsville (B) Regions under different life history and effort scenarios. . . . .	121
<b>Figure 5.5</b> Mean relative spawning biomass for <i>P. leopardus</i> in the Mackay (A) and Swains (B) Region under different life history and effort scenarios. . . . .	122
<b>Figure 5.6</b> Mean relative spawning biomass (RSB) from the last five years of the projection period relative to mean RSB from the last five years of the projection period under the status quo effort scenario for a) results aggregated across regions, b) Lizard Island, c) Townsville, d) Mackay, e) Swains regions under different life history and effort scenarios. . . . .	125
<b>Figure 5.7</b> Proportion of time that mean RSB was greater than status quo levels of RSB for the a) results aggregate across regions, b) Lizard Island, c) Townsville, d) Mackay, e) Swains regions under different life history and effort scenarios. . . . .	127
<b>Chapter 6.</b>	
<b>Figure 6.1</b> Conceptual model of <i>P. leopardus</i> stock structure. . . . .	146

## LIST OF TABLES

### Chapter 2.

<b>Table 2.1.</b> Regions and reefs from which 4-year old <i>P. leopardus</i> otoliths were sampled and analysed for otolith elemental signatures. ....	20
<b>Table 2.2.</b> <i>C. cyanostigma</i> otoliths analysed for elemental signatures. ....	21
<b>Table 2.3.</b> <i>E. fasciatus</i> otoliths analysed for elemental signatures.....	22
<b>Table 2.4.</b> Results of MANOVA comparing otolith elemental signatures of 4-year-old <i>P. leopardus</i> across cohorts, reefs and regions.....	30
<b>Table 2.5.</b> Results of ANOVAs comparing otolith elemental signatures of 4-year-old <i>P. leopardus</i> across cohorts, reefs and regions.....	31
<b>Table 2.6.</b> Results of MANOVA comparing otolith elemental signatures in <i>C. cyanostigma</i> across period (before and after Cyclone Justin) and regions.....	34
<b>Table 2.7.</b> Results of ANOVAs comparing otolith elemental signatures in <i>C. cyanostigma</i> across period (before and after Cyclone Justin) and regions.....	35

### Chapter 3.

<b>Table 3.1.</b> Study years, regions and reefs from which <i>P. leopardus</i> , were sampled and analysed for otolith morphology. ....	49
<b>Table 3.2.</b> Cohort and regions from which <i>P. leopardus</i> were used to investigate the effects of sex on otolith morphology.....	54
<b>Table 3.3.</b> Results of homogeneity of slopes test for the influence of FL on otolith morphological variables of 4-year old <i>P. leopardus</i> . ....	59
<b>Table 3.4.</b> Variable communalities and loadings on the four significant PCs in the otolith morphological data of 4-year old <i>P. leopardus</i> . ....	60
<b>Table 3.5.</b> Results of MANOVA comparing PC I - IV scores of otolith morphology of 4-year old <i>P. leopardus</i> across cohorts, reefs and regions.....	62
<b>Table 3.6.</b> Results of ANOVAs comparing otolith PC scores of otolith morphology of 4-year old <i>P. leopardus</i> across cohorts, reefs and regions.....	62
<b>Table 3.7.</b> Significance test of a) region specific and b) cohort specific CDA of morphological variables from otoliths of 4-year old <i>P. leopardus</i> . ....	65
<b>Table 3.8.</b> Canonical coefficient function representing correlation between the morphological variables and significant DFs, separating cohorts of 4-year old <i>P. leopardus</i> within regions.. ....	68

<b>Table 3.9.</b> Correctly classified individuals of 4-year old <i>P. leopardus</i> per cohort in each region .....	68
<b>Table 3.10.</b> Correctly classified individuals of 4-year old <i>P. leopardus</i> per region in each cohort. ....	68
<b>Chapter 4.</b>	
<b>Table 4.1.</b> Study years, regions and reefs within regions from which <i>P. leopardus</i> were sampled and analysed for growth and mortality estimates. ....	78
<b>Table 4.2.</b> Results of a) overall and b) region-specific ANCOVA homogeneity of slopes test comparing the slope of the relationship between body weight and the covariate FL of <i>P. leopardus</i> across reefs, regions and year. ....	84
<b>Table 4.3.</b> Results of the SNK tests for comparisons of slopes of the relationship between body weight and the covariate FL of <i>P. leopardus</i> among years for each reef within regions. ....	85
<b>Table 4.4.</b> Results of a) overall and b) region-specific ANOVAs comparing average FL of 4-year old <i>P. leopardus</i> across reefs, regions and year. ....	86
<b>Table 4.5.</b> Results of the ANOVA comparing average VBGF parameter $L_{\infty}$ of <i>P. leopardus</i> across reefs, regions and year. ....	90
<b>Table 4.6.</b> Results of the ANOVA comparing average (a) 90 <sup>th</sup> percentiles of age ( $A_{90}$ ) and (b) age richness ( $A_R$ ) of <i>P. leopardus</i> across reefs, regions and year. ....	92
<b>Table 4.7.</b> Results of the ANCOVA comparing mortality rates among reefs and regions for the 4, 6 and 7 yo cohorts of <i>P. leopardus</i> . ....	95
<b>Table 4.8.</b> Summary of statistically significant results (X) of spatial and temporal patterns in life history characteristics of <i>P. leopardus</i> . ....	97
<b>Chapter 5.</b>	
<b>Table 5.1.</b> a) Life history and b) effort scenarios simulated to examine their implications for the relative spawning biomass of <i>P. leopardus</i> . ....	109
<b>Table 5.2.</b> Region-specific and overall estimates of the VBGF parameters and age-specific mortality rates. ....	116