Latitudinal and temporal comparisons of the reproductive biology and growth of snapper, *Pagrus auratus* (Sparidae), in Western Australia

This thesis is presented for the degree of
Doctor of Philosophy at Murdoch University

Submitted by

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B.Sc. (Hons)

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2006

DECLARATION

I declare that this thesis is my own account of my research and contains as its main content of work which has not previously been submitted for a degree at any university unless otherwise stated.

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ABSTRACT

This study focused on obtaining sound quantitative data on the reproductive biology, length and age compositions and growth of the snapper *Pagrus auratus* in the waters off Carnarvon at *ca* 25^{o}S and Perth at *ca* 32^{o}S on the west coast of Australia and at *ca* 34^{o}S on the south coast of Western Australia. Sampling thus encompassed both sub-tropical and temperate waters and the geographical range within which this species is abundant in Western Australia. The resultant data were used to explore the ways in which the biological characteristics of *P. auratus* differ with latitude and thus water temperature. An intensive sampling regime for eggs and spawning individuals of *P. auratus* was conducted in Cockburn Sound, a large marine embayment in the Perth region at *ca* 32^{o}S. The resultant data were used to elucidate where and when spawning occurs in this large marine embayment and to determine more precisely the factors that influence the timing of spawning. The implications of the results presented in this thesis for the management of *P. auratus*, a species that has been subjected to very heavy fishing pressure in recent years, are discussed.

The time and duration of spawning of *P. auratus* in the subtropical waters of Carnarvon differed markedly from those recorded for this sparid in the temperate and cooler waters of the Perth and the south coast regions. Spawning at Carnarvon occurred predominantly in the five months between late autumn (May) and mid spring (September), whereas it took place mainly in the three months between mid spring (October) and early summer (December) in the Perth region. Spawning of *P. auratus* on the south coast occurred predominantly in October and November in 2003 and 2004 and scarcely at all in 2005. Gonadal recrudescence was thus initiated

when water temperatures were close to their maximum but declining in Carnarvon, and close to their minima and rising in the Perth and south coast regions, respectively. The prevalence of fully mature and spawning females in all three regions was greatest in those months when water temperatures lay between 19 and 21^{o}C. Collation of the data in this thesis and those provided in the literature for other populations showed that the spawning period was related to latitude, occurring far earlier in sub-tropical than temperate waters.

The females and males attained maturity at a far smaller total length (L_{50}) in the Carnarvon region, *i.e.* 378 and 353 mm, respectively, than in the Perth region, 585 and 566 mm, respectively, and also the south coast region, *i.e.* 600 and 586 mm. The trends exhibited by the age at maturity parallel those for length, with the A_{50}s for the two sexes increasing from *ca* 4 years in Carnarvon to *ca* 5.6 years in the Perth region and nearly 7 years in the south coast region. The L_{50} and A_{50} at maturity thus both increased with increasing latitude.

Marginal increment analysis demonstrated that, irrespective of the number of opaque zones in the otoliths of *P. auratus*, a single such opaque zone is laid down each year in these otoliths. Furthermore, the trends exhibited by the monthly marginal increments showed that the opaque zone is laid down predominantly in winter in the subtropical waters of Carnarvon, as opposed to mainly in spring in the temperate waters of the Perth and south coast regions. Thus, the timing of formation of the opaque zone in the otoliths of *P. auratus* along the Western Australian coast is not related to the trends exhibited by water temperature, but, in both the Carnvarvon and Perth regions, was coincident with the timing of spawning.

The maximum total lengths recorded for females and males in the Carnarvon region, *i.e.* 864 and 840 mm, respectively, were considerably less than the

corresponding values of 1051 and 1056 mm in the Perth region, and 1083 and 1099 mm in the south coast region. Growth in the Perth and south coast regions was greater than in Carnarvon, as is reflected in, for example, the respective lengths of 820, 720 and 610 mm for females at 10 years of age, as determined from the von Bertalanffy growth equations.

The length and age compositions in the Carnarvon and south coast regions were essentially unimodal, whereas those in the Perth region were bimodal. However, the "mode" in the length-frequency distribution for the south coast region was located well to the right of that in the Carnarvon region, reflecting relatively lower contributions by individuals of the age cohorts of 3 to 6 years. The marked bimodality in the length-frequency distribution for *P. auratus* in the Perth region was due to the presence of a group of mainly smaller individuals caught outside Cockburn Sound and another of mainly larger individuals that were caught in Cockburn Sound and which formed part of a spawning aggregation in that embayment.

The proportion of fish > 10 years old in the Carnarvon region declined markedly between 2003 and the following two years, presumably reflecting the effect of heavy fishing pressure. This contributed to the decision by fisheries managers to reduced the TAC in those waters after 2003. Age-frequency data demonstrated that annual recruitment success in Cockburn Sound varied greatly, with the 1991, 1992 and 1996 year classes being particularly strong, and recognizing that the relative numbers of the first two year classes did decline progressively between 2002 and 2004. Annual recruitment was particularly variable in the south coast region, with the catches of the 1996 year class dominating the samples.

The relative number of early stage *P. auratus* eggs in ichthyoplankton samples collected from Cockburn sound on each of four new moons during the spawning seasons of four consecutive years peaked in November in three of those years, *i.e.* 2001, 2003 and 2004, and in November/December in the remaining year, *i.e.* 2002. This showed that spawning in this embayment peaked during these months, at which times the mean sea surface temperatures ranged only from 19 to 20^{o}C.

The prevalence of spawning fraction females in sequential samples demonstrated that spawning peaks at the new and, to a lesser extent, full moons. This helps account for the strong positive correlation between spawning fraction and tidal regime, with spawning being greatest when the tidal range is greatest.

Spawning times, back-calculated from the ages of the eggs collected during ichthyoplankton surveys in Cockburn Sound on each of 16 new moons within the spawning periods of four successive years, demonstrated that, in this embayment, *P. auratus* spawns at night and within the first three hours of the onset of the ebb tide. The distribution of egg concentrations on the 16 new moons showed that, each year, spawning occurred firstly in the north-eastern area of Cockburn Sound and then in the middle and finally north-western areas of this embayment.

In the Perth region, the marine embayments of Cockburn and Warnbro Sound act as nursery areas for *P. auratus* during the first two years of life. The majority of 2 to 5 year old fish and a large proportion of the 6 year old fish occupy the marine waters outside the embayments. The remaining 6 year old and almost all of the older fish begin to move in September into particularly Cockburn Sound, where they form relatively large spawning aggregations between October and December, before undergoing a massive emigration from this embayment in December/January. The limited returns from fish that were tagged in Cockburn Sound and were subsequently

caught outside this embayment indicate that, following spawning, *P. auratus* does not tend to move in a particular direction.

Pagrus auratus stocks are heavily exploited in offshore, oceanic waters and in embayments, such as Cockburn Sound, where they are particularly susceptible to capture because of the tendency of this species to form spawning aggregations in these same easily accessible locations each year. The data obtained during this thesis show that the L_{50} at maturity of females and males in temperate waters, *i.e.* nearly 600 mm, is far greater than the current minimum legal length (MLL) of 410 mm TL. There is thus a need to increase the MLL and/or reduce fishing pressure on immature individuals in open waters. However, the effectiveness of an increase in the MLL may be limited because there is evidence that *P. auratus* suffers from fishing-induced barotrauma. Closures of specific areas during the spawning season of *P. auratus*, such as those that have been applied in Cockburn Sound and Shark Bay, are potentially a very effective method for reducing the effects of heavy fishing on spawning individuals.

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Acknowledgements

I would first like to recognize the efforts of my three supervisors. To my two supervisors from Murdoch University, Emeritus Professor Ian Potter and Professor Norm Hall, thank you for the tremendous amount of support, guidance and knowledge you bestowed, and an especially big thank you for your extended efforts during the final writing period of this thesis which was subject to such a short time frame, it was an amazing effort. To my supervisor from the Department of Fisheries, Dr Rod Lenanton, thank you for your support and guidance, not only during the period of my PhD but during my time at Fisheries. I would also like to acknowledge Dr Mike Moran, very many thanks for, firstly, employing me to work with you at Fisheries and, secondly, starting me on the path of snapper research, I would not be where I am today if it wasn't for your belief in my abilities.

I would like to extend my thanks to my colleagues at the Department of Fisheries, for whom there are too many to mention, but in particular to Gary Jackson, Jeff Norris and Ben Rome for the many good times, cheers fellas. Also thank you to Jill St John and Dan Gaughan for acquiring extra funding (FRDC) for this project and for your guidance not only during my PhD but also my time at Fisheries. Thanks to Tim Leary for the laughs during our numerous south coast treks, I think it's too late to get a Christmas award for running out of fuel at midnight in the middle of nowhere. Also a big thanks to those people who skippered the boat for me during sampling in Cockburn Sound, Keith Shadbolt, Mike Mackie, Paul Lewis, Chris Burton, Dave Harriss, Ron Mitchell, and to Helen Mee, Jan St Quinton and Lee Higgins for their expertise in otolith preparation.

Many thanks to the members of the Centre for Fish and Fisheries Research and staff at Murdoch University for whom there are too many to name individually, but I would like to extend my very many thanks to Dr Alex Hesp, whose impressive knowledge of fish biology and useful discussion helped improved this thesis.

Very many thanks to the numerous recreational fishers who volunteered their time to help tag snapper in Cockburn Sound, it was a fantastic effort. Also thank you to Hal Harvey from Bluewater Tackle and Lou Rummer from WA Bait Supplies for their sponsorship. I would like to express my gratitude to the Wimpress family, in particular Danny, your enthusiasm was inspiring and motivating, thanks for all the laughs, I'm sure we will have many more over the years, cheers buddy.

A special thanks to all the commercial and recreational fishers and processors from the Carnarvon, Perth and south coast regions, your assistance with this research project was greatly appreciated.

And last, but certainly not least, a big thank you to my family for your love and support, during the good and bad times. Mum, the strength and determination you displayed during your defeat of breast cancer was nothing short of remarkable, and Dad, thanks for always pushing me to achieve my best.