Impacts of River Regulation, Drought and Exploitation on the Fish in a Degraded Australian Estuary, with Particular Reference to the Life-history of the Sciaenid, *Argyrosomus japonicus*

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Mulloway *Argyrosomus japonicus* (Photograph courtesy of Brian Kowald, South Australian Research and Development Institute - Aquatic Sciences).

Declaration of Authorship

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Gregory James Ferguson
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Ferguson, G. J., T. M. Ward and M. C. Geddes (2008). "Do recent age structures and historical catches of mulloway, *Argyrosomus japonicus* (Temminck & Schlegel, 1843), reflect freshwater inflows in the remnant estuary of the Murray River, South Australia?" Aquatic Living Resources 21: 145-152.

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Chapter 3

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Chapter 5

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THESIS ABSTRACT

The overall aims of this thesis were to (i) investigate the impacts of river regulation, drought and exploitation on fish assemblages in the lower Murray River system and to identify populations that may be vulnerable (Chapter 2), then for one such population of the sciaenid *Argyrosomus japonicus*, to further investigate the spatial structure of stocks (Chapter 3), the role of environmental flows in the life-history (Chapter 4), and age, growth and reproduction (Chapter 5). Chapter 5 also considers implications for sustainable management of *A. japonicus*.

Annual catch and effort from a small multi-species fishery in the lower Murray River system were stable for 25 years but proportional contribution from each of freshwater, estuarine and adjacent marine habitats, and the species within them, varied (Chapter 2). Fish assemblages generally differed between subsequent 5-year periods and species richness declined steeply in freshwater and estuarine habitats. Species with rapid growth and early maturation (opportunistic strategists), increasingly dominated catches while species with slow growth and late maturation (periodic strategists) declined. Truncated population age structures suggested longevity overfishing of three periodic strategists, and one intermediate strategist species, with a population of the sciaenid *A. japonicus* identified as particularly vulnerable.

Shape and trace element composition of otoliths were evaluated for their ability to delineate stock structure of *A. japonicus* in South Australia (Chapter 3). Low mean concentrations of Ba:Ca in otoliths from the western coast contrasted strongly with high levels in otoliths from the eastern coast, indicating sub-structuring of the stock. Constrained Canonical Analysis of Principal Coordinates (CAP), of elemental concentrations was used to allocate individual otoliths to western, central and eastern coasts with respectively, 100, 100, and 87% success. Otolith shape (elliptical Fourier descriptors) validated these results although classification success was lower with 78, 59 and 70% of otoliths allocated to western, central and eastern coasts respectively. Successful use of otolith shape to differentiate between *A. japonicus* from an aquaculture facility and wild stocks may be useful for determining the success of possible stock enhancement in future.

For the population of *A. japonicus* centred about the Murray River system, age distributions were dominated by the 1993 age class, which comprised 35% and 41% of 2001 and 2002 catches, respectively. In 1993 annual freshwater inflow was 2.5 times the 25 year average. Freshwater inflow explained 28% and 35% of the variability in year class strength in the nearshore marine fishery in 2001 and 2002, respectively. These results suggest that this population is estuarine-

dependent, the estuary provides important refuge for juveniles, and strong year classes, or their absence, may be related to freshwater inflow to this environment.

Validated, otolith-based growth rates for *A. japonicus* in South Australia were the lowest reported world wide and were lower ($p \leq 0.001$) on the east coast (L_{inf} = 1,406.18, K = 0.136, t_0 = -0.252, n= 561) than the west coast (L_{inf} = 1,419.83, K = 0.182, t_0 = -0.098, n=157) which also suggested that they are separate populations (Chapter 4). On the east coast, juveniles (2-6 years) utilise habitat within the Murray River estuary and sub-adults/adults (7-25 years) occur exclusively in adjacent nearshore waters. Size at maturity (SAM_{50}) was 811 and 812 mm TL for males and females respectively, and was 57% of L_{inf} in eastern South Australia.

Setting restoration targets for depleted populations of *A. japonicus* and other vulnerable large-bodied native species should initially be based on conserving remnant age structures, and then rebuilding them. The population of *A. japonicus* centred about the Murray River estuary in eastern South Australia (i) has high size/age at maturity, (ii) the lowest reported growth rates in the world, (iii) is dependent on estuarine habitat for juveniles, and also (iv) on flood pulses to establish a strong year class. This population is depleted due to a combination of habitat degradation, loss of environmental flows, and longevity overfishing, and would benefit from management measures that aim to preserve capacity for egg production, allow recruits to enter the adult population, and maintain long-tailed age structures. Measures that would contribute to these aims for *A. japonicus* in eastern South Australia include (i) legal minimum size commensurate with at least SAM_{50} (i.e. > 810 mm TL), (ii) protection of juveniles in estuaries and shallow nearshore waters, (iii) maintenance of environmental flows, and (iv) protection of spawning/feeding aggregations.

In the Murray River estuary, age distributions of adult *A. japonicus* from the nearshore environment may provide an indicator of environmental health because its reproductive success may be dependent on freshwater inflows, and because it is the apex predator in the Murray River estuary. Such species-based indicators could also be developed for golden perch (*Macquaria ambigua*) and black bream (*Acanthopagrus butcheri*) with improved knowledge of stock structure and life-history.

Thesis Preface

Note on Chapter Style

This thesis begins with a General Introduction (Chapter One) to estuaries, and anthropogenic impacts on fish communities and populations. Information available on multi-species estuarine fisheries is highlighted. Here the broad research objectives of the thesis are established. The General Introduction is followed by four research chapters (Chapters Two to Five) addressing the outlined research objectives. Finally, the environmental, biological and management implications of the findings are addressed in the General Discussion (Chapter Six).

Chapters are presented in logical order, rather than in the order in which the work was done. Sampling opportunities for age/size information on the case study species, *Argyrosomus japonicus*, and also golden perch, black bream and greenback flounder were limited due to severe drought conditions that began in the same year as this project.

Each chapter of this thesis that presents original data (Chapters 2-5) has been written in a style suitable for publication in a scientific journal and can be read as a separate study. Chapter 4 was published in an international, peer-reviewed journal in 2008 and is presented as published (see Appendix 1 for permissions from publisher). Chapter 2 has also been submitted to an international, peer-reviewed journal. Each chapter is preceded by a statement outlining the contributions of all co-authors to the research therein. Tables and figures appear within the text and all references cited in this thesis are compiled at the end of the thesis and not at the end of each chapter.