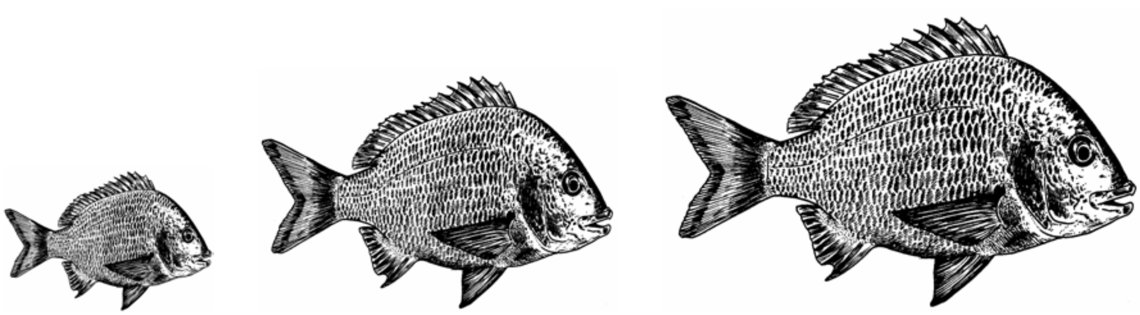
Selection for faster growing black bream *Acanthopagrus butcheri*



By

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Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed…………………………………………………………….

Let me be a little braver
When temptation bids me waver,
Let me strive a little harder
To be all that I should be.
Let me be a little meeker
With the brother that is weaker
Let me think more of my neighbour
And a little less of me

Acknowledgements

It is approaching 15 years since I left the Kimberley at the onset of a late monsoon to pursue a higher education in the conservation and management of aquatic resources. I wasn't sure what I was getting myself into and with the benefit of hindsight that was probably a good thing too! It took a lot of beer but I finally got here.

My most sincere thanks go to my good friend and mentor Alan Lymbery. I also wish to recognise Mark Starcevich for his outstanding assistance in all manner of things throughout this project. In addition, I would like to express my gratitude to the staff at the Aquaculture Development Unit in Fremantle, especially Greg Jenkins, Ken Frankish and Gavin Partridge. Others who have helped in various ways include Gavin Sarre, Johan Greeff and Stan Malinowski, and a handful of anonymous reviewers of this work. My final thanks are extended to my family and friends for their encouragement over the years.

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Abstract

In Australia, the widespread clearing of native vegetation has resulted in large areas of once-productive agricultural land being affected by rising saline groundwaters. There is considerable interest among farmers and rural landowners throughout Western Australia, in the possibilities that inland saline aquaculture may offer for a potentially productive use of land and water resources that can no longer support traditional agriculture. Black bream (*Acanthopagrus butcheri*) appear to be an ideal candidate for the developing saline aquaculture industry of inland Western Australia, however their current maximum growth rates are too slow for profitable production. The high productivity of modern breeds of terrestrial livestock species is primarily due to genetic improvement programs utilising selective breeding, and similar gains have also been made where they have been implemented for aquatic species. Before the growth rate of black bream can be genetically improved, however, it is necessary to estimate both the extent of genetic improvement required and the extent of genetic (co)variation in those growth traits which will be subject to, or affected by, selection. The aims of this study were to:

(1) Determine the extent of genetic improvement in growth rate required for black bream to be considered as a profitable aquaculture species.

(2) Estimate the potential for growth rate to be improved through heterosis when different black bream strains are crossbred.

(3) Estimate the additive genetic variation for growth rate, which exists within populations of black bream.

(4) Estimate the genetic (co)variation which exists between growth rate and other production traits.

A partial budget analysis investigated whether enhanced growth rates of black bream would improve profitability and justify a genetic improvement program. It was conducted for two different fish production systems; a commercial operation that incurred more operating expenses due to costs associated with farm initiation (stand-alone farm model) and an existing farm that diversified into aquaculture using the saline water resources of established farm dams (integrated farm model). Sensitivity analyses indicated that a 33% increase in growth rate to at least 200g/annum would allow either production system to return a profit at a farm-gate price of AUS$6/kg whole fish, with fish survival rates of 98% for the stand-alone farm and 65% for the integrated farm model. These results provided a breeding objective, being an improvement in growth rate by at least 33%.

A complete diallel cross of two black bream populations was used to estimate the comparative advantages that might be gained from straight-breeding and crossbreeding. At 90 days of age, the growth traits of standard length, total length and wet weight, varied significantly among all straight-bred and crossbred lines, and among half-sib groups within lines. Differences among half-sib groups explained 6.8% of the total variance in standard length, 8.3% in total length and 7.1% in wet weight, giving estimated heritabilities over all lines of 0.27 ± 0.11 for standard length, 0.33 ± 0.13 for total length and 0.28 ± 0.12 for wet weight. There was no evidence for heterosis in any traits when straight-bred and crossbred lines were compared, and phenotypic (r_P = 0.95 – 0.98) and genetic (r_G = 0.63 – 0.69) correlations were high among all growth traits.

I used the estimated heritability for wet weight of 0.28 to optimise a factorial mating design from a single population, and to estimate the contribution of additive genetic, non-additive genetic and maternal effects to variation in growth traits of black bream at 75, 130 and

180 days of age in the hatchery. Maternal genetic and environmental effects were greatest at 75 days of age, accounting for 9.1% of total phenotypic variance in wet weight, 11.4% of variance in standard length and 8.8% of variance in total length. At later ages maternal effects were much reduced, explaining 0.8 – 3.7% of phenotypic variance in growth traits. Additive genetic effects were greatest at 130 days of age, when they accounted for 17.4% of total phenotypic variance in wet weight, 21.4% of variance in standard length and 18.7% of variance in total length. Additive genetic effects were negligible (<1%) at 75 days of age and 4.8 – 5.5% of total phenotypic variance in growth traits at 180 days of age. Non-additive genetic effects (which also included common environmental effects due to families being raised in the same tank) explained 5.8 – 7.3% of total phenotypic variance in growth traits at 75 days of age, but were much smaller at later ages. Variable stocking densities among tanks up to 75 days significantly affected all growth trait measurements below 180 days of age.

One of the most important of these traits is feed conversion efficiency. Feed conversion efficiency (FCE) is the effectiveness with which feed is converted to saleable fish product. Feed costs are a major input to aquaculture production systems and genetic changes in FCE may therefore have an important influence on profitability. FCE is usually expressed by a composite measure that combines feed intake and growth rate. The two most common measures are feed conversion ratio (feed intake/weight gain over a specified time interval) and its inverse, feed efficiency. Feed conversion ratio and feed efficiency are measures of gross FCE, because they do not distinguish between the separate energy requirements of growth and maintenance. There is abundant evidence of substantial genetic variation in FCE and its component traits in terrestrial livestock species and, although data are few, the same is likely for cultured fish species. The major problems with selecting from this variation to genetically improve FCE in fish species are:

- It appears impractical to measure feed intake on individual fish, so that family mean data must be used.
- We do not know the optimal time period over which to test fish for FCE.
- We do not know the genetic correlations between FCE under apparent satiation or restricted intake conditions, or between FCE at different times in the production cycle.

I measured the relationships between feed intake to apparent satiety and weight gain in replicate half-sib families of black bream at four times over a 56-day test period. After 42 days, I found significant additive genetic variance in both weight gain and feed intake, and a stabilisation in family group variation in both traits. This indicates that 42 days is the minimum test period over which to measure genetic variation for FCE in black bream. There were high, positive phenotypic (and probably genetic) correlations between weight gain and feed intake after 42 days. There was no detectable genetic variation for either feed efficiency (weight gain/feed intake), or residual feed intake, which is the difference between the actual feed intake of an individual and the intake predicted from its body weight and growth rate. I argue that selection for improved FCE might be better achieved not by using a composite measure, but by using a weighted selection index that accounts for the genetic covariance among weight gain, feed intake and other correlated traits.

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