Proceedings of the Aquafin CRC Snapper Workshop held on 26 September 2002 at the Airport Motel & Convention Centre, Melbourne (Aquafin CRC 2001/208)

edited by

Geoff Allan

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**Fisheries Research Report Series**

This series presents scientific and technical information on general fisheries research and the documents in the series are intended to be progress reports on ongoing investigations. Titles in this series may be cited as publications, with the correct citation on the front cover.

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**Fisheries Research in New South Wales**

Research at NSW Fisheries is based at a number of locations, including Cronulla, Port Stephens, Narrandera, Grafton and Coffs Harbour.

Studies cover commercial fisheries, recreational fisheries, conservation issues and aquaculture.

The major role of research conducted by NSW Fisheries is to provide information upon which relevant Fisheries Management policies and strategies are developed, monitored and assessed in terms of the Department’s obligations under the NSW Fisheries Management Act, 1994.
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ACKNOWLEDGEMENTS

The workshop was funded by Aquafin CRC and FRDC through project no. 2001/208 “Increasing the profitability of snapper farming by improving hatchery practices and diets” and I would like to thank Peter Montague, CEO, Aquafin CRC and Patrick Hone, Programs Manager, FRDC for their continuing support. I would also like to thank workshop delegates who travelled far and wide to attend. Their enthusiastic participation contributed to the success of the workshop and was greatly appreciated. I would also like to thank Helena Heasman for help in organising the workshop and assisting with the preparation of the proceedings.
1. EXECUTIVE SUMMARY & RECOMMENDATIONS

Geoff Allan

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Introduction

To satisfy specified outputs for the Aquafin CRC project no. 2001/208 “Increasing the profitability of snapper farming by improving hatchery practices and diets”, a one day workshop was held on 26th September 2002 at the Airport Motel & Convention Centre in Melbourne. The agenda and list of workshop delegates are attached as Appendices 1 and 2. The aims of the workshop were:

- To identify and discuss research on snapper and other marine fish being done within and external to the CRC to ensure CRC snapper research does not unnecessarily duplicate or repeat previous research and is directed at industry bottlenecks.
- To consider beneficial synergies through linkages with R & D on other temperate species.

Speakers were asked to address the following:

1. Industry status for their state
2. Project aims and staff
3. Milestones and progress
4. Communication cooperation
5. Future plans
6. Challenges and new priorities

Eleven presentations were made and copies of talks are attached as Appendix 3.

The workshop culminated in a discussion session, summarized below.

Expanding focus to include other marine fish species

The key discussion topic was the issue of expanding the scope of future R & D to include other marine species in addition to snapper. The close similarities in the problems faced and solutions for many of the candidate marine species make broadening the current narrow focus on snapper to encompass other marine fish species critical. Several participants stressed that farming a combination of species was the approach favoured by industry. Farmers needed to be able to diversify their species to improve marketing opportunities and minimise risks (e.g. of hatchery failure for one species). Having made this point, it was stressed that it was unlikely that farmers would actively farm more than 2-3 species.
Suggested Areas of Discussion

i. Catalogue of species (R & D being conducted in different states and IP issues).
ii. Identify “strategic” discipline areas – priority constraints
iii. Communications (interactions, exchanges, workshops). Industry involvement A MUST.
iv. Identify gaps in expertise/skills/species.

i & ii Species and priority constraints

<table>
<thead>
<tr>
<th>Species</th>
<th>Constraints (x = no constraints)</th>
<th>growout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snapper</td>
<td>mainly in NSW &amp; Qld (constraint linked to cost of production)</td>
<td></td>
</tr>
<tr>
<td>Mulloway</td>
<td>x cost/prod/tech/motion/health</td>
<td></td>
</tr>
<tr>
<td>Barramundi</td>
<td>supply markets/health</td>
<td></td>
</tr>
<tr>
<td>King George Whiting</td>
<td>high cost/slow growth</td>
<td></td>
</tr>
<tr>
<td>Yellowtail Kingfish</td>
<td>health/rear/deformities/marketing</td>
<td></td>
</tr>
<tr>
<td>Bream</td>
<td>x slow growth</td>
<td></td>
</tr>
<tr>
<td>Trumpeter</td>
<td>high cost/deformities/health</td>
<td></td>
</tr>
<tr>
<td>Gummy shark</td>
<td>high cost/culture systems/diet</td>
<td></td>
</tr>
<tr>
<td>Tuna</td>
<td>larval rear (all issues)</td>
<td>diet</td>
</tr>
<tr>
<td>Australian Bass</td>
<td>x x high cost/slow growth/nutrition</td>
<td>diet/post harvest quantity</td>
</tr>
<tr>
<td>Black bream</td>
<td>x slow growth/nutrition</td>
<td></td>
</tr>
<tr>
<td>Sea horses</td>
<td>x feeding/marketing/colour</td>
<td></td>
</tr>
<tr>
<td>Cobia</td>
<td>? not yet evaluated for Australia</td>
<td></td>
</tr>
<tr>
<td>Mahi Mahi</td>
<td>x cost of production</td>
<td></td>
</tr>
<tr>
<td>Grouper</td>
<td>broodstock domestication/feeds</td>
<td></td>
</tr>
</tbody>
</table>

iii. Communications

It was suggested that a database be developed to list R & D projects being undertaken (i.e. who’s working on what and where). Peter Montague offered to assist by placing it on the Aquafin CRC website. Steven Clarke (Leader, Aquafin CRC Production Program) offered to coordinate the formation of small working groups to develop ideas for newsletters, websites, chat sites, training/skill development etc.

iv. Gaps

National capacity to build health diagnostics. The states will benefit by a national initiative to streamline this. Patrick alerted us to FRDC Project Number: 2001/256 Development and establishment of a national system for minor uses of products for the protection of livestock in aquaculture and fisheries - a draft blueprint, prepared by Peter Taylor (CPA Research Pty Ltd), a copy of which has since been distributed to workshop participants.

- Hatchery propagation group – strong need for fish propagation group or network.
- Live feeds issues – improve technology transfer. Would benefit from “network” (see above).
- Genetic selection for health.
- Inland saline aquaculture linkages.
- There is potential for a CRC for salinity?
- Recirculation for marine fish – reduction of costs (need for training – example given of Tom Losordo’s recirculating workshops at NSWF).
- Ability to uptake overseas technologies (need for training the trainers).
• Technology (engineering innovations) not available.
• Should we get involved in long-term marketing issues?
• Communication important; Geoff offered to organise workshop in 2 years time but not next year.
• Ways of encouraging industry participation? Good idea to visit farms and talk to growers. Industry needs to set itself targets (e.g. target for reducing FCRs; hatchery survival). Improving production is ultimate goal. (Suggested by commercial feed manufacturers Skrettings & Ridley).
• Biotechnology IGF (Flinders University).
• Transgenics technology (sterility issues).

Conclusions and Recommendations

1. CRC R & D should be expanded to include “marine fish” and not be restricted to just snapper.
2. A working group or network for marine fish propagation and larval rearing unanimously endorsed as high priority.
3. “Solving” larval rearing a priority for striped trumpeter, groupers and gummy shark.
4. Reducing costs of producing fingerlings a priority for snapper (mainly in NSW/Qld) and kingfish (reducing deformities).
5. High costs of growing juveniles to market size (including because of slow growth) a priority for snapper, mulloway, striped trumpeter, Mahi Mahi, King George Whiting, Australian bass, black bream.
6. Grow-out diet development a priority for tuna, snapper, mulloway, gummy shark, Australian bass, black bream, grouper.
7. Cobia seen as having potential but not evaluated yet for Australian conditions.
8. Health issues priority for snapper, mulloway, barramundi, kingfish, striped trumpeter.
2. WORKSHOP INTRODUCTION

Peter Montague

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The Aquafin CRC is a research and education provider, specialising in aquaculture of finfish. It is a joint venture of a large group of research institutions and universities, industry associations and companies, and the Fisheries R&D Corporation, and its effectiveness depends entirely on the collaborative efforts of these partners, their staffs and students.

The purpose of the CRC is to meet major needs of the Australian finfish aquaculture industry for new and improved technologies, to provide scientific information for environmental risk managers in government and industry, and to enhance the skills of people working in and for aquaculture. It has a strong emphasis on Atlantic salmon and Southern Bluefin tuna.

The CRC has a fixed life span of 7 years (2001-2008), although this could possibly be extended if it competes successfully with new applicants in the selection round expected in 2006.

The CRC’s objectives can be expressed in broad terms as:

- To enhance the contribution of long-term scientific and technological research and innovation to Australia’s sustainable economic and social development;
- To enhance the transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia;
- To enhance the value to Australia of graduate researchers; and
- To enhance collaboration among researchers, between researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources.

The characteristics of the CRC are:

- A close and direct relationship with industry, and commercial approach to intellectual property, to ensure that the research in fact contributes to economic development;
- Inclusion of FRDC as a Participant, and use of the pre-existing structures set up by FRDC to manage research on tuna and salmon;
- Research program leaders in the scientific disciplines (production, health and environment) to build cross-species and inter-institutional cooperation throughout the CRC;
- Purposeful and innovative education programs to develop a new generation of scientists who have both excellent research and technical skills and a strong affinity for the aquaculture business.

The CRC’s interest in this workshop is to see national R&D collaboration enhanced in the marine finfish aquaculture field.
3. STATUS OF MARINE FISH PRODUCTION IN NSW

Stewart Fielder, Mark Booth, Geoff Allan

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1. Industry status in NSW

Farming of marine fish in NSW is developing and is principally based on seacage growout of snapper, *Pagrus auratus* and mulloway, *Argyrosomus japonicus* for consumption and extensive larval rearing of the catadromous Australian bass, *Macquaria novemaculeata* for production of fingerlings for stock enhancement of freshwater recreational fisheries. Small numbers of other estuarine species (silver bream, *Acanthopagrus australis*, black bream, *Acanthopagrus butcheri*, sand whiting, *Sillago ciliata* and eels, *Anguilla australis* and *A. reinhardtii*) have been produced intermittently for research and commercial evaluation. Farming of barramundi, *Lates calcarifer* in freshwater, recirculation tanks is also increasing. Hatchery production of barramundi fingerlings is not permitted in NSW and fingerlings are purchased from certified, interstate hatcheries. Although 56 and 19 permits have been issued to operate growout farms and hatcheries in NSW, respectively, less than ten of these facilities are productive (Table 1).

Table 1. Number (,000) of marine fish fingerlings produced by hatcheries in NSW.

<table>
<thead>
<tr>
<th>Species</th>
<th>Year</th>
<th>1997/98</th>
<th>1998/99</th>
<th>1999/00</th>
<th>2000/01</th>
<th>2001/02</th>
<th>2002/03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snapper&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>60</td>
<td>90.5</td>
<td>49.2</td>
<td>40.3</td>
<td>(40)</td>
<td></td>
</tr>
<tr>
<td>Mulloway&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.5</td>
<td>0.1</td>
<td>0.3</td>
<td>0 (52)</td>
<td>140 (235)</td>
<td>200 ?</td>
<td></td>
</tr>
<tr>
<td>Silver bream&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand whiting&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian bass&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>100</td>
<td>10 (275)</td>
<td>80.7 (300)</td>
<td>167 (250)</td>
<td>250 (100)</td>
<td>250 ?</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>figures in (n) are fingerlings produced by NSW Fisheries

<sup>b</sup>estimated values

<sup>c</sup>intensive clearwater and greenwater larval rearing

<sup>d</sup>intensive clearwater, greenwater and extensive fertilised pond larval rearing

<sup>e</sup>for stock enhancement of recreational freshwater fisheries and farm dam stocking

Two seacage growout facilities have recently commenced commercial production of snapper and mulloway and (Table 2) and production in 2002/03 is estimated at 140t. Snapper are mostly sold as 450-550g plate-size fish and relatively small volumes of mulloway have been sold as 750-1000 g fish. However one grower anticipates producing 3-6 kg mulloway to access different domestic and export markets. Demand for aquaculture snapper and mulloway from Sydney, Melbourne, Brisbane and Newcastle markets is high and currently exceeds supply. The snapper farming industry however has had difficulty competing with wild-caught product due to market bias against the aquaculture product.
Table 2. Quantity (t) of market-size fish produced by industry in NSW.

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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Snappera</td>
<td>0.4</td>
<td>0.9</td>
<td>13.4</td>
<td>20.0</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>Mullowayb</td>
<td>6.0</td>
<td>0.1</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td>100.0</td>
</tr>
<tr>
<td>Eelsc</td>
<td>0.6</td>
<td>2.3</td>
<td>2.4</td>
<td>0.6</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Barramundi(d)</td>
<td>0.1</td>
<td>11.2</td>
<td>16.9</td>
<td>65.4</td>
<td>100.0</td>
<td>120.0</td>
</tr>
</tbody>
</table>

*Estimated values based on number of fish on hand at growout sites
\(a\)seacage growout
\(b\)seacage and estuarine ponds
\(c\)landbased recirculation (freshwater)

Two problems currently hinder major expansion and viability of snapper farming. The first bottleneck is a reliable supply of high-quality, cheap fingerlings. The only dedicated commercial snapper hatchery in NSW is not operating due to company restructure and hatchery-refurbishment. NSW Fisheries at the Port Stephens Fisheries Centre has produced relatively small quantities of snapper to assist industry development. Hatchery technology for snapper production in Australia has mostly developed using intensive clearwater or greenwater methods.

Significant progress to improve intensive hatchery production has been made. It is now possible to spawn high-quality eggs all year using truncated phototherms and hatchery-reared broodstock (Fielder et al., 1999) and larval growth has been almost doubled by identification of the optimal larval salinity, temperature and photoperiod regime (Fielder et al., 2002; unpublished data). This will result in cheaper fingerling production but costs such as live feeds and labour for intensive hatcheries are still high. Alternative, cheaper larval feeds or rearing methods need to be identified. Also, other marine fish hatchery operators (mulloway and bass) in NSW mostly use extensive, fertilised pond techniques. Reliable extensive larval rearing of snapper has not been demonstrated to date and must therefore be developed to enable existing and new extensive hatcheries to diversify into fingerling snapper production. Management of disease in hatcheries is also an area in need of R&D. Significant mortality of snapper and mulloway fingerlings has occurred following infestation of a dinoflagellate, *Amyloodinium ocellatum*. Methods to exclude and/or treat infestation of this parasite need to be developed.

The second bottleneck to profitable snapper production is the lack of cost-effective high-performance diets and feeding systems for both hatchery and grow-out. Growout diets need to produce fish with desirable marketing traits, including colour. The skin colour of seacage grown fish is currently very dark compared with that of “pink” wild-caught snapper. The market has been reluctant to purchase “dark” fish and consequently prices have been downgraded. Fish are marketed as a “healthy” product, largely because fish fat has relatively high contents of the omega-3 highly unsaturated fatty acids. However, while replacing fish meal and fish oil in fish diets may reduce diet cost, it will also reduce these health benefits. Reducing feed wastage by making sure pellets are water stable and by determining the best feeding frequencies and feeding rates will help minimise pollution from fish farms. To achieve these goals, diets are being developed that satisfy but not oversupply essential nutrients and that are made from high quality, highly digestible, readily obtainable ingredients.
2. Project aims and staff

FRDC Project Number: 2001/208
CRC Project Number: 2.3
Project Title: Aquafin CRC – Increasing the profitability of snapper farming by improving hatchery practices and diets.

**Hatchery methods.** The project will aim to improve survival and growth of snapper fingerlings by refining intensive rearing and developing extensive rearing methods. In particular, the optimum age and density of larvae to stock into extensive ponds will be determined. Different live and artificial feed combinations, especially those using rotifers and artificial diets alone, will be rigorously tested to determine the optimum feeding strategy for Snapper larvae. Strategies to reduce or treat the incidence of parasites will be developed with particular attention to the problem of *Amylodinium* sp, its exclusion or therapeutic treatment.

**Grow-out diets.** The project will aim to improve quality of snapper to fetch premium prices. Best quality snapper need to have red/orange skin and white flesh. Dietary supplements to change skin colour need to be assessed in combination with farming practices (such as shading cages) to develop better ways to produce the red/orange snapper sought by consumers. New diet formulations e.g. by replacing fishmeal, that do not reduce the benefits of fish having a “healthy” high content of highly unsaturated fatty acids will be developed. Feed wastage and pollution from fish farms will be minimised by ensuring pellet stability and determining the best feeding frequencies and feeding rates. "Eco-friendly" diets will be developed that satisfy but not oversupply essential nutrients and that are made from high quality, highly digestible, readily obtainable ingredients.

**Table 3.** Project 2.3 Snapper project staff.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Geoff Allan</td>
<td>Principal Investigator</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Mr Stewart Fielder</td>
<td>Scientist</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Mr Mark Booth</td>
<td>Scientist</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Mr Bill Bardsley</td>
<td>Senior Technician</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Ms Geraldine McMahon</td>
<td>Technician</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Mr Bill Bardsley</td>
<td>Technician</td>
<td>NSW Fisheries, PSFC</td>
</tr>
<tr>
<td>Prof. Bob Lester</td>
<td>Professor of Parasitology</td>
<td>University of Qld</td>
</tr>
<tr>
<td>Ms Priya Pitt</td>
<td>PhD student</td>
<td>University of Qld</td>
</tr>
<tr>
<td>Dr Jian Qin</td>
<td>Lecturer</td>
<td>Flinders University</td>
</tr>
<tr>
<td>Mr Wayne Hutchinson</td>
<td>Senior Research Scientist</td>
<td>SARDI, West Beach</td>
</tr>
<tr>
<td>Ms Michelle Burford</td>
<td>Research Scientist</td>
<td>CSIRO, Cleveland</td>
</tr>
<tr>
<td>Mr Andrew Bald</td>
<td>General Manager</td>
<td>Pisces Marine Aquaculture</td>
</tr>
<tr>
<td>Mr John Hedison</td>
<td>General Manager</td>
<td>Silver Beach Aquaculture</td>
</tr>
<tr>
<td>Dr Ray Johnson</td>
<td>General Manager</td>
<td>Ridley Agriproducts</td>
</tr>
</tbody>
</table>
### Milestones and Progress

<table>
<thead>
<tr>
<th>MILESTONES (by time)</th>
<th>Days</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-Dec-01</td>
<td>1</td>
<td>Completion of early weaning in intensive tanks experiment</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>2</td>
<td>Completion of first trial to evaluate zooplankton productivity in fertilised ponds</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>3</td>
<td>Characterisation of Amlyoodinium and other parasites and evaluation of parasite problems in snapper hatcheries and current methods of control</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>4</td>
<td>Establishment of parasitic organisms in culture.</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>5</td>
<td>Completion of experiment to determine requirements for protein and energy</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>6</td>
<td>Completion of experiment (1) to quantify ingredient utilisation</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>7</td>
<td>Identified optimum age of stocking of snapper larvae in extensive fertilised ponds</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>8</td>
<td>Completed first pond trial to evaluate zooplankton production</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>9</td>
<td>Determination of species of Amlyoodinium and genetic evidence of subspecies or strains</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>10</td>
<td>Efficacy of orally-administered compounds evaluated</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>11</td>
<td>Completion of experiment (1) to quantify carbohydrate utilisation</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>12</td>
<td>Completion of experiment (1) to improve skin colour</td>
</tr>
<tr>
<td>30-Dec-01</td>
<td>13</td>
<td>Identified optimum stocking density of snapper larvae in extensive fertilised ponds</td>
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<td>14</td>
<td>Completed first trial to evaluate suitability of pond-grown zooplankton for intensive larval production</td>
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<td>Identified optimum commercial weaning diets and feeding strategies for intensive rearing of snapper larvae</td>
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<td>Strength of acquired immunity in fish determined</td>
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<td>Completion of experiment (1) to quantify ingredient digestibility</td>
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<td>Completion of experiment (2) to quantify ingredient utilisation</td>
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<td>30-Dec-01</td>
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<td>Determined optimum culture methods for sustainable production of zooplankton production in ponds</td>
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<td>21</td>
<td>Phototaxis of Amlyoodinium evaluated</td>
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<td>Causes of parasite mortality away from fish determined</td>
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<td>Method to increase parasite mortality tested</td>
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<td>Determined optimum rearing strategy (intensive/extensive) for snapper larvae</td>
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<td>Determined optimum feeding strategy for early weaning of snapper larvae</td>
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<td>Completed experiments/recommendations for feeding strategies</td>
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</tr>
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<td>36</td>
<td>Completed first pond trial to evaluate zooplankton production</td>
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<td>Determination of species of Amlyoodinium and genetic evidence of subspecies or strains</td>
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<td>Efficacy of orally-administered compounds evaluated</td>
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<td>30-Jun-02</td>
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<td>30-Jun-02</td>
<td>43</td>
<td>Identified optimum commercial weaning diets and feeding strategies for intensive rearing of snapper larvae</td>
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<td>30-Jun-02</td>
<td>44</td>
<td>Determined optimum culture methods for sustainable production of zooplankton production in ponds</td>
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<td>Determined optimum feeding strategy for early weaning of snapper larvae</td>
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<td>Completed second experiment to quantify N,P and C budgets</td>
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</table>
All of the project milestones were completed or partially-completed to June 30 2002.

**Fingerling Production Component**

*Completion of first trial to evaluate zooplankton productivity in fertilised ponds*

This is partially completed. Three 500 m$^2$ ponds were filled with 200 $\mu$m filtered estuarine water and fertilised with nitrogen and phosphorous at 1 mg l$^{-1}$, respectively and an organic carbon source (lucerne hay at 900 kg/ha). Water quality parameters (salinity, temperature, pH, dissolved oxygen) were measured daily in each pond. Every three days samples of plankton were collected from each pond by siphoning 150 l of water from a 50 mm diameter hose which was suspended in mid-water in each pond. The collected water was then poured through a 50 $\mu$m screen and all collected zooplankton was fixed and archived for later analysis. The trial ended after 21 days. Zooplankton samples were fixed in buffered formalin and will be assessed to estimate the frequency, size and genera of zooplankton, which grew in fertilised ponds during the trial.

*Completion of early weaning of snapper larvae in intensive tanks experiment*

An experiment was successfully completed to evaluate the performance of snapper larvae when fed different combinations of live feed (rotifers and artemia) and formulated pellet diet (ML-powered, Nippai, Japan). Snapper larvae (10 dah) were stocked into 100-L tanks and fed different combinations of rotifers, artemia and ML pellet diet (five replicate tanks per treatment) (Table 4).

<p>| Table 4. Feeding regime for snapper larvae from 14 – 45 days after hatching. |
|---------------------------------|-------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rotifers (Days after hatch)</th>
<th>Artemia (Days after hatch)</th>
<th>ML diet (200 um) (Days after hatch)</th>
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<tr>
<td>1</td>
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<td>20-33 (full ration)</td>
<td>25-45</td>
</tr>
<tr>
<td>2</td>
<td>10-35</td>
<td>20-33 (50% ration)</td>
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<td>10-35</td>
<td>Nil</td>
<td>25-45</td>
</tr>
<tr>
<td>4</td>
<td>10-35</td>
<td>20-33 (full ration)</td>
<td>15-45</td>
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<td>5</td>
<td>10-35</td>
<td>20-33 (50% ration)</td>
<td>15-45</td>
</tr>
<tr>
<td>6</td>
<td>10-35</td>
<td>Nil</td>
<td>15-45</td>
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</table>

After 45 days larvae in all treatments had metamorphosed and were fully weaned onto a pellet diet (12 days exclusively fed pellet). Neither survival (73-98%) nor final total length was affected by feeding regime (Fig. 1). It was possible to rear high-quality snapper larvae on a diet devoid of artemia.
Figure 1. Total length of snapper larvae fed different combinations of artemia and ML diet.

Identified optimum age of stocking of snapper larvae in extensive fertilised ponds

An experiment to determine the effect of larvae age at stocking on growth and survival of snapper larvae in fertilised ponds was attempted in early May 2002 but was not completed due to failure of zooplankton blooms. It was suspected that proliferation of a large, and therefore inedible, diatom in the ponds contributed to poor zooplankton production. The experiment was postponed until October/November 2002 when water temperatures will be suitable for optimal snapper larvae growth.

Fish Health Component

(PhD student Ms Priya Pitt, Supervisor Professor Bob Lester, University of Queensland (UQ))

• Characterisation of Amyloodinium and other parasites and evaluation of parasite problems in snapper hatcheries and current methods of control.
• Establishment of parasitic organisms in culture.

Development of techniques to maintain Amyloodinium sp.

Juvenile snapper infested with the parasite Amyloodinium sp. were successfully transferred from PSFC to UQ to provide an initial inoculum of parasites. Significant effort has been made to successfully establish a continual culture of Amyloodinium at UQ using toados as host fish species. Toados are euryhaline, easily obtained near UQ and tolerant of regular handling and maintenance in small aquaria. Infested toados are regularly removed and bathed in freshwater for 6 to 9 mins to remove external Amyloodinium tomonts. The tomonts are then collected from the freshwater bath and used to inoculate uninfested fish.
Amyloodinium tomonts remained viable after freezing and have been used successfully to propagate the infestation following the method described above. This suggests that Amyloodinium tomonts are potentially resistant to a wide range of environmental conditions and therefore has implications for methods of control and/or eradication from hatcheries.

Experiments will commence soon to determine the effect of light intensity on the phototactic response of Amyloodinium under laboratory conditions.

**Diet Development Component**

- Completion of experiment to determine requirements for protein and energy

**Effects of digestible energy content on the digestible protein requirements of juvenile Australian snapper Pagrus auratus**

The effects of dietary digestible protein and digestible energy content on performance of juvenile snapper Pagrus auratus was evaluated. Our experimental design called for seven dietary digestible protein contents to be formulated at each of three digestible energy contents (21, 18 and 15MJ/kg; Appendix 1; Table 5). A commercial diet for which preliminary growth data of snapper was available was included as an internal control (Ridley Aquafeeds Pty Ltd).

**Materials and Methods**

Diets were formulated following the determination of individual ingredient digestibility coefficients at PSFC. Diets were manufactured on a dry weight basis using high quality fish meal (Ridley Aquafeeds Pty Ltd: supplier), extruded wheat (Ridley Agriproducts Pty Ltd: supplier), fish oil (cod liver oil – Janos Hoey: supplier) and two inert fillers (diatomaceous earth; carboxy methyl cellulose). All diets were fortified with 1.5% vitamin / mineral premix (NSW Fisheries formulation) including 0.1% vitamin C (Stay-C 35) before being ground. Diets were then thoroughly dry mixed before adding sufficient distilled water to enable a high quality, cold pelleted 3mm sinking pellet to be produced. Diets were dried in low temperature drying cabinets at < 45°C until moisture contents were less than 8%.

Eight juvenile snapper (mean initial weight 30g) were systematically placed in each of 66 perforated 200L floating cages. Floating cages were held in 10 000L fibre-glass tanks in the green house facility at PSFC. Each 10 000L tank held 8 floating cages. Cages were fitted with lids and feeding trays. Each dietary treatment was randomly allocated to three experimental units. All fish were acclimated on the commercial control diet for 10 days prior to being placed on experimental diets. Fish in each cage were carefully hand fed twice daily (= 0830 and = 1430h) to apparent satiation for six days a week. Fish were fed once daily to apparent satiation on Sundays (= 0830h). The experiment was completed after 57 days. At completion of the experiment, all fish were individually weighed and performance indicators determined. Two fish from each cage were randomly selected and killed for chemical analysis in order to determine retention efficiencies for protein and energy. The remaining fish from the growth trial were transferred to a digestibility lab where they continued to be fed their respective test diets. Three diets from each energy series was selected so that the highest, middle and lowest digestible protein contents could be evaluated. These diets were mixed with chromium oxide to allow determination of apparent dietary digestibility coefficients.
Results/Discussion

The practical component and all outstanding chemical analyses of samples from the growth and digestibility experiment have been completed. Fish health during this experiment was excellent with 100% survival rates recorded for all treatments. Digestible protein and energy contents of test diets was confirmed by digestibility assay, with measured values for protein reasonably close to formulated values. Digestible energy content was more variable, particularly for the low digestible energy series. Irrespective of digestible energy content, weight gain and protein deposition increased with increasing contents of dietary digestible protein (Appendix 1; Table 6; Figure 2). However, snapper fed on diets containing low and mid energy levels gained more weight than snapper fed on the high energy series. Diets containing about 45% digestible protein and 17MJ kg-1 digestible energy should be sufficient to promote good growth in snapper.

• Completion of first experiment to quantify ingredient utilisation

Utilisation of four agricultural protein sources by Australian snapper Pagrus auratus.

The utilisation of four agricultural ingredients (protein sources) by snapper was tested by growth assay; poultry offal meal (Steggles Pty Ltd), meatmeal (Ridley Pty Ltd), bloodmeal (Lachley Meats Pty Ltd) and solvent extracted soybean meal. Diets were formulated to a single digestible protein (45%) and energy level (17MJ/kg) based on the previous outcomes of digestibility and growth experiments undertaken at PSFC. The dietary inclusion content of test ingredients (Appendix 1; Table 7) was increased at the expense of fishmeal, extruded wheat or fishoil, with the remainder balanced by carboxy-methyl-cellulose or diatomaceous earth. A commercial barramundi diet which had been evaluated in terms of growth and digestibility was used as an internal control.

Materials and Methods

Diets were formulated following the determination of individual ingredient digestibility coefficients at PSFC. Diets were manufactured on a dry weight basis and all diets were fortified with 1.5% vitamin / mineral premix (NSW Fisheries formulation) including 0.1% vitamin C (Stay-C 35) before being ground. Diets were then thoroughly dry mixed before adding sufficient distilled water to enable a high quality, cold pelleted 2mm sinking pellet to be produced. Diets were dried in low temperature drying cabinets at < 45°C until moisture contents were less than 8%. In total, 12 diets were evaluated in this trial.

Fifteen juvenile snapper (mean initial weight 14g) were systematically placed into each of 55 perforated 200L floating cages. Floating cages were held in 10 000L fibre-glass tanks in the green house facility at PSFC. Each 10 000L tank held 8 floating cages. Cages were fitted with lids and feeding trays. Each dietary treatment was randomly allocated to five experimental units. Fish were fed twice daily (0830 and 1500h) to apparent satiation and once on Sundays (0830h). At completion of the experiment (50 days), all fish were individually weighed. Three fish from each cage were randomly selected and killed for chemical analysis in order to determine retention efficiencies for protein and energy.

Results/Discussion

Survival of fish was high in this experiment. Weight gain for fish fed diets containing either 36% poultry meal, 35% meat meal and 42% soybean meal matched the weight gain of fish fed the commercial control diet (Figure 2). FCR’ ranged between 1.4 and 2.0 for all treatments (1.47 for control diet) and tended to increase in response to increasing contents of test ingredients. Diet and
carcass samples have been submitted for chemical analysis and will be used to examine fish composition and determine the retention efficiencies for dietary protein and energy.

![Graph showing weight gain of juvenile snapper fed different diets.](image)

**Figure 2.** Weight gain of juvenile snapper fed diets containing increasing contents of poultry offal meal (M), meat meal (M), meat and blood meal (M/B) and soybean meal (S) compared to a commercial barramundi diet (COM). Values are mean ± sd for 5 replicate tanks.

### 4. Communication and cooperation

Staff of the fish breeding and diet development projects at PSFC meets with NSW industry stakeholders regularly to disseminate research results and discuss production and R&D issues. Four presentations that include results from this project have been given (see list of publications). One of these presentations was made at the FRDC Aquaculture Nutrition Subprogram meeting (Cleveland, Qld, February, 2002), two presentations at the World Aquaculture Society Conference, World Aquaculture 2002 (Beijing, China, April 2002) and a final presentation at the 6th International Symposium on Aquatic Nutrition (Cancun, Mexico, September 2002).

### 5. Challenges – new priorities

- Identification of sites (coastal, offshore and inland) suitable for marine fish culture in Australia.
- Encouragement to establish new marine fish hatcheries in NSW and Qld. Current hatchery supply is too small and unreliable for the existing grow-out sector but the grow-out sector is too small to justify construction of a large, efficient marine fish hatchery. Government support as well as industry collaboration are essential to overcome this constraint.
- Developing larval rearing technology and diets, which decrease cost of production and increase quality of snapper fingerlings and market-size snapper. This technology will be applicable to other new and developing temperate marine fish in Australia.
- Develop/validate technology for marine fish farming using saline groundwater of inland Australia.
Recognising that many marine fish farms in Australia (as elsewhere) are likely to benefit from having two or three species under culture to spread risk and maximise marketing opportunities. The most suitable species “mix” will depend on the available species, culture facilities and proximity to and type of markets. Suitable candidate species, eg mulloway, kingfish and cobia, need to be identified and constraints to their culture identified as a first priority.

6. References and Publications (Snapper research since 1992 in chronological order)


Conference Abstracts


APPENDIX 1

Table 5. Ingredient composition (dry basis) and measured digestible protein and energy contents of test diets fed to juvenile snapper *Pagrus auratus*.

<table>
<thead>
<tr>
<th>Ingredient (%</th>
<th>Diet1</th>
<th>Diet2</th>
<th>Diet3</th>
<th>Diet4</th>
<th>Diet5</th>
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Table 6. Performance of snapper fed experimental diets for 57 days.

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<th>DE intake (kJ/kgBW/d)</th>
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Table 7. Ingredient and gross nutrient composition of test diets fed to snapper containing poultry meal, meat meal, blood meal and soybean meal.

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<th>minerals</th>
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Nutrient composition

| D. Protein | 44.6 | 44.6 | 44.5 | 43.6 | 44.7 | 45.7 | 43.1 | 44.1 | 44.1 | 44.0 |
| D. Energy  | 17.2 | 17.3 | 17.4 | 17.6 | 17.2 | 17.1 | 17.3 | 17.3 | 17.3 | 17.3 |
4. PISCES MARINE AQUACULTURE – COMPANY PERSPECTIVE

Andrew Bald

Director, Pisces Marine Aquaculture
GPO Box 1906, Sydney NSW 2001
☎ 02 4984 2028; Email: andrewbald@pisces.com.au

Company

- Now considered a serious business within investment community
- In process of increasing company capitalisation
  - In negotiation with institutional investor
  - If not successful will float company on Newcastle Stock exchange
  - Major expansion will follow capital raising proposed for November 2002
- Will continue to invest in technology including grading and harvesting equipment and feeding technology.

Snapper

- PMA farmed snapper are an excellent product.
- Fish skin colour causes initial marketing barrier but once past initial barrier have been getting repeat business.
- Very high demand for snapper after strong initial resistance. About July this year noted a major shift in attitude with customers.
- Snapper are the priority so the supply of Snapper fingerlings is a priority by first quarter.
- Staff prefer working with snapper.
- Selling 1 tonne of snapper per week for last 3 months.
- Regularly harvesting over 500kg per harvest, 2 harvests per week.
- 450-550 g fish usual market size.
- 45,000 fish in water.
- Estimated sales of 35-40 tonnes snapper 2002/03.
- Goal ~ 500 tonnes within 3 years.
- Demand is continuing to grow and the quality of our fish is continuing to improve. Our suppliers have this week called us to tell us that our fish are the best they have ever had.

Mulloway

- Began selling at 500 g despite preconception that small Mulloway would have poor taste, i.e.”Soapies”.
- Fillets. Bigger fish might get better price.
- 190,000 mulloway in hand.
- >100 tonnes over next year.

Total: Snapper + mulloway 140 t before June 2003.
Future Directions

- PMA has massive assets – under utilized.
- Fingerling supply major constraint.
- Hatchery industry development and health certification/hatchery certification an issue. Fingerlings must be properly weaned and vetted for disease.
- Snapper needed because of proven demand and ease of handling vis-à-vis Mulloway.
- Other species important to fully utilize assets, i.e. growout lease.
- Mixed farming important and need other species to fulfil demand (wholesalers like being able to source more than one aquaculture species from the same supplier for a range of reasons including reliability, trust etc etc).
- Yellowtail kingfish possible future species in NSW.
- Buoyancy of pellets an issue (prefer pellets that sink slowly to floating pellets).
- $1800/t grower feed – too high.
- Cost-effective diets very important. Economics seem to illustrate that it may be better to accept poorer FCR (e.g. 2.2.5:1) but benefit from lower price feed, i.e. rather than kg of Food/kg of Fish, should consider $$/kg of Fish.
5. INLAND SALINE CULTURE OF MARINE SPECIES IN NSW

1Mehdi Doroudi, 2Geoff Allan & 2Stewart Fielder

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☎ 03 5887 3366; Email: mehdi.doroudi@fisheries.nsw.gov.au
2 NSW Fisheries, Port Stephens Fisheries Centre
☎ 02 4982 1232; Email: geoffrey.allan@fisheries.nsw.gov.au

Farming of marine species in coast line is limited by high land prices, shortage of suitable sites, environmental constraints and conflict with other land and water users. As highlighted in the National Strategy on Aquaculture (1994), it is clear that a shortage of suitable coastal sites is a major constraint to the expansion of aquaculture industry in Australia. At the same time, rising saline groundwater is the biggest environmental problem in Australia and currently affects over 2.5 million ha of land. It is estimated that within the next 30-40 years, the affected area will grow more than fourfold. One of the key methods to improve the effects of salinisation is to pump the saline groundwater into large ponds for disposal by evaporation. If it can be proven that inland saline groundwater is suitable for growing marine finfish, incorporating aquaculture ponds into these evaporation schemes will not only provide an economic return to the costly business of building and operating groundwater interception schemes but also greatly reduce costs of establishing aquaculture ponds.

Results of preliminary studies conducted by NSW Fisheries at Port Stephen Research Centre and Wakool-Tullakool Sub-Surface Drainage Scheme (WTSSDS) showed that the chemistry of the saline groundwater is different to that of oceanic seawater. Saline groundwater from the WTSSDS has approximately 95% less potassium than similar salinity oceanic seawater, and consequently is not suitable for survival and growth of marine species. However, the potassium concentration of groundwater can be fortified easily and cheaply by adding potash and once this was done, snapper (Pagrus auratus) held in tanks survived and grew at the same rate as they grown in seawater. The results of this research showed that using plastic liner solves the problem of aged sediments in the ponds. An acclimation protocol was also developed for fish transported from Port Stephens to Wakool in this phase of the project. An experimental pond culture at WTSSDS showed that cold climate (minimum 8°C) during winter at Wakool did not result in mortality of snapper, but growth was slow. Growth of snapper increased rapidly during summer when water temperatures increased to 29°C.

Based on the preliminary results and in order to develop aquaculture as a business initiative in saline affected inland areas, it was essential to continue and develop our research program to evaluate the commercial practicality of inland saline groundwater for aquaculture; therefore, NSW Fisheries, together with Murray Irrigation Ltd and NSW Department of State and Regional Development have commenced a new project to develop this potential. The specific objectives of this project are:

1. To develop a protocol for sustainable, commercially viable culture of snapper, mulloway (Argyrosomus japonicus), black-tiger prawn (Penaeus monodon) and silver perch (Bidyanus bidyanus) using inland saline groundwater.
2. To promote commercial development of inland saline aquaculture as a business opportunity for existing and planned saline groundwater interception schemes.
To achieve above objectives, a new research and demonstration facility, the Inland Saline Aquaculture Research Centre has been constructed at the WTSSDS, the largest evaporation scheme in Australia with over 1600 ha of evaporation ponds, near Wakool in southern NSW. The Centre includes $6 \times 0.05$ ha plastic-lined earthen ponds, supplied with freshwater and saline groundwater from a dam and two evaporation ponds (each have different salinities), respectively, a small-scale experimental tank facility and a temperature controlled laboratory.

The combined effects of salinity and potassium level on survival of mulloway fingerlings were studied in this Centre over a period of 44 days. Triplicate aquaria were held at salinities of 15, 25 and 35 ppt with potassium levels of 40, 60, 80 and 100% in a $3 \times 4$ factorial combination to evaluate the survival and specific growth rate (SGR) of mulloway fingerling over a period of 44 days. Response surface contour maps for survival and SGR of mulloway fingerling were shown in Figs 1 and 2, respectively. The regression analysis indicated that linear and quadratic effects of salinity and potassium level were not contributing to variances in survival and SGR data significantly ($P > 0.05$). No statistically significant ($P > 0.05$) salinity-potassium interaction was found for survival and SGR of mulloway fingerling over a period of 44 days.

The result of our laboratory studies confirmed that inland saline groundwater from WTSSDS is suitable for growth and survival of snapper and mulloway, provided the salinity ranges from 15-35 ppt and potassium levels are adjusted to above 40% of those concentrations present in seawater at the same salinity. Therefore, mulloway fingerlings were transferred into a 0.05-h pond containing saline groundwater at 23 ppt and 70% potassium level to evaluate the survival, growth rate, productivity and food conversion ratio over a period of 12-15 months. More ponds will be stocked by snapper in coming months to develop a growout technology using inland saline groundwater. In addition to snapper and mulloway, other species such as silver perch and black-tiger prawn have also potential for culture using saline groundwater. Experiments with silver perch and tiger prawn are underway.

In order to develop aquaculture as a business initiative in saline affected inland areas, it is essential to commercially validate the suitability of saline groundwater for culture of marine or salt tolerated freshwater species. If successful technology is developed and proven in pilot-scale, inland saline aquaculture can be part of a solution for rising salinity in those areas where groundwater interception schemes and evaporation ponds are needed to prevent rising salinity destroying agriculture or urban infrastructure.
Figure 1. Response surface estimation of survival of mulloway fingerling at salinity and potassium level over a period 44 days.

Figure 2. Response surface estimation of specific growth rate (g/day) of mulloway fingerling at different salinity and potassium levels over a period of 44 days.
6. INDUSTRY STATUS AND RESEARCH ISSUES FOR MARINE FINFISH AQUACULTURE IN SOUTH AUSTRALIA

Wayne Hutchinson

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☎ 08 8200 2443; Email: Hutchinson.Wayne@sa.gov.au

Introduction

Apart from southern bluefin tuna (Thunnus maccoyii), commercial culture of marine finfish in South Australia is currently confined to production of yellowtail kingfish (Seriola lalandi), Atlantic salmon (Salmo salar), sea run rainbow trout (Oncorhynchus mykiss), and mulloway (Agyrosomus japonicus). In addition, SARDI is persisting with research to develop hatchery production methods and improve growth performance of King George whiting (Sillaginododes punctata) due to the high market acceptance of this species. Previous attempts to commercialise production of snapper (Pagrus auratus) and black bream (Acanthopagrus butcheri) have either been considered unprofitable or remain less viable than species currently being cultured.

YELLOWTAIL KINGFISH

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<tr>
<td>2002/03</td>
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Research Issues

Parasite infestations during grow-out

The skin fluke Benedenia seriolae and the gill fluke Zeuxapta seriolae have been identified as the parasites that have caused high mortalities of fish in sea cages in South Australia. Both species are particularly important and have a history of creating major problems for yellowtail (Seriola spp) culture in Japan. Treatments that have been used to control flukes include trials with praziquantel as an in-feed medication and hydrogen peroxide administered as a bath in lined cage systems similar to those used for treatment of gill amoeba of Atlantic salmon in Tasmania.

This problem is being addressed by ARC funded parasitological research conducted by Dr Ingo Ernst (The University of Adelaide) and Dr Ian Whittington (South Australian Museum and The University of Adelaide). This research aims to develop a Parasite Management Plan based upon an understanding of parasite life cycles, infection dynamics, and measurement of parasite populations. This will allow farmers to monitor parasite levels and manage the problem through improved farm practices and treatments that should reduce current production costs.
Deformities

In 2001 a total of approximately 800,000 YTKF fingerlings were produced by the two commercial marine finfish hatcheries operating in South Australia, Spencer Gulf Aquaculture (SGA) at Port Augusta and Clean Seas Aquaculture Hatchery (CSAH) at Arno Bay. These hatcheries report end of nursery deformity levels between 10 – 70%. Currently this equates to significant lost earnings with further costs attributed to unrecorded losses due to cannibalism of deformed fish, days required for manual assessment of all fish prior to dispatch from the nursery; and loss of production and value of deformed fish in sea cages. There is a need for research that will identify the cause/s of deformities so that methods can be implemented to minimise these to enhance industry growth and product quality. SARDI have prepared an application to FRDC for funding to commence this research in a strategic manner with industry.

Interactions of farmed and wild fish

Recently there has been considerable concerns from recreational and commercial fishers over alleged escape of farmed kingfish. These concerns include impacts of increased numbers of kingfish on other commercial and recreational species (i.e. King George whiting, silver whiting, southern calamari), appearance of deformed fish captured by fishers, and possible future reduction in genetic fitness of wild stocks.

The industry would like to commence research required to address these concerns and would also like to assess the background level of parasites carried by wild yellowtail kingfish. Initial genetic aspects associated with the former issue will be incorporated in an assessment of the genetic and environmental basis of deformities, as part of SARDI’s FRDC application. A more comprehensive application on the issues within this topic will be submitted in the next funding round. The latter information will be incorporated into the Parasite Management Plan to monitor any increase in parasite level due to sea cage farming operations as this activity increases and may cause increased infection levels and threaten wild stocks. Recommendations for industry codes of practice need to be developed to help mitigate any potential impacts.

MULLOWAY

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</table>

SARDI was contracted by the SA Marine Finfish Farmers Association Inc. to produce between 40,000 – 60,000 mulloway fingerlings over the summer of 2000 – 2001. This involved capture and induced spawning (mid December) of broodstock capture by hook at the mouth of the Murray River. Approximately 380,000 1-5 g fingerlings were delivered to growers from 1.2 million eggs with a further 40,000 low grade excess fingerling euthanased.

These fish have been grown in sea-cages, recirculating seawater systems and ponds. Those grown in sea-cages in Boston Bay (Port Lincoln) have performed below expectation and average approximately 500 g after 18 months with wide size variation from 100 g – over 1.0 kg. This has been attributed to late stocking such that fish have only experienced one full summer combined with inability of farm staff to attend to these fish fully during extensive redevelopment of
infrastructure and expansion of yellowtail kingfish aquaculture over this period. Fish in sea cages have proven to be extremely resilient and trouble free with respect to disease problems. Fish stocked in recirculating seawater treatment systems have achieved good growth performance reaching market size of 400 – 600 g in 7-9 months. Fish cultured in ponds at Arno Bay have also proven to be resilient with growth under ambient conditions similar to that observed in the sea cages. Growers remain encouraged by this species and the hatchery aims to produce another batch of fingerlings early in the season (Oct-Nov 2002). If these fish receive improved management (i.e. feeding and grading) this will provide a better indication of potential performance.

Another major problem with mulloway is the market price. Commercialisation of this species will require a strategy to increase market demand nationally and identify potential international markets. If this can be done then the species may prove to be worth pursuing given the beneficial hatchery production, reasonable growth rate, grow-out resilience and adaptability to a range of salinities for saline groundwater systems.

**ATLANTIC SALMON AND SEA RUN RAINBOW TROUT**

<table>
<thead>
<tr>
<th>Year</th>
<th>Atlantic Salmon</th>
<th>Rainbow Trout</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001/02</td>
<td>65</td>
<td>8</td>
</tr>
<tr>
<td>2002/03</td>
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<td>30</td>
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<tr>
<td>2003/04</td>
<td>120</td>
<td>100</td>
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</table>

Sea cage culture of Atlantic salmon and rainbow trout is conducted at Cape Jaffa and Rivolli Bay in the south east of South Australia. At these locations a cool current extends along the coast providing maximum summer water temperatures of 20°C. Salmonids have been cultured at these locations over the past 5 years and there has been a steady industry expansion as experience has been gained and infra-structure accumulated. Farmers involved operate small scale hatcheries on their land based sheep and cattle farms. These hatcheries utilise pristine fresh groundwater at a constant 13-14°C. Over the years considerable problems have been encountered with the transfer of fish from hatchery ponds into sea cages. This problem is being improved annually through improvements in handling and transfer methods used. Further improvement has been made by manipulation of photoperiods to advance smolting. This has enabled smolts to be ready for stocking in July/August before sea temperatures start to increase.

Problems facing the industry relate primarily to environmental interactions of sea cages that overly seagrass in relatively shallow water depths (7-15m) protected by off-shore reefs. Monitoring programs are being followed by industry that have been designed to provide indications of any emerging environmental impacts. It is expected that as the industry evolves there will need to be development of modified farming procedures and management requirements to accommodate production and environmental needs of the unique circumstances at these locations.

Amoebic gill disease has been recorded in South Australia but is yet to cause any problem for sea cage farming. Of more concern is the market situation for Atlantic salmon given the small size of this developing industry in comparison to likely national and international competitors. It is hoped that a relatively small (i.e. 2,000 tonnes pa) industry will be able to develop a suitable market niche for the product.
KING GEORGE WHITING

Development remains at the research stage for King George whiting. Further research is required to address;

- Egg quality and volumes to support commercial scale hatchery operations.
- Increase larval survival from hundreds and thousands to hundreds of thousands.
- This will allow selection of best preforming stock and reduce production costs per fingerling.
- Improve growth rate during on-growing. The current production cycle is approximately 2.5 years to a market size of 220-250g. This will need to be reduced to a maximum of 2 years.

SARDI is continuing research until June 2003. During this time one out of season and another in season spawning will be covered to provide opportunities to improve egg quality and supply problems. Larval rearing trials using protocols modified to suit slow developing species will be conducted. Further consideration of the species will be based upon the outcome of research over this period.

SNAPPER

<table>
<thead>
<tr>
<th>Year</th>
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<tbody>
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<td>0</td>
</tr>
<tr>
<td>2002/03</td>
<td>0</td>
</tr>
</tbody>
</table>

Much of the development of marine finfish aquaculture in South Australia has flowed from early projects undertaken from 1995 that aimed to commercialise culture of snapper. SARDI provide research and technical assistance to these developments. No snapper have been produced in South Australia since the production year spanning July 2000 until June 2001. After 3 years (1997 – 2000) of commercial hatchery and sea cage development the industry considered that the returns from this species were not sufficient to warrant further fingerling production. This was primarily due to relatively poor growth rates of 18-20 months to market size of 400-500g. In addition, poor prices were received for inferior coloured product compared to wild caught fish. Farmers were able to change the colour of market size fish using pigment enhanced feeds but the redness of the skin was produced against a dark background of melanized skin. Regardless of improvements that could be made to address these issues there is little expectation that snapper will be grown in South Australia unless problems arise with better performing yellowtail kingfish.

BLACK BREAM

Black bream were produced at Clean Seas Aquaculture Hatchery at Arno Bay in 1999/2000 and 2000/2001 with a maximum of 40,000 produced. This species is no longer cultured due to:

- Poor demand for fingerlings.
- Fingerling quality.
- Poor growth rates.
- Low prices received.
The hatchery would continue this species if sufficient fingerling demand was available and would be able to address quality issues. Most of the fish produced were stocked in a range of types of recirculating systems. Poor growth rates were observed for this species in these systems. These results may be attributed in part to unrealistic growth projection (i.e. 400 g in 1 year) using untested systems run by inexperienced operators. The poor growth rates may also in part be attributed to precocious sexual development at about 150 g. Again there would need to be a stronger demand for product to support research needed to overcome problems experienced with this species.

SOUTHERN BLUEFIN TUNA PROPAGATION

In South Australia, propagation of southern bluefin tuna (SBT) is being pursued by the Stehr Group that operates Clean Seas Aquaculture Hatchery at Arno Bay. Considerable renovation of this facility has occurred over the past 2 years to increase production of yellowtail kingfish. Future phases of development include provision for facilities that will support propagation of SBT. The Aquafin CRC have had considerable difficulties initiating proposed research on SBT propagation due to a range of concerns of most other members of the Tuna Boat Owners Association of Australia.

SUMMARY

A commitment to long term research programs is required to allow commercialisation of new species as some of these will require development of specialised hatchery production methods and commitment to broodstock improvement programs to improve growth performance, disease resistance and maintain product quality.

Research has shown that there are few species of marine finfish that are both immediately responsive to hatchery production; and command high market price. King George whiting is an example of a species for which hatchery production and grow-out has proven difficult yet has high market appeal. Alternatively mulloway is a species that is easy to produce in the hatchery and has minimal problems during grow-out yet has poor market demand. Although most of the problems of hatchery production and grow-out of species such as snapper, mulloway and black bream can be solved there will be no incentive to do this unless opportunities can be seen for improved returns from stronger markets. Already there are marketing problems that are restricting production of yellowtail kingfish with growers electing to reduce potential stocking levels until better markets can be found.

Another area of future research should be the development of alternative culture systems to take advantage of off-shore culture locations and land based opportunities that have not as yet attracted effort required to prove viability. Off shore systems will only be practical if production in near-shore locations proves viable in the long term. Land based systems include coastal ponds using low-lying coastal land, inland saline pond systems and development of economically viable recirculation systems.
7. MORPHOLOGICAL AND PHYSIOLOGICAL CHANGES IN THE DIGESTIVE TRACT OF KING GEORGE WHITING (SILLAGINODES PUNCTATA)

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Abstract

The appropriate food supply is one of the most critical factors determining the success of larval fish culture in the early stage. To improve larval rearing techniques, a good understanding of larval digestive physiology and feeding ecology is necessary. The morphological changes of the digestive tract in King George whiting (Sillaginodes punctata) were examined in this study. From 4 days after hatch (DAH), the larval digestive tract rapidly developed to accommodate the event of first feeding, which was onset on 5 DAH. Both mouth and anus opened on 4 DAH. Most of the larvae started to feed on 5DAH. Soon after, the intestine constrictions and two pyloric caeca appeared, and the digestive tract was divided into three distinct parts: foregut, midgut and hindgut. Food consumption on rotifers substantially increased from 8 DAH. The size of the digestive tract increased but little change in morphological structure was observed from 8 DAH to 26 DAH. This period coincided with the fact that King George whiting only fed on small food organisms such as rotifers. Our study suggests that feeding behaviour of King George whiting larvae is determined by the morphological changes in the digestive tract. The physiological changes within the digestive tract and the feeding adaptation to these changes in King George whiting larvae still remain un-investigated.

Introduction

The aquaculture potential of King George whiting has increased over the past few years due to its high market price, flesh quality, and the need for aquaculture diversification. But until now, techniques for large scale fish rearing of this species have not been well established due to the lack of understanding of its feeding requirement at the larval stage. Despite the commercial farming interest for this species, little attention has been paid to larval fish biology (Hyndes et al., 1998; Jenkins and Welsford, 2002), especially on the morphological and physiological developments related to functional abilities in feeding, digestion, growth and survival.

Currently, two approaches have been adopted to improve the effectiveness of mass production of marine fish larvae: (1) manipulation of feeding strategies, including feeding regime, nutritional requirement and weaning techniques; and (2) determination of ideal environmental conditions, including suitable temperature, salinity, pH, DO, and light conditions (Liao et al., 2001). The appropriate food supply is one of the most critical factors determining the success of larval fish culture in the early stage. The optimal feeding strategy for larval fish rearing should be developed based on the understanding of digestive physiology (Govoni et al., 1986; Sarasquete et al., 1995; Hamlin et al., 2000), feeding ecology (Canino and Bailey, 1995; Johnston and Mathias, 1996) and nutritional requirement of fish larvae (Watanabe and Kiron, 1994; Sargent et al., 1999; Takeuchi,
Before considering King George whiting as a new candidate for marine aquaculture, the understanding of digestive physiology and feeding ecology is required.

The development of digestive tract is closely related to larval fish growth and survival. Physiological studies on the digestive system of larval fish do not only contribute to the understanding of the biology of fish larvae, but also provide solid information toward applied marine biology related to aquaculture. The determination of feeding strategy is important for the solution of low survival and slow growth in fish larvae. High mortality of larval fish could be resulted from inappropriate feeding during the following three critical periods: first feeding, metamorphosis, and weaning period. The basic knowledge of digestive physiology and feeding ecology during early larval developmental stages will contribute to improving the fish growout performance.

Although the larviculture technique may vary among fish species, the basic feeding protocol is similar across hatcheries. Marine finfish larvae are fed with enriched rotifers or *Artemia* nauplii as starter feed and then are weaned to feed on commercial formulated feed in certain period during the development of larval fish (Lee and Ostrowski, 2001). This feeding technology has been used for commercial fish fry production for several decades, but failure has been encountered for delicate species such as King George whiting. The reason is that there is a lack of understanding of the relationship between the morphological development and functional physiology at various larval stages. Therefore, it is necessary to understand the digestive physiology and feeding ecology of King George whiting larval fish before establishing a successful protocol for rearing this species. The objectives of this study were to (1) understand the ontogenetic development of digestive system of King George whiting larvae, including changes in histological structure and histochemical functions (e.g., digestive enzyme activities), (2) understand the gut dynamics and functions in King George whiting larvae at different larval stages, including movement, gut contents and evacuation time, and (3) develop weaning techniques for King George whiting based on the knowledge of digestive physiology and gut dynamics.

**Material and methods**

The experiment was conducted in twenty 25-L fiberglass tanks at SARDI, West Beach, South Australia. Upon hatching, fish larvae were stocked in the tanks at a density of 60-100 individual per litre. Newly hatched larvae were collected to measure the initial length and dry weight. All tanks were supplied with filtered (25 µm) seawater in a flow-through system. One air stone was used in each tank to provide gentle aeration and to promote a homogeneous distribution of microalgae, live food (rotifers and *Artemia* nauplii) and fish larvae. Overhead fluorescent light was provided with light intensity at the water surface approximately 200-500 lx. Photoperiod was controlled at 12 L:12 D. Rearing temperature during the experiment was controlled at 19°C ± 0.5°C. The experiment lasted 26 days.

The morphology of the digestive tract of King George whiting larvae (*n* = 5) during early development was studied from the first day after hatch (0 DAH) to 26 DAH. The larvae were sampled randomly from each tank and examined under a Leca dissecting microscope. Photographs were taken with a digital photomicrographic camera at the time of observations. For histological evaluations, fish samples were taken daily from 0 DPH to 20 DPH, every 2 days from 21 DAH to 26 DAH. Light microscope was used in the histological study of digestive system ontogeny in King George whiting.

Gut content analyses and gut evacuation (residence times or gut passage rate) were determined by counting food items under dissecting microscope and the passage of tagged rotifers and *Artemia* nauplii through the gut respectively in different development stages. Daily food consumption rate was estimated from the knowledge of average gut contents, feeding period, and gut evacuation.
time in different stages. The food selection of King George whiting larvae was studied by providing fish with rotifers, *Artemia* nauplii, adult copepod and formulated feed during the larval rearing period. These feed items are the principal feed for mass production of marine finfish larvae.

**Results and Discussion**

At the first of hatching (0 DAH), the incipient gut was apparent as a simple undifferentiated straight tube ventrally between yolk-sac and urine bladder. The simple gut was closed at both anterior and posterior ends. One day after hatching (1 DAH), the digestive tract elongated rapidly as larvae grew and yolk sac absorption occurred. The incipient urine bladder opened at the same place as anus that would open several days later. The anterior part of the gut curved down and connected with the tissue, which connected with the yolk-sac and oil globule. The anus opened on 0 DAH, however, this opening was actually the outlet of the urine bladder instead of the gut opening.

The oesophagus formed on 2 DAH, which was much earlier than the mouth opening. The posterior end of the larval digestive tract opened from 2 to 3 DAH, though the anus was not functional at this time. The urine bladder opened at the end of the gut through a valve and the lumen of the posterior part of the gut was expanded. But the digestive tract was still undifferentiated and was not divided into different functional structures until 5 DAH.

From 4 DAH, the larval digestive tract developed very rapidly to prepare receiving exogenous food. The mouth opened on 4 DAH and the anus became functional soon after as liquid was expelled to outside, even though the larvae did not feed at this time. The intestinal constriction was formed on 5 DAH. Two pyloric caeca appeared on 5 DAH at the posterior part of oesophagus. Since then, the larval digestive tract was divided into foregut, midgut and hindgut by two distinct intestinal constrictions. The swimming bladder appeared on 5 DAH. Most of larvae started first feeding on 5 DAH.

After first feeding, the anterior part of the midgut enlarged with the lumen of the whole midgut was further expanded. Two pyloric caeca substantially increased in size on 7 DAH. Food particles were observed in the midgut at this age. In addition, the rectum (hindgut) developed folds on 7 DAH. The larval fish fed on rotifers on 8 DAH and the rectum was fully functional by showing frequent vermicular motion for contraction and evacuation. The lumen of midgut was the widest in volume when compared with the other two portions of the digestive tract. It seems that digestion and absorption of food mainly occurred within the midgut at this stage.

On 8 DAH, the swimming bladder was substantially inflated. By 10 DAH, the larval gut elongated with the enlarged lumen as fish grew. Blood circulation was easily observed in the midgut but was not obvious in the rectum. This fact confirms that the digestive and absorptive functions are well established, and the major part of the digestive tract for nutrient absorption in larval King George whiting is the midgut at 8-10DAH. By 16 DAH, the intestine (mid- and hindgut) increased in size. However, little change was observed in morphological structures of the digestive tract until 26 DAH, which coincides with the fact that King George whiting larvae did not change their food type from rotifers to *Artemia* nauplii from 16 to 26 DAH. The weaning protocol will be developed based on the understanding of the development of the digestive system of King George whiting larvae. The structural and functional changes in the digestive system will give useful knowledge to establish the weaning technique for King George whiting larvae.
References


Acknowledgements

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8. SNAPPER CULTURE – THE WA PERSPECTIVE

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The Aquaculture Development Unit (ADU) of Challenger TAFE is actively supporting and promoting the emerging Western Australian aquaculture industry through a number of different avenues. These include conducting relevant applied research projects, the supply of live feeds, eggs and juveniles and the provision of training services. Training programs are specifically targeted to effect transfer of technology and techniques developed in the hatchery and in the field to members of the aquaculture industry. The ADU also provides technical advice and assistance in the planning, development and operational stages of a marine aquaculture business.

Applied research projects at the ADU have focussed on the development of cost-effective production techniques for marine finfish and abalone culture. Target species have included snapper (*Pagrus auratus*), black bream (*Acanthopagrus butcheri*), King George whiting (*Sillaginodes punctata*), WA Dhufish (*Glaucosoma hebraicum*), the Roe's abalone (*Haliotis roei*) and the Staircase abalone (*Haliotis scalaris*). Investigations are also currently underway with yellowtail kingfish (*Seriola lalandi*) and mulloway (*Argyrosomus japonicus*).

The ADU commenced investigations into snapper in 1991. Snapper was chosen as a suitable candidate for commercial culture based on its high profile as a premium table fish and on the available culture technology from Japan.

Initial efforts focussed on egg production from wild broodstock, however, eggs obtained from naturally spawning broodstock at Underwater World, Perth were also reared and ongrown for broodstock purposes. These broodstock began spawning naturally at two years of age and since this time have been spawning on a regular basis without hormone induction or temperature/photoperiod manipulation. Although wild snapper spawn only over a two to three month period each season, the naturally spawning broodstock at the ADU spawn for most of the year.

When the ADU first commenced investigations into snapper, the major bottleneck was in hatchery technology and operations. The extended spawning season of the snapper broodstock at the ADU has, however, allowed extensive investigations into larval rearing methods and this bottleneck has been largely overcome. The ADU has developed a cost-effective, tank based method for producing snapper juveniles. Larvae are cultured semi-intensively at densities of 20 larvae/litre in tanks ranging in size from 5,000 to 50,000 litres. Typical survival to weaned juvenile is 40 – 50%, with most mortality occurring at weaning. Mortality is the result of cannibalism by the larger fish, which have adapted more rapidly to the formulated diet. Trials are currently planned to further improve survival by rearing larvae in a McRobert Aquaculture nursery system. The passive grader within this system can grade larvae with minimal stress and damage, potentially minimising post-weaning cannibalism by separating those larvae that wean more readily.

Based on experience in snapper hatchery production, the ADU recently received funding from the Fisheries Research and Development Corporation to publish a hatchery manual for the Australian snapper industry. This manual combines the joint expertise in snapper culture of the ADU and of the Port Stephens Research Centre of NSW Fisheries. In addition, contributions were received...
Aquafin CRC Snapper Workshop, G.L. Allan

from the South Australian Research and Development Institute and other groups and individuals involved in snapper culture. The CD-ROM format of the manual is now available from WestOne Services and the text version is currently in press.

The facilities at the ADU are sufficient to act as a transitional commercial hatchery to aid in the development of the emerging snapper or yellowtail kingfish industry. Alternatively the ADU can also sell either fertilised snapper eggs, larvae or domesticated broodstock to commercial hatcheries.

As the previous hatchery technology bottleneck for snapper production has been largely eliminated, other bottlenecks have emerged. The foremost of these in Western Australia are site availability, marketing and environmental concerns. These three aspects are currently being addressed by the ADU.

Site availability

Despite having a large coastline, sites for seacage culture and pump-ashore shore-based operations are limited in Western Australia. The straight, exposed coastline is lacking in sheltered sites and little supporting infrastructure for developments. The relatively few sites considered suitable for sea-cages or pump-ashore operations are generally in high use areas, are considered to have high conservation value due to their location or are remote.

Saline groundwater offers a unique opportunity to develop and expand the aquaculture of marine species. Where groundwater interception schemes (and associated evaporation ponds) are needed to control rising salinity, incorporating aquaculture ponds may reduce the capital cost of salinity control and provide an attractive business opportunity.

One of the ADU’s current projects, in partnership with the WA Department of Agriculture's Engineering Water Management Group, CY O'Connor TAFE and industry representatives, is to develop aquaculture industries in areas suffering economic decline through land degradation and salinity.

The major difficulties confronting groups wishing to grow fish in inland waters in WA lies not in the somewhat limited choice of species, but in the choice of production systems and the available water source. The ADU and collaborators are investigating solutions for both these problems.

The ADU was awarded an AusIndustry Grant recently for a study tour of inland saline aquaculture in the USA to investigate production systems. Representatives from the ADU, AgWA, CY O'Connor TAFE and private industry are travelling to the USA in August 2002. Information from the study tour, combined with research from Israel and input from the Department of Fisheries, will be used in the development of a demonstration project to test a commercial saline aquaculture culture system in the Wheatbelt from 2003.

ADU is also investigating potential inland saline water sources for aquaculture in the Wheatbelt of WA. Saline groundwater is currently being pumped in a number of locations throughout Western Australia to protect high value public assets and farmland from rising saline groundwater tables. An example where pumping is being used for conservation reasons is at Lake Toolibin, a 300-hectare ephemeral wetland located in a Conservation and Land Management (CALM) reserve, 250 km south-east of Perth. One of the strategies to save the lake from salinisation has been to pump saline groundwater from Lake Toolibin to Lake Taarblin, a nearby lake severely degraded from salinity. Approximately 800 kL per day of saline groundwater are pumped from 12 bores spread across the floor of the lake. Data collected over recent years has shown that the pumping regime is significantly lowering the groundwater table across certain areas of the lake floor. With continued success, pumping will continue in the long term. In an effort to reduce the costs of pumping,
CALM have expressed interest to enter into cost-sharing arrangements with commercial companies who may wish to utilise this water as a resource.

The ADU is currently testing water sources from both infrastructure protection and conservation schemes, such as Lake Toolibin, for its use in aquaculture. The ADU Biologist, Mr Gavin Partridge was recently awarded a Commonwealth grant to assist in these studies.

AusIndustry has also funded a collaborative project between the Aquaculture Development Unit and a private company, McRobert Aquaculture Systems, to build a state-of-the-art marine recirculating system at the ADU site. The system is being used for demonstration and training purposes as well as research. The system is currently being used to study aspects of snapper production including the effects of temperature on growth and metabolic rate, the cost of supplying pure oxygen and the species’ ability to tolerate high stocking densities. Growth and metabolism data collected from this system will be used to validate the bioenergetics model developed for snapper by The Department of Fisheries – WA.

Marketing

The wholesale price of snapper in Western Australia has been historically low as there is a 550 tonne wild capture industry in Shark Bay. As a result, the perception in WA is that snapper is not a species that will fetch a premium price. It has been long-maintained by the ADU and others that aquaculture snapper will not be in competition with the wild-caught snapper industry as they are different products. For example, the legal size limit for snapper in WA of 41 cm precludes it from the plate-size whole-fish market.

Although this has been long-asserted in WA, the testing of this hypothesis only commenced in May, 2001. The ADU has been growing and supplying local restaurants with 400 – 450 gram snapper on a weekly basis since this time, to assess both the restaurant and customer demand and price for this product. Currently these restaurants are prepared to pay a generous premium over similar sized wild-caught product due to the promise of quality, including freshness, and consistency of supply.

These fish are being grown in the ADU hatchery in flow-through tanks at stocking densities up to 25 kg/m³. Temperature during the grow-out period has ranged from 18 to 22°C (seasonal temperature variation of the ADU bore) and the diet has mainly consisted of Skretting's 45:22 salmon grower. These fish reached the marketable size of 400 – 450 grams in 14 months (from egg).

Environmental issues

One of the current impediments to the development of a marine fish grow-out industry along the WA coast-line is the public and NGO perception of lack of sustainability of the industry and the lack of understanding of environmental implications from government agencies involved with environmental licensing. The ADU and others are attempting to address these potential impediments.

The ADU has recently received a WA state grant to develop a 40 hour VET module for the 'Environmental Management of Marine Finfish Growout Operations in Western Australia'. This project is in partnership with the Conservation Council of Western Australia, the MG Kailis Group of Companies and the Esperance Marine Institute.

This project will identify and document sustainable national and international aquaculture guidelines for marine fish farming and set standards for the development of the industry in WA. The expectation is that these guidelines, established in consultation with the industry, conservation
groups and the community, will encourage this valuable new industry to become established in Western Australia in an ecologically sustainable manner. Best-practice information and technologies will be collated and community and stakeholder research undertaken. The Environmental Management Course for Marine Finfish Growout Operations for WA will be developed to cater for the training needs of this industry.

Key ADU staff have been instrumental in the creation of a new industry association in Western Australia, The Marine Fishfarmers Association Inc (MFA). The first project instigated by this group is a workshop titled "Sustainable Development of Marine Fishfarming in Western Australia". The MFA has forged a strong relationship with the Conservation Council of WA in the hosting the workshop and has attracted world-renowned conservationist, Dr David Suzuki as the keynote speaker. The workshop, to be held at the new Maritime Museum in Fremantle on October 29th 2002, will be opened by the Hon Kim Chance, Minister for Fisheries and will open the debate for sustainability of marine fish developments in Western Australia.
9. TEMPERATE MARINE FIN-FISH R&D IN WESTERN AUSTRALIA

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Historically the development of a marine fin-fish culture industry in Western Australia (WA) has not been strong. The reasons for this are numerous and varied but, despite these impediments, several ventures have been attempted with varying degrees of success.

The Department of Fisheries (DoFWA) is actively supporting and promoting the Western Australian aquaculture industry in a complementary manner to the active work by the Aquaculture Development Unit (ADU) of Challenger TAFE. To help achieve this DoFWA is assisting the development of a marine fin-fish industry through a number of different initiatives. One of these initiatives was the development of the Mariculture Research and Advisory Group in 1999, which is co-located with the ADU of Challenger TAFE in Fremantle.

Through key appointments to the Mariculture Research and Advisory Group, two clear strength areas in aquaculture research have been identified and form the basis for the research initiatives directed at marine fin-fish production. These areas are hatchery and grow-out production and are underpinned by an emphasis on feeding strategies and fish health.

Hatchery production

The refinement of technology for live feeds in the hatchery forms the core focus of the projects in this area. There are specific projects examining the development of hatchery systems, production of live feeds, live feed enrichments and the development of formulated feeds to replace or supplement live feeds.

Hatchery systems

Several new systems have been engineered to meet the demands of the hatchery production research. Notable among these is a new intensive larval system and an Artemia production system.

The intensive larval culture system is based on a 24-tank, flow-through, upwelling, green-water, conical fibre-reinforced plastic system. It has also been designed to allow for the automatic control of light, temperature, water filtration and flow rate and feed delivery. The primary, but not sole, use for this new system is for use with larval fish nutrition assays, particularly the assessment of microdiets.

The Artemia production system is novel in that it has extremely low maintenance requirements. In addition it has considerable prospect for commercial upscaling. Similar to the intensive larval system, the Artemia production system is also automated, including an automatic enrichment dosing system for supply of enrichments and a submersible light system for separating cysts and nauplii. One of the key attributes of this system is the low variability (CV% < 3%) in production characteristics for a single source of cysts.
Live feeds

One of the key resources used in larval production is Artemia cysts, which are hatched and used as a live feed for fish larvae. However, the supply of Artemia cysts is well recognised as limited and unreliable. An initiative, funded by the Fisheries Research and Development Corporation (FRDC 2001/220), has been undertaken to look at means of improving the value of existing Artemia resources and identifying the potential of some new untapped sources.

One of the main objectives of this FRDC research project is the evaluation of locally sourced Artemia, produced at major salt fields in WA (e.g. Cognis, Dampier Salt, Cargill). These samples are being characterised with assistance from the International Artemia Reference Centre in Belgium.

A series of studies has also been undertaken evaluating the potential of Artemia under a range of scenarios. A survey of commercially available enrichments has been completed demonstrating wide-ranging differences between the different types of enrichments. Differences in nutrient composition, subsequent Artemia composition and even larval fish composition, when fed those enriched Artemia have been documented. The effects of the different enrichments have also been evaluated in fish larvae growth assays and additional fish larvae stress tests. Further studies have examined the bacterial loading associated with both the enrichments and the Artemia sources studies. The effects of different stages of preparation (e.g. washing) on the bacterial loading have also been established. An additional outcome from this work has been the development and refinement of a proprietary enrichment, with mega-doses of critical vitamins, whose performance is superior to those presently available in the market (Kolkovski et al., 2000a).

Formulated feeds

In addition to the development and evaluation of live-feed resources, research is also being directed at the development of formulated larval feeds in the form of microbound and micro-encapsulated diets. This objective also forms one of the aims of the FRDC Artemia replacement project.

Microdiet assessment is being undertaken with three fish species; barramundi, yellowtail kingfish and pink snapper. Included among the objectives are the assessments of commercially available microdiets and a range of protein resources (Kolkovski et al., 2000b; Kolkovski and Tandler, 2000). This later aspect is to be coupled with an assessment of the enzymatic potential of the various larval species to further identify what capacity they may have to utilise such protein resources (Kolkovski, 2001). Additional studies examining the endocrine control of digestive processes in larval fish are also planned (Kolkovski et al., 2000c). This aspect of the project will form the basis of a PhD project being undertaken by Mr Gavin Partridge of Challenger TAFE.

Grow-out production

Improving the efficiency of grow-out production of fin-fish aquaculture has been the major goal of a wide range of research projects undertaken in WA in recent years. In addition, some further development work has also been undertaken to enhance the opportunities for prospective aquaculture initiatives. Several of these projects are pertinent to temperate marine fin-fish production in general and pink snapper production specifically.
Site assessment

A geographic information system (GIS) based study with associated ‘ground-truthing’ has been undertaken to determine the location of suitable land-based aquaculture sites in WA (Kolkovski and Machin, 2002). Using defined geographic requirements, sites were identified and subsequently assessed further for their suitability as potential aquaculture sites. Numerous sites, with considerable potential have been identified around the West Australian coast, with many in areas suitable for temperate marine fin-fish culture.

Diet evaluation and development

Between 1998 and 2000, experiments were undertaken evaluating the growth performance and feed efficiency of snapper fed a range of commercial and research diets, differing primarily in protein and energy content. This research was part of a Department of Agriculture (DoAWA) led, Grain R&D Corporation funded project on lupin use in aquaculture feeds and was conducted at the ADU, Challenger TAFE facilities. While most experiments were conducted over a period of 6 to 10 weeks and used fish over a size range of 30 g to 100 g, some additional experiments were more long term (6 months) and used fish of a larger size (190 g to 400 g). In these later experiments, better performance was observed with fish fed diets containing a higher energy level (22MJ/kg to 23MJ/kg). Typically, the growth rates of the larger fish fed the high-energy diets were better (1.45 g/d cf. 0.99 g/d over the size range 190 g to 400 g) than those of fish fed the lower energy diets. Similarly the feed conversion ratios (1.1:1 cf. 1.5:1 over the size range 190 g to 400 g) were also better by fish fed the high-energy diets.

Additional small-scale studies, in conjunction with Central West TAFE and Glen Forrest Stockfeeders, examined the supplementation of astaxanthin (as carophyll pink) at rates of 0 mg/kg, 36 mg/kg and 72 mg/kg. Tristimuli L*a*b* colorimetry was used to assess changes over time and with treatment. There were several key findings. The transfer of fish from a sea-cage to the indoor laboratory induced a significant lightening of the skin over a 9-week period. The addition of astaxanthin did not influence a* values (redness) as much as expected, but did significantly influence L* values (lightness). This study was subsequently used to complement additional pigmentation studies undertaken by NSW Fisheries (Warner-Smith et al., in preparation).

Bio-energetic modeling

One of the key recent advances made by the Mariculture Research and Advisory Group was the adoption and further development of bio-energetic modeling as a tool for feed design, feed management and waste output estimation (Lupatsch et al., 1998). Assisted by an Aquaculture Development Fund (ADF) grant world–leading fish bio-energeticist, Ms Ingrid Lupatsch, was brought out to WA to assist the project. Concomitant with this was a separate series of studies that was undertaken by the Mariculture Research and Advisory Group to define the maintenance energy and protein requirements of pink snapper. These studies also defined the fish’s metabolic weight exponent, efficiency of energy and protein digestion from a reference diet, efficiency of protein and energy use, composition variation with size, and influence of temperature on metabolic energy requirements.

The bio-energetic model accurately defines growth potential, feed use efficiency and even iteratively suggests the ‘ideal’ diet at any specific growth phase of pink snapper. This work has also identified that production would be best optimised by the initial use (5 g to 80 g fish size range) of a high-protein (50% to 55%) and low-energy (16 MJ/kg to 18 MJ/kg) diet, followed by a lower protein level (40% to 50%) and slightly higher energy levels (20 MJ/kg to 22 MJ/kg) before potentially feeding extra-large (500 g +) fish a lower protein (35% to 40%) diet with ultra-high energy (22 MJ/kg to 24 MJ/kg). All estimates are crude protein and gross energy values.
Since this work, several studies have been undertaken to validate the findings. Notably, the ADU of Challenger TAFE presently uses this bio-energetic model to manage the feeding of its recirculating indoor-aquaculture project. The outcomes (excluding iterative diet designs) of this work have been placed on the internet (http://www.wa.gov.au/westfish/aqua/broc/output). This interactive resource, developed with assistance from the University of WA (UWA), is intended to allow prospective and active fish farmers to better manage their feed use and help estimate the environmental consequences of those choices (Kolkovski et al., 2002).

**Ingredient evaluation**

A priority research issue of the Mariculture Research and Advisory Group is the evaluation and development of Australian grain resources as prospective aquaculture feed ingredients. To this end, three externally funded research projects on ingredient evaluation have been undertaken over the past three years. Each of these projects involved the use of pink snapper as a model/test species. In addition a collaborative investment in a DoAWA led project from 1999 to 2000 was also undertaken.

The recently completed Grains R&D Corporation project, evaluating the use of canola meals and oils, identified the nutritional value of a variety of products when fed to pink snapper (Glencross, 2002). This project identified that canola meals have substantial nutritional value when included in diets on a digestible basis (Glencross et al., submitted B; submitted C). Notably there is variability in the nutritional value of canola meals depending on the method by which the oil is industrially extracted from the seed (e.g. solvent-extraction or expeller-extraction).

The potential for the use of canola oil (crude and refined) and soybean oil to replace added fish oil in diets for pink snapper was also evaluated. While 100% replacement was achievable with refined oils, undefined contaminants (most likely tannins and/or glucosinolate derivatives) limit the inclusion of crude canola oil to 75% replacement of the added fish oil or 3% of the total diet (Glencross et al., submitted D).

A Grains Research Committee (GRC) project evaluating the nutritional variability of lupins as a feed ingredient used rainbow trout as its primary model species. Additional work also examined the evaluation of the same key lupin, wheat gluten and soybean resources when fed to pink snapper (Glencross et al., submitted E). This work showed numerous similarities between the nutritional responses of rainbow trout and pink snapper, supporting the view that rainbow trout was generally an excellent model species for other carnivorous/omnivorous fin-fish species. An additional piece of work in this project included a major internet–based review of lupin use in aquaculture diets, which includes a section on the feeding of lupins to sea breams/pink snapper (Glencross, 2001). (http://www.wa.gov.au/westfish/res/broc/report/lupin).

An Australian Research Council (ARC) SPIRT grant was obtained with UWA in 1999, which comprises the PhD project of Mr Sid Saxby. The project examines the potential for regulating waste production from pink snapper culture through judicious ingredient use. Outcomes of this work include the further evaluation of the digestible value and summit-dilution responses of several key ingredients sourced from WA. Key methodological findings on the use and influence of fillers were also established allowing better experiment design (Saxby et al., 2001). The project has also established stripping methods for faecal collection from pink snapper to help avoid dissolution errors in digestibility and waste excretion determinations, which are suspected to be problematic in settlement faecal collection.
Environmental impact assessment

One of the impediments to the development of cage based aquaculture in WA is the perceived threat of environmental impact associated with such ventures. To begin addressing such an issue several activities are being undertaken. One of the research issues is being tackled in a project examining aspects of the environmental impact of snapper aquaculture in sea-cages.

In a joint project being undertaken with Stirling University in the UK, a PhD student, Ms Malene Felsing, is undertaking a project to develop methods of assessment and examine aspects of the benthic environmental impact associated with sea-cage culture. She is using the DoFWA experimental sea-cage facility, located at an existing commercial aquaculture lease inside Fremantle harbour. All experiments have used a BACI (Before-After-Control-Impacted) design to examine experimental effects, based on the assessment of changes in chemical, physical and biological parameters.

The first of these experiments characterised the impact associated with relatively low inputs (56 g/m²/d) into the cage and surrounding ecosystem over a 70 d period. At the end of this study period no accumulation of nutrients on the bottom below the cages was detected. The impacts of commercial stocking densities (10 to 12 kg/m³) were investigated in a second and longer study (120 d). Feed inputs in this experiment were recorded at 77g/m²/d. As in the first experiment, no significant accumulation of nutrients occurred below the cages. However, during this second experiment visual and video observations suggested that this result might be because of resident populations of wild fish scavenging any waste matter.

To follow up from observations of the second trial, a third trial was undertaken to examine the role of mega-fauna in nutrient removal near such sea-cage systems. Fish were stocked in two groups of sea cages, one where a net from the surface to the sea bottom excluded wild fish, and a second group where the wild fish had full access to waste. At the end of the study period (62 d) a significant accumulation of nutrients in the sediments was found in the vicinity of the cage with fish, but excluding wild fish. This enrichment was unmatched at the control site where the wild fish had access to the sediments and the control for the effect of the cage (Felsing et al., 2002).

In a follow up study to examine the nitrogen partitioning in the benthos under the cage, a stable isotope (¹⁵N) labeled feed was fed to pink snapper. Prior and subsequent to the feeding of the labeled feed, samples of benthos, cage epiphytes and local fauna were sampled. Preliminary findings from this study are inconclusive with irregular signals being detected amongst the test samples. Consistent with earlier studies, little nutrient enrichment was again noted below the sea-cages. Assessment of the changes in benthic macro-invertebrate community structure of this and earlier experiments is still in progress.

Fish health assessment

The fish health group within DoFWA have been involved with marine fin-fish aquaculture since 1989. The group provides a general disease diagnostic service to both industry and other researchers.

Early attempts to commercially sea-cage rear pink snapper were undermined by continual problems with gill flukes. Similar problems occurred with dhufish (Pironet and Jones, 2000). A successful PhD project to investigate problems including exophthalmia in Dhufish revealed that the haemoglobin profile of dhufish was such that the species was probably unsuitable for aquaculture using existing technology (Stephens et al., 2001; 2002a; 2002b).
A number of pathologies associated with diet have been investigated in dhufish and barramundi, leading to close cooperation with nutritionists. Investigation of “bloat” in pink snapper and barramundi, together with microbiologists from DoAWA, has identified the bacteria responsible. It is hoped a vaccine now under development in Tasmania, will provide protection for fish in the future.

Summary

Partnerships with industry are a key component of marine finfish work by DoFWA. This includes specialist advisory services in design, husbandry, nutrition and health to complement the general provision of extension activities by Aquaculture Development Officers. These roles have been evident in past and ongoing contributions to pink snapper, barramundi, dhufish, mahi mahi, yellowtail kingfish and aquarium fish initiatives. However, current emphasis on pink snapper will decline unless there is significant commercial progress in coastal, inland saline or recirculating aquaculture systems. Despite this, pink snapper will continue to be important as a model species for larval feeds and ingredient evaluation. The application of R&D in WA is affected by several limitations including difficulties with raising capital for aquaculture in general, very limited available sites for temperate sea-cage farming, low “landed-price” of marine finfish and high transport costs to non-local markets. The increased use of bores to combat salinization in WA offers significant opportunities and excellent opportunities exist for production in an array of land-based facilities.

References


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Glencross, B.D., Hawkins, W.E., Curnow, J.G. Evaluation of canola oils as alternative lipid resources in diets for juvenile red seabream, Pagrus auratus. Aquaculture Nutrition. SUBMITTED-D.

Glencross, B.D., Hawkins, W.E. A comparison of the nutritional value of lupin (Lupinus spp.) kernel meals fed to rainbow trout (Oncorhynchus mykiss) and red seabream (Pagrus auratus). Aquaculture. SUBMITTED-E.


10. THE DEVELOPMENT OF MARINE FIN-FISH FARMING IN TASMANIA

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1. Industry status in Tasmania

Production from marine fin-fish farming in Tasmania started in the late 1980’s and is currently restricted to sea cage culture of Atlantic salmon, *Salmo salar* and other salmonids. The industry developed quickly due to the establishment of a large hatchery, the use of proven European hatchery technology, a high level of government involvement, excellent cage culture sites, and good water quality (Treadwell et al., 1991). Salmon production in Tasmania in 2000/01 was 15,000 tonnes worth an estimated $170 million. This was an increase of some 27% on the previous year. While the salmon industry continues to grow rapidly it is facing difficulties with weaker prices, lower demand and increased competition from overseas producers. In addition, there are concerns over recent high water temperatures and low rainfall and the associated increased costs of controlling parasites and predators (Battaglene and Cobcroft, 2002). The future outlook for the industry is unclear but production is unlikely to increase in the short term.

Against this background there is an increasing interest in developing alternative species for marine fin-fish farming. However, the choice of suitable species is restricted in comparison with mainland Australia. Most success has been achieved in rearing flatfish, *Rhombosolea tapirina* and black bream *Acanthopagrus butcheri* which are now both routinely produced for experimental research (Pankhurst and Butler, 1996; Shand et al. 1999a & b; Cox and Pankhurst, 2000). Investigations on other coldwater species are in the early experimental stage, the most advanced being for striped trumpeter *Latria lineata* which are thought to have great potential for sea cage culture. They were chosen as a potential aquaculture candidate because of their eating qualities, their docile nature and ability to be held in captivity at high densities. However, striped trumpeter have a complex and extended larval phase with a 9 month "paperfish" stage and they have not proven easy to culture.

Excellent progress has been made in understanding and controlling reproduction in striped trumpeter (Morehead et al., 2000). Broodstock collected from the wild are now routinely spawned year-round through temperature and photoperiod control. Some problems with early larval rearing have also been overcome and egg incubation and early larval rearing protocols have been established (Cobcroft et al., 2001). The mortality peak associated with first-feeding was reduced using better live feed production techniques and improving water quality particularly at the air/surface interface (Trotter et al., 2002). Despite the significant progress to date, insufficient numbers of striped trumpeter juveniles have been produced to trial cage culture. The current bottleneck to juvenile production remains mortality from flexion to metamorphosis caused by an apparent primary metabolic disorder with a nutritional basis.
2. **Project aims and staff**

FRDC Project Number: 2001/206  
CRC Project Number: 2.4  

The current Aquafin CRC project will in the first instance investigate the most common nutritional disorder in marine larval fish, namely the dietary deficiency or imbalance in the three essential PUFAs (DHA, EPA and AA). Adult striped trumpeter have relatively low proportions of EPA and a high ratio of DHA to EPA (12:1), in their flesh (Nichols *et al.*, 1994). The PUFA content of the eggs and yolksac larvae, while different, also have a relatively high ratio of DHA to EPA (up to 4:1) (Morehead *et al.*, 2001). However, we recognise that other nutrient fractions, e.g. vitamins (especially C, E, A and riboflavin) and free amino acids may also be potentially limiting for fish larvae. During the early phase of the project we will compare the concentrations of these in striped trumpeter eggs and yolksac larvae to natural zooplankton, and zooplankton reared with standard culture techniques.

The project will provide a fundamental understanding of the lipid nutrition of striped trumpeter larvae and juveniles by using the composition of the eggs and yolksac larvae as a control standard. Novel enrichment diets and the use of copepods will be developed to meet these requirements. This should result in improved survival, growth and condition of intensively reared striped trumpeter juveniles. Subsequent production of juveniles will allow assessment of the species as an alternative for sea cage culture in Tasmania. The project also will contribute to the further development of the Australian marine oils industry. The research will also provide commercially important recommendations and developments in how to enrich live feeds for other marine fin-fish larvae.

There are a total of 21 scientists, technicians and PhD candidates researching striped trumpeter from five different facilities (Table 1).
Table 1. Scientists, technicians, and PhD students involved in striped trumpeter research.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Stephen Battaglene (Principal Investigator)</td>
<td>TAFI, Marine Research Laboratories, Taroona</td>
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</tr>
<tr>
<td>Dr David Morehead (Research Scientist)</td>
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<tr>
<td>Dr Matthew Bransden (Postdoctoral Research Fellow)</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Alan Beech (Senior Technical Officer)</td>
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</tr>
<tr>
<td>Bill Wilkinson (Senior Technical Officer)</td>
<td>TAFI, Marine Research Laboratories, Taroona</td>
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<tr>
<td>Ross Goldsmid (Technical Officer –broodstock)</td>
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<tr>
<td>Anna Overweter (Technical Officer – live feeds)</td>
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<td>Graeme Dunstan (Research projects)</td>
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</tr>
<tr>
<td>Mina Augerinos (Technician)</td>
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</tr>
<tr>
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<tr>
<td>Dr Chris Carter (Senior Lecturer)</td>
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</tr>
<tr>
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<tr>
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<tr>
<td>Geoff Grossel (PhD candidate)</td>
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</tr>
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3. **Milestones and progress**

<table>
<thead>
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<tr>
<td>Post doctoral and Research Fellows employed</td>
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<tr>
<td>Specialty oils purchased</td>
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<tr>
<td>Preliminary larvae experiment conducted to determine sample sizes and logistics</td>
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<tr>
<td>Preliminary PUFA assessment of eggs and yolk-sac larvae</td>
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<tr>
<td>Identification of suitable copepods</td>
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<tr>
<td>Assessed the maximum dose of ozone on various developmental stages of eggs</td>
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<td>Purchase water quality metering equipment</td>
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<tr>
<td>June 2002</td>
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<tr>
<td>All staff and PhD candidate employed</td>
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<tr>
<td>Determination of enrichment levels in rotifers and brine shrimp using specialty oils, and other products to match those found in fish eggs</td>
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<tr>
<td>Develop systems for copepod culture and preliminary evaluation of algae diets</td>
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<tr>
<td>Develop techniques for image analysis of live feeds and larvae</td>
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<tr>
<td>Organise trip by visiting overseas nutrition expert</td>
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<tr>
<td>Project information for annual report submitted to Aquafin CRC</td>
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<tr>
<td>December 2002</td>
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<tr>
<td>Test for nodavirus in wild and captive broodstock</td>
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<td>Test if ozone disinfection controls nodavirus</td>
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<td>Rear larvae from ozonated eggs</td>
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<tr>
<td>Established if lipid content of live feeds affects growth and survival of larvae</td>
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<tr>
<td>Identified suitable copepods and established small-scale culture techniques</td>
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<tr>
<td>Process lipid and vitamin samples from experiments</td>
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<tr>
<td>Present results at an interstate conference</td>
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<tr>
<td>June 2003</td>
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<tr>
<td>Results using enriched rotifers analysed and a draft manuscript prepared</td>
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<tr>
<td>Improved survival of post-larvae target &gt; 1% at 100 days of age</td>
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<tr>
<td>Visit by overseas nutrition expert or other suitable scientist</td>
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<tr>
<td>Purchase specialty oils and enrichment products</td>
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<tr>
<td>Process lipid and vitamin samples from experiments</td>
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<tr>
<td>Project information for annual report submitted to Aquafin CRC</td>
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<tr>
<td>December 2003</td>
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<tr>
<td>Larval rearing trial results using enriched brine shrimp analysed and a draft manuscript prepared</td>
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<tr>
<td>Process lipid and vitamin samples from experiments</td>
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<tr>
<td>Present results at an international or interstate conference</td>
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<tr>
<td>Scaled up production and live feed systems to attempt a production of 10 000 post larvae</td>
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<tr>
<td>June 2004</td>
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<tr>
<td>Draft final report to Aquafin CRC</td>
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<td>Project information for annual report submitted to Aquafin CRC</td>
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<tr>
<td>Purchase and construction of systems to house juveniles</td>
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<tr>
<td>Production of a draft hatchery manual</td>
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<tr>
<td>December 2004</td>
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<tr>
<td>Draft PhD thesis available</td>
<td></td>
</tr>
<tr>
<td>Independent reviewers comments included in final report</td>
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<tr>
<td>Final report submitted to FRDC</td>
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<tr>
<td>Production of a hatchery manual</td>
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</table>
The striped trumpeter project has successfully completed all its 2002 milestones. All staff have been employed on the project since the beginning of January. One PhD student was adopted and a new PhD position will be advertised in late 2002. The focus of research has been on early larval rearing and the use of nutritionally enriched rotifers. Experiments have been conducted to examine the effect of enrichment on rotifer survival and fatty acid profile. Results showed that fatty acids are rapidly assimilated into rotifers during enrichment, and that production of rotifers with a fatty acid profile similar to wild striped trumpeter eggs will be possible using either specialty oils (emulsions), other commercial diets available for live feeds, or suitable mixes of these. Similarly, we have demonstrated that rotifer PUFA profiles can be transferred readily to the larvae. Lipid, amino acid and vitamin profiles are being analysed from a large number of egg and larval samples. Bacterial disease has been identified as a potential source of mortality in young larvae. One source of harmful bacteria is the live feeds being fed to the larval fish. We have examined ozonation and antibiotic methods for disinfecting live feeds.

Three larval fish experiments were completed in a 300 L replicated experimental unit, three trials in larger intensive tanks within the hatchery and two extensive greenwater trials in a mesocosm (25,000 L tank). Antibiotics improved digestion, reduced the incidence of grey gut syndrome and the presence of urinary calculi, resulting in more viable larvae. Increased feed ration, with PUFA-rich diets, also reduced the presence of urinary calculi, increased survival, dry weight and viable larvae. An optimal rotifer feed rate was established for optimal development and survival. A novel method of estimating survival was tested using a digital camera and provided a relatively accurate, quick and cheap method for estimating larval abundance. Rapid lipid methodology protocols have also been developed and successfully applied in the project. Larvae did well in mesocosm culture and may do better if supplied with more live feed. The absence of jaw deformities in metamorphosed post-larvae appears to be a major break through. One group of fish from last year and two consecutive batches of fish this year have been on-grown.

The world’s leading authority on larvae lipid nutrition Professor John Sargent, from Stirling University, has agreed to visit TAFI and CSIRO in November 2002.

4. Communication and cooperation

The extended striped trumpeter team meets regularly to discuss progress and plans for future research. Communication with other research groups is through the Aquafin CRC and international and national conferences. We are presently negotiating a closer working relationship with Dr Sagiv Kolkovski from WA Fisheries on enrichment diets for live feeds. Dr Battaglene attended the First International Symposium on Domestication of Bluefin Tuna, Cartagena, Spain, 3-8 February 2002 in his capacity as an alternate member of the Aquafin CRC Board (trip report available upon request). He held discussions with scientists from IFREMER. Dr Tish Pankhurst, Mr Andrew Trotter, Mr Gavin Shaw and Dr Stephen Battaglene also visited France in July to discuss possible collaboration on larval marine fish research. They then attended the 26th Annual Larval Fish Conference in Bergen Norway in July. Three of the presentations given were:


Results have also been communicated by Dr Peter Nichols at several national (e.g. Australasian AOCS, Omega Workshop) and international meetings (Lipidforum, Norway) highlighting the preliminary finding that tank-raised striped trumpeter contain an extremely elevated content of the beneficial long-chain omega-3 PUFA. A similar presentation to that listed above by Lewis et al. (2002) was also provided as an invited lecture to the SINTEF/University of Trondheim Biotechnology Division, May 31, Trondheim, Norway.

The Aquafest 2002 conference in Hobart during September will be targeted as a venue to promote striped trumpeter research. Dr Brown will be giving a presentation on “Evaluating the nutritional requirements of striped trumpeter (Latris lineata) larvae”. Other presentations include:


5. Challenges – new priorities

The challenges include:

- Keeping the administrative work down and the funding agencies happy.
- Balancing the need to produce fish with the requirements to conduct large-scale replicated experiments.
- Publishing the research so that we have a benchmark and maintain, and receive recognition for, scientific achievements, thus avoiding re-inventing the wheel but at the same time retaining the IP and industry endorsement.
- Replicating the research at more than one hatchery to ensure the problems are not site-based and the results are transferable.

6. References


11. MARINE FISH AQUACULTURE IN VICTORIA

Lachlan McKinnon

Marine & Freshwater Resources Institute, P.O. Box 114,
Queenscliff Victoria 3225
☎ 03 5258 0212; Email: lachlan.mckinnon@nre.vic.gov.au

Commercial marine aquaculture in Victoria is comprised almost entirely of shellfish production, the majority of which at present is subtidal blue mussel culture in Port Phillip and Westernport Bays. Land based abalone culture has developed over the last few years, with significant quantities of marketable product expected in the near future. Experimental subtidal scallop growout, and ranching of abalone are also being undertaken by industry. With the exception of one or two commercial facilities with limited capacity for marine/brackish finfish hatchery and land-based growout production, there is currently no large-scale commercial production of marine finfish in Victoria. The recent approval of new marine areas available for aquaculture will facilitate the development of the shellfish aquaculture sectors, while providing additional, but limited, capacity for marine finfish aquaculture development.

The trial production of a number of marine finfish species has been undertaken by industry and MAFRI in partnership arrangements over the last few years. Species and systems examined in recent R&D programs include black bream, flounder, yellowtail kingfish, Atlantic salmon and brown trout in land-based seawater tanks, including integration with commercial, land based abalone aquaculture. Australian bass are currently produced in brackishwater ponds for stock enhancement purposes. In addition, the cage production of a range of finfish species, including snapper, black bream, Atlantic salmon and flounder has been trialed in inland saline groundwater ponds. In many cases, encouraging results were achieved. The integration of salmonids with land-based abalone production, using largely existing infrastructure, showed particular promise with fish up to 2kg produced in nine months. Despite the apparent opportunity for diversification of such enterprises into land-based marine finfish aquaculture, there is at present a clear focus by the abalone aquaculture industry to concentrate efforts in profitable abalone production, before diversification into other species would be considered in the short term.

The Victorian Government recently approved recommendations by the Environment Conservation Council (ECC) in its marine, coastal and estuarine investigation, for 12 new and extended marine aquaculture zones in Victorian waters, making available over 2500 Ha of marine Crown waters and over 50 Ha of Crown land for commercial aquaculture. Of the total water available, about 75% is located within Port Phillip Bay. The remaining area comprises 440 Ha located in Westernport Bay, and 200 Ha off Portland in western Victoria. All Crown land approved for aquaculture development adjoins Port Phillip Bay, and about 30% of this is currently occupied by one abalone farm.

About 13% (250Ha) of the total area available in Port Phillip Bay is presently occupied by mussel farms. Although a significant proportion of the new zones in Port Phillip Bay is considered suitable for finfish aquaculture from a practical and technological perspective, a number of environmental constraints presently limit the possibility of this aquaculture sector developing in the near future in the bay. The State Environment Protection Policy (Waters of Victoria) (SEPP) for Waters of Port Phillip Bay, states a target net reduction of nitrogen discharged to the Bay of 1000 tonnes by 2006 from a predetermined baseline. The consequences of this have been the recommendation by the ECC that “commercial finfish aquaculture should not be considered for Port Phillip Bay until preliminary trials have been conducted…”. Furthermore, the ECC
recommends that such trials must demonstrate that commercial aquaculture operations can be carried out with “no net additional nutrient input into Port Phillip Bay”.

This has implications for land-based operations already discharging to Port Phillip Bay. Although presently licensed to discharge up to a predetermined maximum quantity of nitrogen, these operations will be expected to demonstrate “best practice” to reduce the net quantity of nitrogen discharged to a minimum level, ideally zero. Where net nitrogen emission is greater than zero, the licence holder may be required to participate in nitrogen offset programs, the technical feasibility of which is currently being investigated. Under such conditions, the integration of finfish aquaculture with existing land-based abalone farms discharging to Port Phillip Bay has the potential to be prohibitive to the farms’ environmental performance, and is likely to become less attractive to abalone farmers.

Consequently, until such time as a workable nitrogen offset program for aquaculture can be developed for Port Phillip Bay, the realistic potential for commercial marine finfish aquaculture in Victoria in the near future is limited. Any marine finfish aquaculture likely to proceed would be restricted to cage culture operations at the 200 Ha Portland Aquaculture Zone, and to a lesser extent, 40 Ha of new water at the Flinders Aquaculture Zone in Westernport Bay, or in tanks or ponds on private land. The ambient conditions off the Victorian coast may limit the choice of species for commercial culture, and no proposals for commercial finfish aquaculture have been received to date, however possible candidates for culture may include snapper, mulloway, salmonids, yellowtail kingfish and southern bluefin tuna. The potential for marine recirculation systems is yet to be explored in Victoria, and may provide a focus for future R&D, however any R&D in Victoria related to marine finfish aquaculture will need to be relevant to the needs of industry.

Management planning for the existing and new aquaculture zones is presently underway, and includes environmental characterisation of the zones, allocation of leases and development of baseline and ongoing environmental monitoring strategies. It is anticipated that draft management plans for at least one aquaculture zone will be completed within 12 months, and that all characterisation surveys will be completed in two years. The aquaculture zones in Port Phillip Bay are presently of highest priority in the planning process.
12. IMPROVED HATCHERY & GROW-OUT TECHNOLOGY FOR GROUPER AQUACULTURE IN THE ASIA-PACIFIC REGION

Kevin Williams, David Smith, Ian Williams, Simon Irvin, Margaret Barclay & Michelle Jones

CSIRO Marine Research, P. O. Box 120, Cleveland QLD 4163
07 3826 7284; Email: Kevin.Williams@csiro.au

Faculty of Natural Sciences & Agriculture, University of Western Australia 6907

What was done and why

Polka dot or humpback grouper *Cromileptes altivelis* is one of the most highly prized species of groupers, fetching prices of US$90-100/kg in the live fish market of Hong Kong. The recent development of technology for large-scale hatchery production of polka dot grouper fry in Indonesia as part of this ACIAR Project and its successful uptake by hatcheries in Bali has now resulted in a plentiful supply of fingerlings for aquaculture. As information on the nutritional requirements of polka dot groupers is almost non-existent, we carried out a series of growth assay and digestibility studies to determine the optimum dietary protein and lipid specification for growing fingerlings. Subsequent to these findings, further growth assay and metabolism experiments were undertaken to see if the fish could be stimulated to better use lipid as an energy source and so spare or reduce the amount of protein needed in the diet.

How the research was done

The optimum dietary protein to lipid ratio for polka dot grouper was determined by feeding fingerlings one of 10 pelleted diets in which the dry matter (DM) crude protein (CP) concentration varied from 41 to 63% at 5.5% increments and in combination with either 15 or 24% DM fat (a 3:1 mixture of fish oil and soybean oil). These diets were fed to four replicate tanks of fish (450 fish in total; 11.6 g average initial weight) in an 8-week comparative slaughter growth assay that included measuring nutrient digestibility. Fish were held in 90 L tanks with flow-through seawater at 29ºC.

A subsequent comparative slaughter growth assay (and digestibility) experiment employing the same culture conditions as before was carried out to see if supplying dietary lipid at moderate (15% added oil) or high (30% added oil) concentrations and in the form of either long-chain fatty acids (LCFA, as olive oil) or medium-chain fatty acids (MCFA, as coconut oil) affected the way the fish used the lipid as an energy source. Five diets, a low-lipid (7% DM), high-protein (82% CP DM) control diet and four ‘lipid’ diets that together comprised a 2 x 2 factorial of the two types and two concentrations of lipid, were fed to six replicate tanks of fish (300 fish in total; 14 g average initial weight) for 8 weeks. The formulation of the ‘lipid’ diets was identical to the control except that the required amount of lipid was included at the expense of defatted fishmeal with a concomitant lowering of the dietary CP from 82 to 69 and 57% DM for the 15 and 30% lipid treatments, respectively. These same ‘lipid’ diets but radioactively labeled with ^14^C-octanoic acid (as a marker of MCFA) and ^14^C-oleic acid and ^14^C-palmitic acid (as markers of LCFA) were fed to fish and the fate of the labeled ^14^C was determined using metabolism chambers. For these studies, 7 to 9 replicates of each treatment were used and the presence of the ^14^C in the fish, in the
chamber water and in the respired CO$_2$ was quantitatively determined for the ensuing 22 h post-feeding.

What was found

Fish productivity and CP digestibility improved linearly with increasing dietary CP; energy digestibility was lower for the high lipid diets and fish on these diets were fatter, but did not grow faster, than those fed low lipid diets (Table 1).

Table 1. Apparent digestibility (AD) of crude protein (CP) and energy (E) of diets and specific growth rate (SGR), dry matter (DM) food conversion ratio (FCR), DM body fat (BF) and retention of digestible N (RDN) and digestible E (RDE) of fish.

<table>
<thead>
<tr>
<th>Response</th>
<th>CP (%)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCP (%)</td>
<td>46.8$^C$</td>
<td>55.3$^{BC}$</td>
</tr>
<tr>
<td>ADE (%)</td>
<td>59.9$^A$</td>
<td>58.4$^B$</td>
</tr>
<tr>
<td>SGR (%/d)</td>
<td>1.12$^C$</td>
<td>1.11$^C$</td>
</tr>
<tr>
<td>FCR (g/g)</td>
<td>1.58$^C$</td>
<td>1.49$^C$</td>
</tr>
<tr>
<td>BF (%)</td>
<td>23.5</td>
<td>23.2</td>
</tr>
<tr>
<td>RDN (%)</td>
<td>58.6$^A$</td>
<td>48.8$^B$</td>
</tr>
<tr>
<td>RDE (%)</td>
<td>35.0$^C$</td>
<td>38.6$^C$</td>
</tr>
</tbody>
</table>

$^{A,B,C; X,Y}$ Within comparisons, means without a common letter differ ($P < 0.05$).

Fish required significantly more digestible N per unit weight gain with increasing dietary CP content and this relationship was unaffected by the amount of lipid in the diet (Fig. 1).
Figure 1. Relationship between the digestible N content of the diet and the amount of digestible N required per kg weight gain of fish fed diets containing either 15 (▲) or 24 (■)% fat.

Increasing the amount of lipid in the control diet by adding 15% of olive oil (LCFA) at the expense of fishmeal resulted in a 14 to 20% improvement in growth rate and food conversion, a doubling of the body fat content of the fish (from 15 to 29% DM) and the retention of dietary protein was increased by 28% (from 25 to 32%). Higher addition of olive oil (30%) reduced voluntary food intake by 40%, and consequently depressed growth rate by 32% while protein retention and body fat content were unchanged. Adding coconut oil (MCFA) instead of olive oil depressed food intake by 59%, with a similar reduction in growth rate and no increase in protein retention. The amount of dietary lipid retained as body fat in the fish relative to that oxidized for energy decreased with increasing dietary lipid and was less for MCFA than for LCFA lipids (Fig. 2).

Figure 2. The amount of consumed dietary lipid retained as body fat or oxidized by fish fed either a low lipid (7% DM) control (Con) diet or diets with either 15 or 30% added olive oil (LCFA) or coconut oil (MCFA).

The percentage distribution of radioactivity following ingestion of 14C-labelled diets containing either olive oil or coconut oil at inclusion rates of 15 or 30% showed by polka dot grouper oxidized MCFA far more rapidly than LCFA (Table 2).
Table 2. Percentage distribution of radioactivity following ingestion of $^{14}$C-labelled diets containing varying inclusion rates of either coconut oil (MCFA) or olive oil (LCFA).

<table>
<thead>
<tr>
<th>Diet lipid</th>
<th>Fish Respired CO$_2$</th>
<th>DOM</th>
<th>POM</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% LCFA</td>
<td>70$^B$</td>
<td>15$^B$</td>
<td>11$^B$</td>
</tr>
<tr>
<td>30% LCFA</td>
<td>67$^B$</td>
<td>11$^B$</td>
<td>11$^B$</td>
</tr>
<tr>
<td>15% MCFA</td>
<td>23$^A$</td>
<td>51$^A$</td>
<td>26$^A$</td>
</tr>
<tr>
<td>30% MCFA</td>
<td>17$^A$</td>
<td>49$^A$</td>
<td>34$^A$</td>
</tr>
</tbody>
</table>

DOM = Dissolved organic matter in metabolic chamber water.
POM = Particulate organic matter (faeces and in some cases, regurgitated feed) in metabolic chamber water.

Respiration rate of fish fed diets containing MFA was significantly higher than those fed LCFA (Fig.2).

Figure 2. Respiration rate of fish following ingestion of diets containing 15 or 30% of either coconut oil (MCFA) or olive oil (LCFA).
What was concluded

- Diets for fingerling polka dot grouper should contain not less than 44% DM digestible protein (about 60% CP).
- Increasing the lipid content of the diet above about 15% did not promote greater oxidation of the fat but rather led to increased body fat deposition, a reduction in food intake and a slowing of growth rate.
- Replacement of LCFA lipids (such as fish or long-chain vegetable oils) with MCFA lipids (such as coconut oil) did increase the rate of fat oxidation but had a detrimental effect on food intake, and consequently also on growth rate.

Acknowledgement

This research was supported with funds from the Australian Centre for International Agricultural Research (Project FIS/97/73) and with funds from Australia’s AusAID program (CARD Project 15). The supply of polka dot grouper fry from the Gondol Research Institute of Mariculture, Bali for the research is gratefully acknowledged.
13. IMMUNE RESPONSE IN MARINE FISH

Barbara Nowak

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Locked Bag 1-370, Launceston Tasmania 7250
☎ 03 6324 3814; Email: B.Nowak@utas.edu.au

Introduction

Health of cultured fish is a prerequisite to successful aquaculture. As all fish encounter pathogens, the fish’s immune response plays a significant role in maintaining their health. While our understanding of fish immune response has improved dramatically in the last few decades, most research has focused on carp, *Cyprinus carpio*, channel catfish, *Ictalurus punctatus*, and rainbow trout, *Oncorhynchus mykiss*. Furthermore, it was shown that there are significant species-specific differences. For example, species from family Gadidae show a lack of specific antibody response, common in other fish species. Also, ontogeny (development) of immune response is species-specific and in general it is slower in marine fish than in freshwater fish. The only truly marine fish species, which immune response has been investigated in considerable detail, is sea bass *Dicentrarchus labrax*, species cultured in Mediterranean. New reagents, cell markers and primers required for the investigation of immune response have to be developed for each species. Investigation of health and resistance to diseases (for example following vaccination or use of immunostimulants or different diets) relies on our knowledge of fish immune response and availability of methods and reagents. This knowledge and methods should be developed concurrently with development of new species for aquaculture to avoid significant delays when developing disease control strategies for new aquaculture fish species.

Research in Australia

Snapper

Our knowledge of snapper immune response is much greater than of other marine fish cultured in Australia, this is mostly due to three PhD theses. The first one was completed in 1999 at University of Western Australia by S. McBride (supervisor Dr D. Keast). This project studied dynamics of glutamine and its relationship to the immune response. More recently, R.N. Morrison (University of Tasmania and Aquaculture CRC, supervisor Dr B. Nowak and consultant Dr J. Hayball) and M.T. Cook (University of Adelaide, supervisors Dr P. Hayball, Dr J. Hayball, Dr B. Nowak) have been working on snapper. Most of their research was done at IMVS, fish were held at SARDI. Dr John Hayball (Dame Roma Mitchell Cancer Research Laboratories, Hanson Institute/Institute of Medical and Veterinary Science) was instrumental to the success of these projects.

Ex vivo culturing of snapper peripheral blood leucocytes was documented by two researchers (McBride 1999, Morrison 2002). The conditions are shown in Table 1.
Table 1. Conditions for culture of snapper peripheral blood leucocytes.

<table>
<thead>
<tr>
<th>Condition</th>
<th>McBride 1999</th>
<th>Morrison 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture media</td>
<td>RPMI</td>
<td>L-15</td>
</tr>
<tr>
<td>Osmolality</td>
<td>350 mOsm</td>
<td></td>
</tr>
<tr>
<td>Supplementation</td>
<td>2.5% heat-inactivate homologous snapper plasma</td>
<td>10% pooled human serum and 5% pooled snapper serum</td>
</tr>
<tr>
<td>Cell density</td>
<td>9.09 x 10⁶ cells/mL</td>
<td>2.5 x 10⁶ cells/mL</td>
</tr>
<tr>
<td>Mitogen (optimum)</td>
<td>PHA 0.45 µg/mL</td>
<td>PHA 1-2 µg/mL</td>
</tr>
<tr>
<td></td>
<td>LPS 250 µg/mL</td>
<td></td>
</tr>
<tr>
<td>Incubation temperature</td>
<td>28°C</td>
<td>20°C</td>
</tr>
</tbody>
</table>

Anti-snapper Ig MAb s were developed and partially characterized during R.N. Morrison’s PhD (three clones available, the clones are deposited with Dr John Carragher, Flinders University). Additionally, the same PhD project produced anti-snapper Ig PAb s (some still available from R. Morrison, University of Tasmania). Methods for isolation of leucocytes, detection of antibody secreting cells, isolation of snapper Ig, flow cytometric analysis of proliferating snapper leucocytes, bleeding snapper, isolation of peritoneal cell populations, respiratory burst of snapper macrophages, snapper head kidney and spleen cDNA library development, use of anti-human CD3e antibody to identify snapper mIg leucocytes, snapper alternate, pentraxin and classical complement mediated lysis of sheep red blood cells, sandwich ELISA to measure pentraxin level were all developed and are documented in Morrison 2002 and Cook (in preparation).

Enhancement of macrophage respiratory burst and growth rate of snapper by in feed administration of EcoActiva in winter was shown by Cook et al (2002). The effect on macrophages was consistent with results of in vitro studies (Cook et al 2001). However, this immunostimulant had no effect at summer temperature and even at winter temperatures it did not affect complement activity.

**Tuna**

Basic haematology was described by Kirsten Rough (University of Tasmania MAppSc). This study documented morphology and percentage composition of peripheral blood leucocytes in wild and captive tuna. Significant progress in the area of immune response in southern bluefin tuna was achieved by Marianne Watts during her PhD (University of Tasmania, supervisors Dr Barry Munday and Dr Chris Burke). Serum immunoglobulin, lysozyme and classical and alternative complement activity were analysed in different groups of wild and captive fish. Fish held in captivity for longest time had the highest levels of the humoral immune factors. A histological study determined that small lymphocytes were present in kidney of northern bluefin tuna by 8 day post hatch and in thymus by 13 day post hatch, however functional studies were not done. Limited volumes of sheep anti-tuna Ig PAbs and rabbit anti-tuna Ig H chain PAb s are available from Dr M. Watts (University of Tasmania).

**Barramundi**

Immune response of barramundi was a focus of a few research projects, mostly focusing on practical aspects (vaccine development). ELISAs to measure specific antibody titres were developed (University of Queensland, University of Tasmania). Vaccine against *Vibrio harveyi* resulted in an increase in antibody level, but not in a significant enhancement of serum lysozyme activity or head kidney macrophage phagocytic activity (Crosbie 2001, University of Tasmania and Aquaculture CRC). There was a relationship between antibody level in blood serum and
bactericidal activity of the serum (Crosbie 2001). Recombinant carp interleukin 1-beta showed significant effect as an adjuvant used in vaccine against Vibrio harveyi, resulting in increased specific antibody titres (Bridle et al 2002). Limited volumes of rabbit anti-barramundi Ig PAbs and rabbit anti-barramundi Ig L chain are available from Dr P. Crosbie (University of Tasmania).

Striped trumpeter

Basic haematology was described by Ann Goodsell (University of Tasmania MAppSc). This study investigated the morphology and percentage composition of peripheral blood leucocytes. No other research has been done so far.

Yellowtail kingfish

No research on immune response of yellowtail kingfish has been done in Australia. Few papers were published by Japanese scientists, one describing protection following vaccination against Lactococcus garvieae (Ooyama et al 1999) and the second one effects of fishmeal replacement diet on disease resistance (Maita et al 1998). These studies used challenge tests, phagocytosis assay and agglutination assays as a measure of fish immune response.

Conclusions

Our knowledge of immune response of marine fish cultured in Australia is limited. The research requires species-specific reagents, cell markers and primers, which have to be developed, before detailed investigation can take place. There is an urgent need for research on immune response of marine fish. A wide range of species cultured or considered for mariculture in Australia will make this research challenging.

Publications


9. Cook, M.T., Hayball, P.J., Hutchinson, W., Nowak, B.F. and Hayball, J.D., 2002. Administration of a commercial immunostimulant preparation, EcoActiva as a feed supplement enhances macrophage respiratory burst and the growth rat of snapper (*Pagrus auratus*, Sparidae (Bloch and Schneider)) in winter. Fish and Shellfish Immunology, in press.


**PhD thesis**

McBride, S., 1999. The dynamics of glutamine in *Pagrus auratus* (snapper) and its relationship to the immune system and stress (University of Western Australia, supervisor Dr David Keast).

Watts, M., 2000. Immunology of southern bluefin tuna (University of Tasmania, supervisor Dr Barry Munday).

Crosbie, P., 2001. Immune response of barramundi (*Lates calcarifer*) to *Vibrio harveyi* bacterin (University of Tasmania, supervisors Dr Barbara Nowak and Dr Barry Munday).

Morrison, R., 2002. Aspects of the acquired immune response of snapper (*Pagrus auratus*), submitted (University of Tasmania, supervisor Dr Barbara Nowak).
Pathogens and diseases reported in fish mariculture in Australia

**Snapper**

- **Bacterial:** epitheliocystis, *Photobacterium damselae*, *Vibrio harveyi*, *Vibrio fluvialis*, *Flexibacter*-like bacteria
- **Parasitic:** *Amyloodinium* sp. (hatchery)
  - Monogenean trematodes (*Anoplodiscus cirrusspiralis*, *Benedinia* sp. and *Neobenedinina* sp.)
  - *Kudoa* sp.

**Tuna**

- **Parasitic:** *Uronema nigricans*
  - *Kudoa* sp.

**Barramundi**

- **Viral:** Betanodavirus (Viral encelopathy and retinopathy - VER)
- **Bacterial:** *Vibrio harveyi*, *Streptococcus iniae*
- **Parasitic:** Monogenean trematode (*Neobenedenia melleni*)

**Striped trumpeter (hatchery)**

- **Viral:** Betanodavirus (VER)
- **Bacterial:** *Photobacterium damselae*, *Vibrio splendidus*, *Vibrio tubyashi*, *Vibrio algolyticus*
- **Parasitic:** Pentacapsular myxozoan, monogenean flukes, copepods

**Yellowtail kingfish**

- **Bacterial:** *Vibrio proteolyticus*
- **Parasitic:** Monogenean trematodes (*Benedenia seriolae*, *Zeuxapta seriolae*), *Kudoa* sp.

**Mahi-mahi**

- **Bacterial:** systemic vibriosis
- **Parasitic:** *Kudoa thyrsites*, monogenean trematodes

**Dhufish**

- **Bacterial:** epitheliocystis, *Photobacterium damselae*, *Vibrio harveyi*, *Vibrio fluvialis*, *Flexibacter*-like bacteria
- **Parasitic:** *Haliotrema abaddon*, *Caligus* sp., marine *Argulus* sp., *Sanguinicola* sp.
14. APPENDICES

14.1. Agenda

14.2. Workshop Delegates

14.3 Print-out of slide presentations
Appendix 1

Thursday 26th September 2002

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker/Institution</th>
</tr>
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<tbody>
<tr>
<td>9:00-10:00</td>
<td>Morning Tea on arrival</td>
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</tr>
<tr>
<td>10:00</td>
<td>Introduction</td>
<td>Peter Montague, Aquafin CRC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patrick Hone, FRDC,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steven Clarke, Aquafin CRC</td>
</tr>
<tr>
<td>10:30</td>
<td>Current status &amp; priorities in NSW</td>
<td>Stewart Fielder / Mark Booth,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSW Fisheries</td>
</tr>
<tr>
<td>10:50</td>
<td>Inland saline culture of marine species in NSW</td>
<td>Mehdi Doroudi, NSW Fisheries</td>
</tr>
<tr>
<td>11:10</td>
<td>Current status &amp; priorities in SA</td>
<td>Wayne Hutchinson, SARDI</td>
</tr>
<tr>
<td>11:30</td>
<td>Marine fish research at Flinders Uni</td>
<td>Jian Quin</td>
</tr>
<tr>
<td>11:50</td>
<td>Current status &amp; priorities in WA (TAFE perspective)</td>
<td>Gavin Partridge</td>
</tr>
<tr>
<td>12:10</td>
<td>Current status &amp; priorities in WA (WA Fisheries perspective)</td>
<td>Brett Glencross</td>
</tr>
<tr>
<td>12:30</td>
<td>Lunch</td>
<td></td>
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<tr>
<td>1:30</td>
<td>Marine fish research at UTAS</td>
<td>Stephen Battaglene, TAFI</td>
</tr>
<tr>
<td>1:50</td>
<td>Marine fish research in Victoria</td>
<td>Lachlan McKinnon, MAFRI</td>
</tr>
<tr>
<td>2:10</td>
<td>Marine fish research at CSIRO</td>
<td>Kevin Williams, CSIRO Cleveland</td>
</tr>
<tr>
<td>2:30</td>
<td>Immune response in marine fish</td>
<td>Barbara Nowak, Aquafin CRC</td>
</tr>
<tr>
<td>2:50</td>
<td>Afternoon Tea</td>
<td></td>
</tr>
<tr>
<td>3:15</td>
<td>Key Issues/Directions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- species &amp; potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- bottlenecks</td>
<td></td>
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<tr>
<td></td>
<td>- priorities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- other relevant research going on we should be aware of (linkages)</td>
<td></td>
</tr>
<tr>
<td>5:30</td>
<td>Close</td>
<td></td>
</tr>
</tbody>
</table>

**Venue**

Airport Motel & Convention Centre, 33 Ardlie Street, Attwood, Melbourne.
Tel: 03 9333 2255; Fax: 03 9333 3366
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**Contact**

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## Appendix 2

**AQUAFIN CRC 2001/208: SNAPPER WORKSHOP PARTICIPANTS**

26th September 2002

Airport Motel & Convention Centre
Melbourne

<table>
<thead>
<tr>
<th>Organisation</th>
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Appendix 3

Print-outs of slide presentations.
INTRODUCTION: Snapper Workshop

Aquafin CRC – What it is and what it’s for

- Research and Education Provider
- Specialises in aquaculture of Finfish
- Main effort in Tuna and Salmon
- Life span 7 years – or more?

Aquafin CRC – What it is and what it’s for

- Research and innovation for sustainable economic and social development
- Implementation of research outputs
- Graduate researchers with affinity for industry
- Enhanced collaboration and use of resources

Aquafin CRC – What it is and what it’s for

- Close industry relationship
- Inclusion of FRDC as Participant
- Disciplinary Research Programs
- Education Program

Aquafin CRC – What it is and what it’s for

- Research Programs:
  - Tuna Propagation
  - Tuna Feeds and Product Quality
  - Hatchery Technologies
  - Diagnostics and Risk Assessment
  - Amoebic Gill Disease
  - Marine Cage Environmental Issues

PARTICIPANTS

University of Tasmania
Tuna Boat Owners Association of South Australia
South Australian R&D Institute and SA Government
Fisheries R&D Corporation
Tasmanian Salmonid Growers Association
CSIRO
Centre for Food Technology
Flinders University
NSW Fisheries
University of Technology Sydney
James Cook University
Pisces Marine Aquaculture
University of Queensland
Tassal Ltd
Department of Fisheries WA
Silver Beach Aquaculture
Institute of Medical and Veterinary Science
Increasing the profitability of snapper farming by improving hatchery practices and diets

Geoff Allan¹, Stewart Fielder², Mark Booth³, Priya Pitt² and Bob Lester²
¹NSW Fisheries Port Stephens Fisheries Centre & ²University of Queensland

Marine finfish cultured in NSW

- Snapper Pagrus auratus
- Mulloway Argyrosomus japonicus
- Bream Acanthopagrus butcheri
- Sand whiting Sillago ciliata
- Barramundi Lates calcarifer - no hatchery production in NSW, all freshwater grow-out
- Eels Anguilla australis A. reinhardtii – based on collection of glass eels or elvers from the wild
- Australian bass Macquaria novemaculeata

Industry fingerling production in NSW

Grow-out production in NSW

Collaborators

- This project forms part of the CRC Research Program for Sustainable Aquaculture of Finfish (Aquafin CRC)
- Participants in the current program include
  - NSW Fisheries (NSWF), University of Queensland (UQ), Flinders University, SARDI, CSIRO, Ridley Aquafeeds, Pisces Marine Aquaculture & Silver Beach Aquaculture
- CRC Project 2.3 officially commenced in 2002 & is due for completion in 2005

Snapper research history

- This project fully integrated an earlier project from the FRDC ADD Subprogram known as ‘Rapid Development of Diets for Australian Snapper Pagrus auratus’
- Builds on an earlier FRDC project ‘Potential of snapper Chrysophrys auratus for aquaculture’
- & CRC for Aquaculture project ‘Improving fingerling production and evaluating inland saline water culture of snapper, Pagrus auratus’
- FRDC project ‘Publication of a manual for the hatchery production of snapper Pagrus auratus’
Problems facing snapper industry

- Lack of cheap, vigorous and healthy fingerlings
- Reliance on expensive live feeds (artemia, rot.)
- Incidence of disease induced mortality
  - especially the protozoan Amyloodinium ocellatum
- Lack of a species specific diet/s for hatchery and grow-out phases + high cost of feeds ($A1500 - $A2000/t)
  - industry currently rely on barramundi and salmon feeds
- Poor skin colour of sea-cage reared fish
  - Very dark and less red than fish harvested from the wild

CRC Project 2.3: Objectives

- To improve the production of snapper fingerlings by
  - developing extensive fertilised-pond rearing techniques for the advanced production of snapper juveniles
  - developing larval feeding strategies to reduce use of live feeds by weaning larvae onto artificial diets
  - developing methods to reliably identify, reduce and or treat the incidence of parasite infestation
- To develop diets and improve skin colour by
  - determining digestibility, utilisation and availability of potential low-polluting ingredients for use in snapper diets (replace FM)
  - determine nutrient requirements for protein/energy
  - Evaluate ability of snapper to use lipid and CHO for energy
  - provide recommendations for feeding strategies
  - reducing skin melanisation and improving skin pigmentation

Intensive larval production

- Captive broodstock
- Spawn year round
- High quality eggs
- Optimum physical parameters identified
- But production costs high $A1.00/snapper
- Need to reduce costs
  - increased survival
  - increased growth = turnover
  - cheaper methods

Improved snapper growth to 33 dah in commercial-scale hatchery (best practice vs new regime)

Intensive larval production: improvements through feeding strategies

- Determine earliest age larvae will accept weaning diets (Jap Vs Aust) & effects on growth & survival
- Investigate effects of live & artificial feed combinations
  - Especially rollers vs copepods vs artificial diets
- Evaluation via rigorous controlled experiments
Extensive larval rearing research: improving the economics

- Optimum age/size to stock?
- Optimum density to stock?
- Benefits of heating ponds (greenhouse +5°C)
- Benefits of supplementing natural pond zooplankton with artemia
- Investigate methods to maximise in pond production of copepods (pond management)
- Best practice may involve mix of both intensive and extensive systems

Health management (UQ)

- Routine monitoring of fish health via parasitology, microbiology & histology
  - wet mount microscopy for parasites
  - blood agar and TCBS for bacteriology of kidney & heart tissue
- Control of Amyloodinium ocellatum
  - Preliminary work at PSFC set foundation for current research
  - Chemotherapy (several antiprotozoal drugs are available, e.g., Secnidazole, may require NRA app. for food fish)
  - Phototaxis control of dinospores
  - Enhanced immunity (beta-glucans)

Diet development research

- Continues research from previous FRDC program (methods established)
- Digestibility of potential ingredients
- Reference diet + ingredient 3 reps
- Fish meal >$1500/tonne
- (fish meal replacers; protein and energy sources)

Health management (UQ)

- Routine monitoring of fish health via parasitology, microbiology & histology
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Diet development research

- Factorial experiments
- Gross requirements for digestible protein and digestible energy at one temperature (25°C)
- Utilisation of ingredients under similar DP and DE contents
- Formulate trial diets
- Validate

Diet development research

- Investigate ionic deficiencies in sources of inland saline groundwater (Wakool = K+)
- Can deficiencies be overcome with dietary supplementation?
- Farm outputs of N, P & C from diets will be quantified using stable isotopes (e.g., 15N-nitrogen)(Michelle Burford, CSIRO - Cleveland)
- These will be used to quantify nitrogen retention in snapper and track nitrogen pathways within the farm environment (water column, sediments etc)
- Results will be used to address EPA concerns regarding pollution from fish farms
Skin colour research

- Farmed snapper very dark and lack natural colour
- Melanisation?
  - Exposure, environment
- Colour
  - Dietary carotenoids, astaxanthin?
  - Environment?
- Previous research by NSWF & WA Fisheries indicated astaxanthin useful for improving skin redness

Skin colour research: results

- Factorial experiments
- Cage colour (black or white)
- Ambient light Vs UV restricted
- Commercial diet no astaxanthin
- Future experiments
  - Cage colours +
  - Different carotenoids

Wild snapper
White cage treatment
Black cage treatment
Farmed snapper plus astaxanthin

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University of Queensland
Tassal Ltd
Department of Fisheries WA
Silver Beach Aquaculture
Institute of Medical and Veterinary Science
Inland saline culture of marine species in NSW

Mehdi Doroudi, Geoff Allan & Stewart Fielder

Rationale:

- high land prices
- shortage of suitable sites
- environmental constraints
- conflict with other land and water users
- rising saline groundwater

Location:

Murray Irrigation evaporation basins at Wakool-Tullakool Sub-Surface Drainage Scheme (the largest evaporation scheme in Australia with over 1600 ha of evaporation ponds)

Preliminary results:

- saline groundwater has 95% less potassium than similar salinity oceanic seawater, and is not suitable for survival and growth of snapper (Pagrus auratus)
- snapper held in tanks survived and grew at the same rate as they grown in seawater when potassium was replaced
- acclimation protocol was also developed for fish transported from Port Stephens to Wakool
- cold climate (minimum 8°C) during winter at Wakool did not result in mortality of snapper, but growth was slow
- growth of snapper increased rapidly during summer when water temperatures increased to 29°C

Major objectives:

- to develop a protocol for sustainable, commercially viable culture of snapper, mulloway (Argyrosomus japonicus), black-tiger prawn (Penaeus monodon) and silver perch (Bidyanus bidyanus)
- to promote commercial development of inland saline aquaculture as a business opportunity for existing and planned saline groundwater interception schemes
Inland Saline Aquaculture Research Centre:
6 × 0.05 ha plastic-lined earthen ponds, a small-scale experimental tank facility, a temperature controlled laboratory and an office supplied with freshwater and saline groundwater from a dam and two evaporation ponds (each have different salinities), respectively.

The combined effects of salinity and potassium level on survival and growth of mulloway fingerlings:
triplicate aquaria were held at salinities of 15, 25 and 35 ppt with potassium levels of 40, 60, 80 and 100% in temperature controlled room (20°C) over a period of 44 days.

the regression analysis indicated that effects of salinity and potassium level were not contributing to variances in survival and SGR data significantly (P > 0.05).

the result of our laboratory studies confirmed that inland saline groundwater from WTSSDS is suitable for growth and survival of snapper and mulloway.

mulloway fingerlings were transferred into a 0.05-h pond containing saline groundwater at 23 ppt and 70% potassium level to evaluate the survival, growth rate, productivity and food conversion ratio over a period of 12-15 months.

more ponds will be stocked by snapper in coming months.

experiments with silver perch and tiger prawn are underway.
Next phase of the project (needs ongoing funding):

develop a successful growout technology for the winning species
expand the Centre (more ponds, recirculation system, green-house)
increase scope of research (hatchery, new species)

if successful technology is developed and proven, inland saline aquaculture can be part of a solution for those areas where groundwater interception schemes is needed to prevent rising salinity
STATUS AND RESEARCH ISSUES FOR MARINE FINFISH AQUACULTURE IN SOUTH AUSTRALIA

Wayne Hutchinson
South Australian Research and Development Institute (SARDI)

Marine Finfish Species Cultured in South Australia

Current Commercial
- Southern bluefin tuna*
- Yellowtail kingfish
- Atlantic salmon
- Rainbow trout
- Mulloway

Discontinued
- Snapper
- Black bream

Research
- King George whiting

* Not included as part of this talk

Marine Finfish Species Cultured in South Australia

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Yellowtail Kingfish

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ISSUES
- Parasites
- Deformities
- Wild-farmed interactions

Types of Deformities

- Deformed jaw
- Spinal deformity
- Short operculum and flared or exposed gills

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- Parasites
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Types of Deformities

- Deformed jaw
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**Mulloway**

**ISSUES**
- Markets
- Growth rates
- Culture systems

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**Atlantic Salmon and Sea Run Trout**

**ISSUES**
- Transfer to sea
- Environmental impacts

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**King George whiting**

**ISSUES**
- Egg supply and quality
- Hatchery production (survival and growth)
- Growth rate in culture systems

**Snapper**

**ISSUES**
- Growth in sea cages
- Skin colour
- Low prices/weak markets

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**Black Bream**

**ISSUES**
- Small demand for fingerlings
- Fingerling quality
- Poor growth rates
- Low prices/weak markets

**SUMMARY**

- Yellowtail kingfish has emerged as the best option for marine finfish aquaculture in South Australia combining hatchery and grow-out advantages with market potential.
- Difficult species require commitment to long-term research programs.
- Few species have immediate combination of production and market advantages.
- Marketing issues a priority for all species.
- Alternative culture systems offer options for future industry expansion.
Digestive Physiology and Feeding Ecology of King George whiting Larvae

Bennan Chen, Jian G. Qin
Flinders University
Martin Kumar, Wayne Hutchinson, Jane Ham & Steve Clarke
South Australia Research & Development Institute (SARDI)

Current Problems in Finfish Larviculture

High mortality during the following periods:
• Transition from endogenous to exogenous feeding
• Metamorphosis
• Weaning

Objectives
• Understand the ontogenetic development of the digestive system in fish larvae.
• Understand the feeding ecology related to feeding strategy in fish larvae.
• Develop weaning techniques for fish larvae.

Research Approach
• Ontogenetic development of the digestive system
  Morphological & histological studies
  Histochemical studies
  Ontogenesis of digestive enzymes: trypsin, pepsin, lipase, alkaline phosphatase, amylase
• Feeding ecology
  Food selectivity
  Gut content
  Food consumption
• Weaning strategies

What we have done so far:
• Morphological changes of the digestive tract from day 0 to day 26 after hatching (DAH)

Experimental conditions
• Source of King George whiting: Brood fish were cultured under captivity at SARDI.
• Eggs: Spawning was induced by hormone injection 48 h before stripping.
• Rearing tanks: 25-L fibreglass tanks.
• Water supply: filtered seawater (50 µm).
• Temperature: 19 °C ± 0.5 °C.
• Light: 200–500 lux and 12 L:12 D.
Before Hatch: 3 days after fertilization

- Oil globule
- Yolk sac

Incipient gut: 0 DAH

- Yolk sac
- Posterior end of the incipient gut

Gut elongation: 1 DAH

- Yolk sac
- Posterior end of gut
- Urine bladder
- Gut elongation

Development of oesophagus and gut opening: 2 DAH

- Oesophagus
- Gut opening
- Posterior gut

Expansion of gut lumen and urine bladder: 3 DAH

- Forming a connection between gut and urine bladder

Mouth opening: 4 DAH

- Mouth opening
- Oesophagus
- Urine bladder
- Midgut lumen
First feeding start: 5 DAH
→ Pyloric caeca & swimming bladder appeared

Larval gut increasing in size: 6-7 DAH

Yolk sac disappeared and the gut well developed: 8 DAH

Digestive tract increased in size: 9-10 DAH

More folds were formed in the digestive tract: 14 DAH

Substantial amount of food in guts: 26 DAH
Summary

- At hatching, the incipient gut was formed without opening at both ends.
- Anus was opened (2 DAH) before mouth (4 DAH).
- First feeding started on 5 DAH.
- Two pyloric caeca appeared on 5 DAH.
- Folds were first observed in rectum at 8 DAH.
- The digestive tract expanded in size from 10 to 26 DAH. No major morphological changes were observed during this period.

Future Research

- Histology
- Digestive enzyme development
- Feeding ecology
  - food selection
  - gut content
  - food consumption
- Weaning techniques

Acknowledgments

- Ployford Memorial Trust offered the PhD scholarship to Bennan Chen.
- SARDI provided experimental facilities.
Snapper Research & Development in WA
- The TAFE Perspective -
Gavin Partridge & Greg Jenkins
Aquaculture Development Unit
Challenger TAFE

**CHARTER**
- To conduct applied research and development projects to stimulate the development of marine aquaculture industries in WA.
- To transfer developed technologies to industry.

**APPLIED RESEARCH**
- Marine Fish Culture
- Recirculating Systems
- Inland Saline Aquaculture
- Abalone

**INDUSTRY DEVELOPMENT**
- Supply of live foods, larvae etc.
- Location for industry R&D
- Participation on reference groups

**TRAINING DELIVERY**
- Certificate of Aquaculture
- Diploma of Aquaculture
- Graduate Diploma
- Short Course Delivery

**BROODSTOCK FACILITIES**

**HATCHERY FACILITIES**

**NUTRITION AND OTHER RESEARCH FACILITIES**

**Temperate Marine Fish at the ADU**

**Snapper (Pagrus auratus)**
- Culturing since 1990
- Year-round natural spawning from domesticated broodstock
- Cost effective culture regime, regular juvenile supply
- Potential to act as a commercial hatchery for industry
- Model species for several funded projects
On-going Improvements

- **Artificial Substrates**
  - Increase surface area for increased production of harpactacoid copepods.
  - Improve water quality.

---

### Improving Survival

Reduce weaning mortality through early grading
Growout Opportunities

- A shortage of sites for growout in WA (seacages and shore based).

Inland Saline Aquaculture

Advantages

- Cheaper, freehold land.
- Fewer environmental issues & competing interests.
- Access to infrastructure.
- Farmers with experience in agribusiness.
- Political will to improve rural economies.
- Access to water being pumped for other uses.

Identification of suitable species.
Identification of water sources with suitable characteristics for supporting growth and survival.
Identification of cost-effective culture methods.

Bioassays in Inland Saline Groundwater

<table>
<thead>
<tr>
<th>Water Source</th>
<th>Na⁺</th>
<th>Cl⁻</th>
<th>Mg²⁺</th>
<th>SO₄²⁻</th>
<th>K⁺</th>
<th>Ca²⁺</th>
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<tr>
<td>16 ppt</td>
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<td>9600</td>
<td>620</td>
<td>430</td>
<td>250</td>
<td>230</td>
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<tr>
<td>Bore 1</td>
<td>5500</td>
<td>9600</td>
<td>640</td>
<td>450</td>
<td>120</td>
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Recirculating Systems

- Collaborative project between McRobert Aquaculture Systems and the ADU
- AusIndustry funded.
- State-of-the-art marine recirculating system for demonstration, training and applied research.
Metabolic rate of 600 gram *Pagrus auratus* at 21°C

<table>
<thead>
<tr>
<th>Time</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
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<td>600</td>
<td>400</td>
<td>200</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Marketing & Economics
- Test marketing to restaurant chain.
- Cultured snapper for plate market.
  - Higher meat recovery / thicker fillet.
  - Fresher / Longer shelf life.
  - Easier to cook.
  - Consistent size and supply.
- Restaurants prepared to pay premium price.

That's all folks.
Brett Glencross, Sagiv Koikovski, Brian Jones, Sid Saxby and Malene Felsing

Mariculture Research and Advisory Group
Department of Fisheries - Government of WA

Temperate Marine Fin-Fish R&D in W.A.

Outline...

Hatchery
- Hatchery Systems
- Live feeds
- Artemia enrichment
- Formulated feeds

Grow-out
- Site assessment
- Diet evaluation
- Ingredient evaluation
- Bio-energetic assessment and modeling
- Environmental Impact Assessment (EIA)
- Fish Health

Hatchery systems...

Specially designed tank systems for fish larvae and Artemia

FRDC Project
Development of marine fish larvae diets to replace imported Artemia

- To develop a standard testing system for evaluating live and artificial feeds for finfish larvae
- To test currently available artificial (commercial) diets
- To formulate artificial larvae diets
- To assess the use of 'local' Artemia and improve their nutrition value
- To develop the use of co-feeding live and dry diets for partial or full replacement of Artemia nauplii

Fish Species:
- Snapper (DoFWA, ADU), Barramundi (JCU), Yellowtail Kingfish (DoFWA, ADU)

Artemia and Rotifer Enrichment

Growth of Yellowtail kingfish larvae (15-30 days old) fed enriched Artemia

- Pigments
- Probiotics
- Vitamins
- Therapeutics
Bacteria counts in fish larvae systems

Two hours after the addition of enriched Artemia

Average CFU's prior to algae and Artemia addition

Utilisation of Microdiets by Marine Fish Larvae.

- Identify digestible, nutritious protein sources.
- Determine optimum ratios of protein sources and hydrolysates.
- Identify optimum diet types.
- Compare enzyme ontogeny of larvae fed various diets as an indicator of diet efficacy.

Test Species
- Snapper
- Barramundi
- Yellowtail kingfish

Grow-out R&D...

- Site assessment
- Diet evaluation
- Ingredient evaluation
- Bio-energetic assessment and modeling
- Environmental Impact Assessment (EIA)
- Fish Health

Site assessment...

Geographical Information Systems
- Desktop based study
- Follow-up ground truthing of key sites

Growth of Yellowtail kingfish larvae (30-45 days old) fed two commercial microdiets

Weight in grams

Initial Weight

Weight Gain

Food Conversion Ratio

Dress out percentage

45-25  45-22  45-10
**Ingredient evaluation...**

**Canola meals and Lupin meals**
- Digestibility trials
  - Expeller canola meal
  - Solvent-extracted canola meal
  - Phytase treated canola meal
  - Canola Protein Concentrate
  - Heat damaged Expeller canola meals
  - Soybean meal
  - Wheat gluten
  - Fish meal
  - Narrow-leaf (L. angustifolius) lupin kernel meal
  - White (L. albus) lupin kernel meal
  - Yellow (L. luteus) lupin kernel meal

- Growth trials
  - Metabolic value of canola meals produced by different oil extraction methods (Summit-dilution)
  - Nutritional value of transgenic (GMO) lupins

**Fish oil replacement - Oil type...**

**Fish oil replacement - Oil grade...**

**Growth bio-energetics...**

**Feed design...**

**Changes to diet protein and energy needs...**
Environmental Impact Assessment...
Projects looking at
• Development of methods
• Invertebrate taxonomy
• Sample collection
• Spatial assessment
• Hydrological assessment
• Assessment of low nutrient input
• Assessment of high nutrient input
• Examination of the role of mega-fauna
• Stable isotope studies

Fish Health...
Diagnostic services
• Disease
• Parasites
Research Assistance
• Nutritional histology (Trout/ Snapper)
• Haematological studies (Dhuifish)

Summary (Hatchery)...
• Major projects on live feed and fish larvae diets have been established.
• Present focus is on the nutritional value-adding of Artemia.
  • Enrichment evaluation
  • Bacterial assessment
• Developing initiatives include
  • Micro-diet development
  • Ingredient evaluation
  • Enzyme ontogeny studies

Summary (Grow-out)...
• Extensive work on feed ingredient (plant meals and oils) use by pink snapper has been done.
• Bio-energetic requirements for maintenance and growth of pink snapper have been defined (feed design and management models also constructed).
• Methods and experience for Environmental Impact Assessment (EIA) of temperate marine cage culture established.
• Over 10 years experience in disease and parasite diagnosis with temperate marine fin-fish.
Marine Fish Aquaculture in Victoria

- Marine aquaculture dominated by shellfish
  - Blue Mussels: 1000t, $2.6M
  - Abalone: 5t, $0.2M
- Marine finfish production limited to brackishwater pond production of black bream, Australian bass

Previous R&D

- Inland saline aquaculture
- Black bream, snapper production
- Aquaculture Enhanced Bay & Inlet Fisheries
- Marine salmonids

Inland Saline Aquaculture

- Range of euryhaline and marine species
  - eg. Snapper, black bream, Atlantic salmon
- Commercial trial proposed “focus farm”
  - In-line tanks in salt-producing works
  - salmonids proposed

Black bream & snapper

- Hatchery & nursery production of juveniles for commercial ongrowing in existing land based facilities
  - eg. abalone farms
- Initial interest but not pursued by industry

Aquaculture Enhanced Bay & Inlet Fisheries

- Ongrowing wild-caught species
  - Value-adding
- Species trialed include King George whiting, sand flathead, greenback flounder
- Mix of commercial fishery & aquaculture expertise
Marine salmonids
- Growout of brown trout & Atlantic salmon in land-based facilities
  - Abalone farms
- Encouraging results
  - 280g - 2kg in 6 months
  - But increased mortality at temps ≥19°C
- Focus of industry on abalone at present

Production of brown trout in marine tanks

Recent/Current R&D
- Australian bass
- Gummy sharks
- Yellowtail kingfish

Australian bass
- Joint Government/industry production of pond and tank reared juveniles
- Conservation/recreation stock enhancement

Gummy sharks
- Collection of shark pups from fishery
- Tank reared
- Fed live callianassid shrimps
- Weaned on to frozen prawns, pilchards & other fresh/frozen feeds
- Unable to wean to artificial feed
- Some growth (mean 6%/week) but increased mortality at temps below 17°C
Yellowtail Kingfish

- Small scale commercial trial underway
  - Industry funded
- Hatchery produced progeny
- Growth up to 15% per week March-June
  - Temps 15-20°C
- No growth from June-Sept.
  - Temps < 13-14°C

Future Developments

- New Marine Aquaculture Zones
  - 12 separate areas, 10 Marine, 2 land-based
  - >2600 Ha total, ranging from 20-1000 Ha each
- 2000 Ha over 8 zones in Port Phillip Bay
- 440 Ha in Westernport Bay
- 200 Ha in Portland Bay
Constraints to Marine Finfish Aquaculture in Victoria

- Prevailing ambient temperatures
  - 10-22°C in Port Phillip Bay
  - Salmonids up to 9 months/year
  - Other species 6 months/year (>15°C)

- Environmental / legislative constraints
  - SEPP for Port Phillip Bay
  - Nitrogen reduction targets (1000t by 2006)
  - No net additional nutrient input

Nitrogen Offset Project

- Port Phillip Bay - no net N increase
- Potential for finfish aquaculture
- Development of N-offset mechanisms applicable to aquaculture
  - e.g. bivalve production
  - Undaria harvesting
  - Constructed wetlands
- Nitrogen Trading/Credits?

Immediate Opportunities for Marine Finfish Aquaculture in Victoria

- Portland Aquaculture Zone
  - 200Ha, 20-30m depth, ≤ 20°C
  - YTK
  - SBT
  - Mulloway
  - Snapper
  - Salmonids

Longer Term Direction for Marine Finfish Aquaculture in Victoria

- R&D
  - Development of profitable marine recirculation systems
  - Combine land based marine recirculation with open water cage culture
- Development of N-offset program
  - Marine finfish culture in PPB/WPB
Grow-out diet development for polka dot grouper *Cromileptes altivelis*

**Background**

- High demand (and price) for live groupers (~US$20 to 90+/kg depending on species, size and market)

**Humpback or Polka dot grouper**

(*Cromileptes altivelis*)

US$80-103/kg

**Background**

- 24,000 t of live grouper traded annually in Hong Kong market (US$1.0B)
- 50% are wild-caught; 50% are on-grown, mostly from wild-caught juveniles
- Grouper larviculture constraint now largely overcome

**Coral trout**

(*Plectropomus spp*)

US$45-57/kg

**Estuary grouper**

(*Epinephelus coioides*)

US$18-28/kg

**Tiger or flowery grouper**

(*Epinephelus fuscoguttatus*)

US$37-53/kg

**Giant Grouper or Qld Groper**

(*Epinephelus lanceolatus*)

US$90-100+/kg

**Hong Kong or Red grouper**

(*Epinephelus akaara*)

US$80-90/kg

Grow-out nutrition: ACIAR Grouper project

**AIM:** Develop compounded feeds that:

- are cost-effective (max productivity; min cost)
- have low environmental impact
- have low reliance on fishery product

FIS97/73: Improved hatchery & grow-out technology for grouper aquaculture in Asia-Pacific region
Objective

Determine key nutrient requirements of polka dot grouper fingerlings and especially the role of lipid in energy metabolism.

Why feed lipid to fish?

Spare amino acids from oxidation
- Reduce dietary protein & hence reduce cost of feed
- Reduce excretion of NH₃ & hence reduce environmental impact of feed

Expt 1: Optimum protein & lipid

- 8-week comparative slaughter growth assay & digestibility; 4 tank reps
- 29°C, flow-through seawater

* 10 Diets: 5 protein levels x 2 energy (lipid)
  - DM CP 41% to 62% at 5% increments
  - DM lipid 15 or 24% (8 or 16% added oil)

Expt 1: Growth & FCR

\[
\begin{array}{c|c|c}
\text{Diet CP (% DM)} & \text{Growth rate (g/wk)} & \text{FCR (DM g:g)} \\
\hline
40 & 20 & 1.8 \\
45 & 25 & 1.6 \\
50 & 30 & 1.4 \\
55 & 35 & 1.2 \\
60 & 40 & 1.0 \\
65 & 45 & 0.8 \\
\end{array}
\]

Expt 1: body composition

\[
\begin{array}{c|c|c}
\text{Diet CP (% DM)} & \text{Carcase fat (DM %)} & \text{Gut fat (DM %)} \\
\hline
40 & 19 & 27 \\
45 & 21 & 25 \\
50 & 23 & 23 \\
55 & 25 & 21 \\
60 & 27 & 19 \\
65 & 29 & 17 \\
\end{array}
\]
Conclusions - Expt 1

- Markedly better growth & FCR with increasing CP up to maximum examined – 62% DM (~58% as-fed)
- No benefit of feeding diets with >15% DM lipid (8% added oil)
- Fish fed high lipid diets were fatter and more of the digestible energy of the diet was retained as body fat

Expt 2: Optimum amount & type of lipid

- 8-week comparative slaughter growth assay & digestibility; 6 tank reps
- 29°C, flow-through seawater
- 5 dietary treatments
  - Control diet with 7% fat (82% CP DM)
  - MCF 15 = 15% coconut oil (69% CP)
  - MCF 30 = 30% coconut oil (57% CP)
  - LCF 15 = 15% olive oil (69% CP)
  - LCF 30 = 30% olive oil (57% CP)
- ** Oil added at expense of de-fatted fishmeal in control diet

Conclusions – Expt 2

- Fish retained more LCF than MCF
- Fish responded negatively to high lipid diets, but utilized moderate levels of LCF better than MCF
- Need to understand the effect that dietary lipid has on appetite
- Need to understand the metabolic effect of type and level of fat in the diet
Expt 3: Utilization of fatty acids

Questions we asked

➢ Would more lipid in the diet promote its greater use for energy

➢ Would medium-chain fatty acids (MCF) be oxidized more readily than long-chain fatty acids (LCF)

Expt 3: Utilization of fatty acids

• $^{14}$C-labelled respirometer experiment; 7-9 reps
• After 6 d adaptation to unlabelled diet, fed single $^{14}$C-labelled feed
• After 22 h, measured total CO$_2$ production and $^{14}$C activity in fish, respired CO$_2$ and respirometer contents
• 6 dietary treatments (15 & 30% MCF & LCF diets as for Expt 2)
  ➢ MCF labelled with $^{14}$C-octanoic acid
  ➢ LCF labelled with $^{14}$C-oleic acid or with $^{14}$C-palmitic acid

Conclusions – Expt 3

• MCF was much more rapidly oxidized than LCF & thus appears to have potential as an energy source for grouper

• Adding more than 15% oil to the diet did not increase its oxidation for energy by grouper
Overall conclusions

- Polka dot grouper have limited capacity to use dietary lipid to spare protein:
  - cf Salmonids >30%
  - Barramundi <20%
  - Grouper <15%
- But will efficiently digest and retain lipid as body fat
- Although MCF are more readily oxidized than LCF, this potential is limited by feedback mechanism that inhibits appetite
Immune response and health of marine fish cultured in Australia
Barbara Nowak
School of Aquaculture
University of Tasmania

Health problems in aquaculture
• Reduced production due to mortality and reduced growth
• Increased production costs due to control and treatment

Disease control in aquaculture
• A significant impediment to the successful culture of finfish is loss associated with disease (losses valued at approx 10%)
• Previous methods used
  – Sanitary prophylaxis
  – Disinfection
  – Chemotherapy (antibiotics)
• Impetus for study of the host defence mechanisms with emphasis on ways of improving disease resistance

Fish immunity
• Fish are the lowest evolutionary group to display the full repertoire of host defence mechanisms
• Innate
  – Transferrin and antiproteases
  – Lysins (CRP)
  – Complement
  – Phagocytosis
• Adaptive
  – B-cells that produce antibody (only IgM)
  – T-cells
    – Helper
    – Cytotoxic
Although both systems are separate they interact considerably with more emphasis on innate early and adaptive later
Fish have an increased reliance on innate compared to higher vertebrates
Two directions of research in the area of health and immunity

- Understanding of immune response
  - species-specific reagents
  - sequences of immune molecules
- Measurement of efficacy of vaccines and immunostimulants
  - challenge
  - performance

Fish immunology

- Model species
  - carp (Cyprinus carpio)
  - channel catfish (Ictalurus punctatus)
  - rainbow trout (Oncorhynchus mykiss)
- Species of interest
  - Atlantic salmon
  - Tuna
  - Snapper
  - Yellowtail kingfish
  - Barramundi
  - Striped trumpeter

Is immune response species-specific?

- Generally, no
  - Same components
  - Same basics
  - Some assay methods can be easily adapted
- Practically, yes
  - Ontogeny
  - Degree of immune response
  - Sequences
  - Reagents
  - Immune assays have to be adapted

Snapper (Pagrus auratus)

- Model species
- Immune response studied (reagents and methods developed)
- Main parasitic problems
  - Amyloodinium sp in hatchery
  - Monogenean trematodes (Anoplodiscus cirrusspiralis) on skin and gills in sea-cages

Application of EcoActiva increases macrophage respiratory burst in winter but not in summer
**EcoActiva increases growth rates of fish held at winter temperature**

- 24°C EcoActiva
- 24°C Control
- 12°C EcoActiva
- 12°C Control

**Yellowtail kingfish (Seriola lalandi)**
- Japanese research on vaccination against Lactococcus garvieae
- Mostly parasitic problems

**Benedenia seriolae - monogenean trematode**
- Skin parasite
- Large financial losses
- Treatment - fresh water or hydrogen peroxide
- Very high fecundity - one female can lay 100 eggs/hour
- Other monogenean trematodes: Heteraxine heterocerca (Japan), Zeuxapta seriolae (Australia, gills)

**Benedenia seriolae**

**Barramundi**
- Aquaculture CRC – development of vaccine against Vibrio harveyi
- Immune response studied (reagents and methods developed)
- Monogenean trematodes can be a problem in sea cages
Effects of vaccination on antibody activity

Effect of vaccination and the use of adjuvants on antibody level

Neobenedenia melleni

Neobenedenia melleni (Coryphaena hippurus)
• No research on immune response
• Systemic vibriosis and parasitic diseases

Kudoa thyrsites

Kudoa thyrsites

Mahi-mahi (Coryphaena hippurus)

Mahi-mahi (Coryphaena hippurus)
• No research on immune response
• Systemic vibriosis and parasitic diseases

Striped trumpeter (Latis lineata)

Striped trumpeter (Latis lineata)
• Basic haematology known
• No research on immune response
• Betanodavirus and myxozoans affected hatchery production
**Pentacapsular myxozoan**

- New species
- Present in central nervous system
- Affects post-larvae and juveniles

**Conclusions**

- Fish diseases can affect development of mariculture
- Early life stages not immunocompetent – knowledge of ontogeny important
- Diseases can be a significant issue in sea cages due to logistical problems with water disinfection and treatment of diseased fish
- Lack of knowledge about pathogens/parasites and their hosts (in particular their immune response and pathophysiology) can be an obstacle in the further development of mariculture

**Conclusions**

- Understanding of immune response and its modulation requires development of species-specific immune reagents for each species or choosing one species as a model
- Investigating the efficacy of vaccines and immunostimulants requires development of challenge protocols
- Health research required to ensure successful development of mariculture in Australia

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