BIOECONOMICS IN AQUACULTURE.

PRELIMINARY ANALYSIS OF THE CULTURE POTENTIAL OF THE FRESHWATER ANGELFISH - *PTEROPHYLLUM SCALARE*


A thesis submitted in fulfilment of the requirements for the degree of Master of Applied Science.

Department of Aquaculture

University of Tasmania, at Launceston.

July 1995.
DECLARATION AND AUTHORITY OF ACCESS

I certify that this dissertation contains no material which has been accepted for the award of any other degree or diploma in any institute, college or university and that to my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the dissertation.

Shane Willis.
July 1995.

This thesis is not to be made available for loan or copying for two years following the date this statement was signed. Following that time the thesis may be made available for loan and limited copying in accordance with the Copyright Act 1968.

Shane Willis.
ACKNOWLEDGMENTS

I would like to sincerely thank my research supervisors, Professor Nigel Forteath, Professor Owen McCarthy and Dr. Jacqueline Flint for their advice and encouragement during my work for this thesis.

Thanks also to Mr. Rick Datodi who has also been a great help, particularly with industry information. Thank you also to my family, particularly my father Greg and sister Louise, for assisting me during my experiments and persevering with me during my research. Thank you to Mandy Reeves who has been so patient and understanding over the past months while I have been completing my thesis.

I would also like to dedicate this work to the memory of my grandmother, Joyce Stewart, who sadly passed away while I conducted this study.
TABLE OF CONTENTS

DECLARATION AND AUTHORITY OF ACCESS ............................................. i
ACKNOWLEDGMENTS .............................................................................. ii
TABLE OF CONTENTS ........................................................................... iii
LIST OF FIGURES .................................................................................... viii
LIST OF TABLES ..................................................................................... x
ABSTRACT ............................................................................................... xiii

CHAPTER 1. INTRODUCTION ................................................................. 1
1.1 Introduction ....................................................................................... 1
1.2 Bioeconomics in aquaculture ......................................................... 4
1.3 Farm design ...................................................................................... 6
  1.3.1 Product-definition ................................................................. 8
  1.3.2 Product-definition of ornamental fish ................................... 10
  1.3.3 Biological submodel ............................................................. 12
  1.3.4 Physical submodel ............................................................... 13
  1.3.5 Economic submodel ............................................................. 15
1.4 Preliminary investigations into the culture potential of P. seafare .... 16
  1.4.1 General biology of P. seafare ............................................... 17
  1.4.2 Culture of P. seafare ............................................................ 25
  1.4.3 Marketing and economic aspects of P. seafare production ...... 27
  1.4.4 Research needed for development of farm design ................. 29
1.5 Research for this study ................................................................. 29

CHAPTER 2. GENERAL EXPERIMENTAL PROTOCOL .......................... 31
2.1 Experimental animals and facilities .............................................. 31
2.2 Water quality monitoring ............................................................ 31
2.3 Water supply ................................................. 32
2.4 Experimental tanks and tank systems .............................................. 32
  2.4.1 Broodstock tanks ............................................. 32
  2.4.2 Egg and larval incubation tanks .................................. 34
  2.4.3 Nursery tanks .................................................. 34
  2.4.4 Small scale recirculating system .................................. 34
2.5 Anaesthesia of fish .................................................. 36
2.6 Length measurement .................................................. 36
2.7 Weighing procedure .................................................. 36
2.8 Growth calculations .................................................. 38
2.9 Feeds .............................................................. 38
2.10 Statistical methods ............................................... 39
  2.10.1 Mean, standard deviation and variance ......................... 39
  2.10.2 Students t-test .................................................. 40
  2.10.3 Analysis of variance ............................................ 40
  2.10.4 Regression analysis .......................................... 41

CHAPTER 3. DEVELOPMENT OF BIOLOGICAL SUB-MODEL ............... 42
3.1 Length - weight relationships and determination of food particle size for *P. scalare* ............................................. 42
  3.1.1 Introduction ...................................................... 42
  3.1.2 Materials and methods .......................................... 43
  3.1.4 Results .......................................................... 44
  3.1.5 Discussion ....................................................... 48
3.2 The effect of incubation technique on ova and larval survival of *P. scalare* ............................................. 50
  3.2.1 Introduction ...................................................... 50
  3.2.2 Materials and methods .......................................... 50
  3.2.3 Results .......................................................... 53
  3.2.4 Discussion ....................................................... 59
3.3 Nursery culture of *P. scalare* under commercial hatchery conditions ............................................. 62
  3.3.1 Introduction ...................................................... 62
3.3.2 Materials and methods .................................................. 62
3.3.3 Results ........................................................................ 63
3.3.4 Discussion ................................................................. 67
3.4 Effect of feeding rate on the growth of *P. scalare* .................. 69
  3.4.1 Introduction ............................................................... 69
  3.4.2 Materials and methods ............................................... 70
  3.4.3 Results ...................................................................... 71
  3.4.4 Discussion ............................................................... 77
3.5 The effect of stocking density on growth and fin factor *P. scalare* juveniles .......................................... 80
  3.5.1 Introduction ............................................................... 80
  3.5.2 Materials and methods ............................................... 82
  3.5.3 Results ...................................................................... 84
  3.5.4 Discussion ............................................................... 90
3.6 Biological submodel ......................................................... 94
  3.6.1 Production stages ....................................................... 94
  3.6.2 Survival ..................................................................... 95
  3.6.3 Reproduction ............................................................ 96
  3.6.4 Growth .................................................................... 97
  3.6.5 Nutrition ................................................................. 98
  3.6.6 Water quality requirements ......................................... 100
3.7 Summary ......................................................................... 101

CHAPTER 4. MARKET CONSIDERATIONS FOR THE ORNAMENTAL FISH MARKET AND IN PARTICULAR *P. scalare* .......... 102
4.1 An international perspective of the ornamental fish industry .......... 103
4.2 Industry survey of Australian ornamental fish industry ................ 107
  4.2.1 Introduction ............................................................... 107
  4.2.2 Method ..................................................................... 108
  4.2.3 Results and discussion ............................................... 112
  4.2.4 Summary of survey results ......................................... 124
4.3 The Australian ornamental fish industry .................................. 125
CHAPTER 6. CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

6.1 Purpose and value of the study ........................................ 208
6.2 Summary of results ..................................................... 210
6.3 Limitations of this study ............................................... 214
6.4 Directions for future research ......................................... 215
6.5 Final comment .......................................................... 217

REFERENCES ............................................................... 218

APPENDIX A QUESTIONNAIRE USED IN INDUSTRY SURVEY .......... 232
APPENDIX B COVER LETTER USED IN INDUSTRY SURVEY .......... 236
APPENDIX C FOLLOW-UP LETTER USED IN INDUSTRY SURVEY .... 238
APPENDIX D IMPORTS OF ORNAMENTAL FISH BY COUNTRY OF ORIGIN .......................................................... 240
APPENDIX E DETAILS OF PROMOTIONAL ACTIVITIES AND COSTS 241
APPENDIX F DETAILS OF COST CALCULATIONS USED TO DEVELOP FINANCIAL STATEMENTS FOR TAS ANGELS ................. 243
APPENDIX G ASSUMPTIONS AND COSTS FOR STAGED EXPANSION SCENARIO .......................................................... 249
APPENDIX H ASSUMPTIONS AND COSTS FOR LEASING SCENARIO .. 253
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour plates of <em>P. scalare</em></td>
<td>18</td>
</tr>
<tr>
<td>2. Map of the natural distribution of <em>P. scalare</em></td>
<td>20</td>
</tr>
<tr>
<td>3. Front view of <em>P. scalare</em>, indicating external morphological sex differences</td>
<td>21</td>
</tr>
<tr>
<td>4. Diagram of small scale experimental recirculating system used in growth trials for juvenile <em>P. scalare</em></td>
<td>35</td>
</tr>
<tr>
<td>5. Lateral view of <em>P. scalare</em> indicating length measurements used in this study</td>
<td>37</td>
</tr>
<tr>
<td>6. Exponential regression of length - weight data for <em>P. scalare</em></td>
<td>45</td>
</tr>
<tr>
<td>7. Linear regression of standard length and upper-jaw length data for <em>P. scalare</em></td>
<td>46</td>
</tr>
<tr>
<td>8. Linear regression of standard length and calculated gape data for <em>P. scalare</em></td>
<td>47</td>
</tr>
<tr>
<td>9. Number of spawnings for <em>P. scalare</em> broodstock pairs during the 55 day experimental period</td>
<td>54</td>
</tr>
<tr>
<td>10. The effect of egg and larval incubation method on absolute fecundity for different sized female <em>P. scalare</em></td>
<td>56</td>
</tr>
<tr>
<td>11. The effect of egg and larval incubation method on cumulative fecundity for different sized female <em>P. scalare</em></td>
<td>57</td>
</tr>
<tr>
<td>12. The effect of egg and larval incubation method on relative fecundity for different sized female <em>P. scalare</em></td>
<td>58</td>
</tr>
<tr>
<td>13. Daily incidence of mortalities of <em>P. scalare</em> juveniles during nursery culture phase</td>
<td>64</td>
</tr>
<tr>
<td>14. Increase in mean standard length of <em>P. scalare</em> juveniles during nursery culture phase</td>
<td>66</td>
</tr>
<tr>
<td>15. Change in mean weight of <em>P. scalare</em> juveniles using different feeding rates</td>
<td>72</td>
</tr>
<tr>
<td>16. Effect of feeding rate on the specific growth rate of juvenile <em>P. scalare</em></td>
<td>74</td>
</tr>
<tr>
<td>17. Linear regression of the food conversion ratio and feeding rate of <em>P. scalare</em> juveniles</td>
<td>75</td>
</tr>
</tbody>
</table>
continued

18. Linear regression of gross efficiency and feeding rate of *P. scalare* juveniles ................................................................. 76
19. Change in mean weight of *P. scalare* juveniles cultured at different stocking densities ......................................................... 85
20. Specific growth rate of juvenile *P. scalare* at different stocking densities ................................................................. 86
21. Effect of stocking density on the food conversion ratio of juvenile *P. scalare* ................................................................. 88
22. Linear regression of stocking density and fin factor data for juvenile *P. scalare* cultured at different stocking densities ................................. 89
23. Generalised international market channel for ornamental fish ................. 105
24. Graphical illustration of proposed production schedule for Tas Angels ......... 163
25. Proposed floor plan of Tas Angels ................................................................. 166
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Design parameters for development of a farm design or system model</td>
<td>7</td>
</tr>
<tr>
<td>2. Product-definition for different product types of food fish</td>
<td>9</td>
</tr>
<tr>
<td>3. Product-definition of live ornamental fish</td>
<td>11</td>
</tr>
<tr>
<td>4. Comparison of Launceston City Water with general fish culture water quality standards and recommendations</td>
<td>33</td>
</tr>
<tr>
<td>5. Composition of Gibson's salmon starter pellets</td>
<td>38</td>
</tr>
<tr>
<td>6. Recommended food particle sizes for <em>P. scalare</em></td>
<td>49</td>
</tr>
<tr>
<td>7. The spawning frequency of <em>P. scalare</em> with different methods of egg and larval incubation during experimental period of 55 days</td>
<td>53</td>
</tr>
<tr>
<td>8. Fecundity of <em>P. scalare</em> using artificial and natural incubation of eggs and larvae</td>
<td>55</td>
</tr>
<tr>
<td>9. Mean larval size and survival rates for <em>P. scalare</em> using natural and artificial incubation of eggs and larvae</td>
<td>55</td>
</tr>
<tr>
<td>10. Initial length, final length and survival of <em>P. scalare</em> fry during nursery culture phase</td>
<td>65</td>
</tr>
<tr>
<td>11. Summary of water quality parameters for nursery tanks</td>
<td>65</td>
</tr>
<tr>
<td>12. Growth and feeding efficiency of <em>P. scalare</em> at different feeding rates</td>
<td>71</td>
</tr>
<tr>
<td>13. Summary of water quality parameters during feeding rate experiment</td>
<td>73</td>
</tr>
<tr>
<td>14. The specific growth rate and food conversion ratio of <em>P. scalare</em> juveniles at different stocking densities</td>
<td>84</td>
</tr>
<tr>
<td>15. Dorsal-fin length, standard length and fin factor of <em>P. scalare</em> juveniles cultured at different stocking densities</td>
<td>87</td>
</tr>
<tr>
<td>16. Summary of water quality parameters for stocking density experiment</td>
<td>90</td>
</tr>
<tr>
<td>17. Production and life stages of <em>P. scalare</em></td>
<td>95</td>
</tr>
<tr>
<td>18. Calculated survival rate and range of <em>P. scalare</em> for production stages</td>
<td>95</td>
</tr>
</tbody>
</table>
19. Calculated annual egg production of *P. scalare* using artificial egg and larval rearing techniques ................................................. 96
20. Growth and production data for *P. scalare* ................................................. 97
21. Recommended food type, particles size, feeding rate and expected food conversion ratio for production stages ................................................. 99
22. Wholesale market value (US$) of tropical ornamental fish .......................... 103
23. Number of farms surveyed and their response rate ............................................. 111
24. Location of ornamental fish farms in Australia ................................................. 113
25. Relative use of production systems by Australian ornamental fish producers .... 114
26. Use of different production intensity of ornamental fish of farms in each state ................................................. 115
27. Percentage of ornamental fish farms using various market channels ............... 116
28. Staffing of ornamental fish farms in Australia ................................................. 117
29. Ornamental fish species currently produced in Australia .................................. 119
30. Actual and estimated production of surveyed ornamental fish farms in Australia ................................................. 121
31. State production of ornamental fish in Australia in the 1994-95 financial year ................................................. 122
32. Number of imports of ornamental fish into Australia and FOB value ................ 127
33. Number and FOB value of imports of ornamental fish into Australian states between 1989 - 90 and 1993 - 94 ................................................. 131
34. Ornamental fish; estimates of number of farms, area, production & value for 1989-90 (O'Sullivan, 1991) ................................................. 132
35. Farm gate prices and price per kg of *P. scalare* in Australia ......................... 137
36. Annual sales of *P. scalare* by Pet & Aquarium Industries Pty Ltd for 1993 - 94 ................................................. 138
37. Estimated annual number and value of sales of *P. scalare* in Australia for 1993 - 94 ................................................. 139
38. Production of *P. scalare* in Australia for the year 1994 - 95 ......................... 140
39. Size and value of geographic market segments for *P. scalare* in Australia for 1993 - 94 ................................................. 141
40. Size of target segments for import replacement of *P. scalare* in Australia for 1993 - 94 ................................................. 144
41. Production targets for Tas Angels .................................................. 145
42. Summary of strengths, weaknesses, opportunities and threats for Tas Angels .... 148
43. Projected annual production of *P. scalare* by Tas Angels during the first five years of operation ................................................................. 162
44. Number and cost of culture tank systems for Tas Angels .......................... 164
45. Product-definition of *P. scalare* for the ornamental fish industry in Australia ... 171
46. Tas Angels marketing schedule for the first five years of operation ............... 188
47. Capital cost requirements for an intensive culture facility for production of 207,000 *P. scalare* ................................................................. 190
48. Depreciation schedule of capital items for Tas Angels .............................. 191
49. Loan repayment schedule for Tas Angels ............................................ 192
50. Cash flow statement for first five years operation for Tas Angels ................. 193
51. Profit and loss statement for first five years operation for Tas Angels .......... 194
52. End of year balance sheet for Years 1 and 5 for Tas Angels .................... 195
53. End of year financial ratios for Tas Angels ....................................... 197
54. Comparison of end of year financial ratios for three scenarios for Tas Angels 202
55. Imports of ornamental fish into Australia by country of origin between 1990-91 and 1992-93 ................................................................. 240
56. Partial cash flow statement for staged expansion of Tas Angels ................. 250
57. Partial profit and loss statement for staged expansion of Tas Angels .......... 251
58. Partial balance sheet statement for staged expansion scenario for Tas Angels .. 251
59. Partial cash flow statement for leasing production facility by Tas Angels ....... 254
60. Partial profit and loss statement for leasing scenario for Tas Angels .......... 255
61. Partial balance sheet statement for Tas Angels leasing suitable premises ....... 256
ABSTRACT

The majority of ornamental fish sold in Australia are imported from overseas farms and wild fisheries mainly based in Asia. The number of ornamental fish imported into Australia in 1991-92 was 7,593,812 tails worth $2,385,000 landed in Australia. Due to the increase in importation costs, it has become more economical and attractive for Australian hobbyists and farmers to produce many species commercially, especially the more specialised higher-value lines of tropical ornamental fish. The industry is expected to expand rapidly during the 1990's and is rated as having sound prospects for the future, with production for 1994-1995 expected to be worth around $10 million (O'Sullivan, 1991).

At present over 20 species of ornamental fish species are cultured on a commercial scale in Australia (McKay and Reynolds, 1983). One such example is the freshwater Angelfish, *Pterophyllum scalare* (Lichtenstein) (Pisces; Cichlidae), a popular medium-priced cichlid. Currently production of this species in Australia is minimal and the biological, marketing and economic aspects of commercial production are poorly understood.

This research project examines the current knowledge of the biology of *P. scalare* and establishes the performance of *P. scalare* under intensive culture conditions. In particular experimentation examines the following areas:

1. Length-weight and length-mouth size relationships;

2. Hatchery production, in particular the effect of artificial incubation of eggs on the reproductive performance of *P. scalare* under commercial culture;

3. Growth and survival of *P. scalare* during the nursery culture phase;

4. Effect of ration level on growth, survival and feeding efficiency; and
5. Effect of stocking density on growth, survival and fin factor.

The results from these experiments suggest that *P. scalare* is a good candidate for intensive culture, with reasonable growth rates, high survival and good feeding efficiency. However, there is potentially a problem with the reproductive output of *P. scalare*. Although these experiments indicate that artificial incubation of eggs can increase the cumulative fecundity of *P. scalare*, egg production is highly variable and large numbers of broodstock must be kept to supply eggs for an intensive culture system. This is an area that needs further research effort.

Preliminary market analysis, based on a survey of the Australian ornamental fish industry, indicates that the majority of *P. scalare* sold in Australia at present are imported. With the increasing costs associated with importing fish, there appears to be considerable market potential for Australian producers to supply *P. scalare* for import replacement. The survey also indicates the rapid growth of the Australian industry and its growing importance as part of the aquaculture industry. It is expected that the industry will continue to grow rapidly throughout the remainder of the decade.

A preliminary farm design is developed, based on these marketing data as well as the biological data, as a basis for assessing the culture potential of *P. scalare* under intensive culture conditions. From this farm design, financial statements are developed to analyse the economic potential of intensive culture of *P. scalare*, and recommendations made for marketing strategies for the enterprise. Analysis indicates that intensive production of *P. scalare* is feasible, but returns are limited due to high capital investment, long establishment and lag-time in production, and small market size. The analysis indicates that with an initial investment of $120,000, an owner/operator would realise a net present value of approximately $35,000 after five years. Improvements in the biological performance of *P. scalare*, the use of polyculture and increasing the market size may further increase the culture potential of this species.
P. scalare offers merit as an aquaculture species in Australia, particularly for a family business, with production and marketing strategies aimed at producing high quality fish for import replacement.