Stock Assessment of the Queensland–New South Wales Sea Mullet Fishery
(*Mugil cephalus*)

Paul A. Bell, Michael F. O’Neill, George M. Leigh, Anthony J. Courtney and Samantha L. Peel

Sustainable Fisheries Unit
Animal Science
Southern Fisheries Centre, Deception Bay
The Department of Primary Industries and Fisheries (DPI&F) seeks a better quality of life for all Queenslanders — a quality of life supported by innovative world-class food and fibre industries, and by responsible and ecologically sustainable use of natural resources.

Our business is about:
- innovative science and commercial uptake of new technology by food and fibre industries
- sustainable use of natural resources
- food safety and protection against imported pests and diseases
- market-driven and ethical food and fibre production.

This publication provides an assessment of the state of the population of Sea Mullet, Queensland’s most commercially valuable finfish resource, and recommendations for future research and data collection.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this report.

© The State of Queensland, Department of Primary Industries and Fisheries 2005

Copyright protects this publication. The State of Queensland has no objection to this material being reproduced but asserts its right to be recognised as author of its original material and the right to have its material remain unaltered.

Inquiries should be addressed to:
Manager, DPI&F Publications
Department of Primary Industries and Fisheries
GPO Box 46
BRISBANE QLD 4001
TABLE OF CONTENTS

1 EXECUTIVE SUMMARY ............................................................................................................. 1

2 INTRODUCTION AND BACKGROUND ................................................................................. 2
  2.1 INTRODUCTION .............................................................................................................. 2
  2.2 BACKGROUND ................................................................................................................ 2
    2.2.1 DISTRIBUTION OF THE FISHERY .......................................................................... 2
    2.2.2 LIFE AS A SEA MULLET .......................................................................................... 2
    2.2.3 ECONOMICS OF THE FISHERY ............................................................................ 3
    2.2.4 SECTORS AND GEAR ............................................................................................. 3
    2.2.5 RECREATIONAL CATCH OF SEA MULLET ............................................................. 4
    2.2.6 MANAGEMENT ....................................................................................................... 5

3 DATA ....................................................................................................................................... 6
  3.1 AVAILABLE INFORMATION ............................................................................................ 6
    3.1.1 BIOLOGICAL ........................................................................................................... 6
    3.1.2 CATCH AND EFFORT ............................................................................................ 7
    3.1.3 TAGGING ................................................................................................................ 8
    3.1.4 PRICING .................................................................................................................. 8
  3.2 DATA QUALITY I: BIOLOGICAL ...................................................................................... 8
    3.2.1 SEX RATIO ............................................................................................................. 9
    3.2.2 AGEING LOGIC ..................................................................................................... 10
    3.2.3 AGE AND LENGTH STRUCTURE ......................................................................... 11
    3.2.4 MISSING DATA ..................................................................................................... 11
  3.3 DATA QUALITY II: CATCH AND EFFORT ....................................................................... 12
    3.3.1 LOGBOOKS – RECORDS OF THE CATCH AND EFFORT ...................................... 12
    3.3.2 CATCH DATA ....................................................................................................... 12
    3.3.3 EFFORT DATA ...................................................................................................... 16
    3.3.4 CATCH RATES ...................................................................................................... 18

4 STOCK ASSESSMENT METHODS ......................................................................................... 20
  4.1 MODELLING THE SYSTEM ............................................................................................ 20
  4.2 MODIFIED PALOHEIMO’S CATCH-AT-AGE MODEL ...................................................... 21
    4.2.1 MODIFIED PALOHEIMO’S CATCH EQUATION ..................................................... 21
    4.2.2 FITTING THE MODEL ............................................................................................ 22
    4.2.3 OBSERVED CATCH ............................................................................................... 22
    4.2.4 STANDARDISATION OF EFFORT ........................................................................... 27
    4.2.5 SELECTIVITY ........................................................................................................ 34
    4.2.6 ESTIMATING TOTAL MORTALITY (Z) .................................................................... 35
    4.2.7 ESTIMATING NATURAL MORTALITY (M) .............................................................. 39
    4.2.8 RECRUITMENT ....................................................................................................... 39
    4.2.9 MODELLING THE MISSING DATA .......................................................................... 40
    4.2.10 CURRENT AND VIRGIN BIOMASS .................................................................... 41
    4.2.11 SURPLUS PRODUCTION AND CONJUNCTION WITH CATCH-AT-AGE .............. 42
  4.3 STATISTICAL CATCH-AT-AGE MODEL ......................................................................... 42
    4.3.1 FORMULATION OF MODEL ................................................................................... 43
    4.3.2 MODEL PARAMETERS AND INPUTS ..................................................................... 43
    4.3.3 FITTING THE MODEL ............................................................................................ 43
  4.4 VIRTUAL POPULATION ANALYSIS .................................................................................. 44
    4.4.1 THE MODEL AND INPUT PARAMETERS ............................................................... 44

5 MODEL RESULTS .................................................................................................................. 46
  5.1 MODIFIED PALOHEIMO’S CATCH-AT-AGE MODEL ...................................................... 46
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1.1 Recruitment</td>
<td>46</td>
</tr>
<tr>
<td>5.1.2 Biomass</td>
<td>46</td>
</tr>
<tr>
<td>5.1.3 Catchability and Selectivity</td>
<td>48</td>
</tr>
<tr>
<td>5.1.4 Assessing the Goodness-of-Fit for the Annual Recruitment Assumption</td>
<td>48</td>
</tr>
<tr>
<td>5.1.5 Assessing the Goodness-of-Fit for the Constant Recruitment Assumption</td>
<td>51</td>
</tr>
<tr>
<td>5.1.6 Equilibrium Biomass Calculation</td>
<td>53</td>
</tr>
<tr>
<td>5.2 Statistical Catch-at-Age Model</td>
<td>54</td>
</tr>
<tr>
<td>5.3 Virtual Population Analysis</td>
<td>60</td>
</tr>
<tr>
<td>5.4 Forecasting with the Modified Palheimo Model</td>
<td>62</td>
</tr>
<tr>
<td>5.4.1 Recruitment Regimes</td>
<td>62</td>
</tr>
<tr>
<td>5.4.2 Management Scenario Simulations</td>
<td>63</td>
</tr>
<tr>
<td>6 Discussion</td>
<td>67</td>
</tr>
<tr>
<td>6.1 Modified Palheimo’s Catch-at-Age Model</td>
<td>67</td>
</tr>
<tr>
<td>6.1.1 Model Behaviour</td>
<td>67</td>
</tr>
<tr>
<td>6.1.2 Recruitment and Mortality</td>
<td>67</td>
</tr>
<tr>
<td>6.1.3 Forecasting</td>
<td>68</td>
</tr>
<tr>
<td>6.2 Statistical Catch-at-Age Model</td>
<td>68</td>
</tr>
<tr>
<td>6.3 Virtual Population Analysis</td>
<td>68</td>
</tr>
<tr>
<td>6.4 The State of the Fishery</td>
<td>69</td>
</tr>
<tr>
<td>7 Recommendations</td>
<td>70</td>
</tr>
<tr>
<td>7.1 Management</td>
<td>70</td>
</tr>
<tr>
<td>7.2 Monitoring</td>
<td>70</td>
</tr>
<tr>
<td>7.3 Research</td>
<td>71</td>
</tr>
<tr>
<td>7.3.1 Biology</td>
<td>71</td>
</tr>
<tr>
<td>7.3.2 Quantitative Research</td>
<td>71</td>
</tr>
<tr>
<td>8 Acknowledgements</td>
<td>72</td>
</tr>
<tr>
<td>9 References</td>
<td>73</td>
</tr>
<tr>
<td>10 Appendices</td>
<td>75</td>
</tr>
<tr>
<td>10.1 Age Frequencies</td>
<td>75</td>
</tr>
<tr>
<td>10.2 Length Frequencies</td>
<td>77</td>
</tr>
<tr>
<td>10.3 Von Bertalanffy Growth</td>
<td>79</td>
</tr>
<tr>
<td>10.4 Modified Palheimo Approximation</td>
<td>81</td>
</tr>
<tr>
<td>10.5 Regression Output for Standardisation of Catch-Rates</td>
<td>83</td>
</tr>
<tr>
<td>10.6 Catch-Curve Regressions</td>
<td>85</td>
</tr>
<tr>
<td>10.6.1 Longitudinal Catch Curve Model 1</td>
<td>85</td>
</tr>
<tr>
<td>10.6.2 Longitudinal Catch Curve Model 2</td>
<td>85</td>
</tr>
<tr>
<td>10.6.3 Cross-Sectional Catch Curve Model</td>
<td>86</td>
</tr>
<tr>
<td>10.7 Matlab Code for Catch-at-Age Analysis</td>
<td>87</td>
</tr>
<tr>
<td>10.8 John Hoenig’s Review</td>
<td>92</td>
</tr>
</tbody>
</table>