STOCK ASSESSMENT REVIEW WORKSHOP

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1. NON-TECHNICAL SUMMARY

98/129	Stock Assessment Review Workshop

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Objectives

1. To review and evaluate existing stock assessment and monitoring programs and methods relating to fishery resources in SE Queensland, with particular reference to eastern king prawns, spanner crabs, tailor and saucer scallops.
2. Use existing data on eastern king prawns, spanner crabs, tailor and scallops to develop and test alternative assessment techniques.
3. To advise the Queensland Fisheries Management Authority and DPI Fisheries Group of the biological status of these resources, and make recommendations on future directions and/or priorities for research and monitoring.
4. To develop appropriate strategies for monitoring and assessment of southern Queensland fisheries resources at levels commensurate with the value of resources and risk of overfishing.
5. To train Queensland based fisheries scientists in recently developed stock assessment procedures
6. The consultant should report on workshop proceedings as well as limitations or bottlenecks to effective stock assessment in Queensland. The consultant should also offer recommendations which may alleviate such limitations to stock assessment in Queensland and improve stock assessment procedures in that state.

Non-technical summary

A three day stock assessment course was presented by Dr Malcolm Haddon of the Australian Maritime College and Dr James Scandol of the Quantitative Training Unit for Fisheries. Techniques such as biomass dynamic and age based modelling were covered.

Thereafter, a Stock Assessment Review Workshop, funded by the Fisheries Research and Development Corporation (FRDC), Department of Primary Industry, Queensland (DPI) and the Queensland Fisheries Management Authority (QFMA), was held in August at the Southern Fisheries Centre, Deception Bay, Queensland. It was convened by stock assessment scientist Ms Cathy Dichmont of DPI, and facilitated by Dr Malcolm Haddon from the Australian Maritime College (AMC). Commercial fishers, recreational fishers, managers and scientists were all represented at the workshop. It should be noted that the workshop only reviewed, analysed and

commented on some of the major fishery resources of southeast Queensland. The resources chosen for review were determined through a series of Resource Priority Workshops held within DPI. Those workshops concluded that the primary southeast Queensland resources are spanner crabs (*Ranina ranina)*, eastern king prawns (*Penaeus plebejus*), saucer scallops (*Amusium japonicum balloti*), sea mullet (*Mugil cephalops*), tailor (*Pomatomus saltatrix*) and an inshore finfish component of bream (*Acanthopagrus* spp), whiting (*Siliago* spp.) (excluding the trawled stout whiting) and dusky flathead (*Platycephalus fuscus*).

The workshop reviewed and evaluated present stock assessment and monitoring programs in order to investigate and develop alternative assessment techniques. A further objective was to make recommendations on the future directions and priorities for research and monitoring. Also, where possible, the biological status of the resources being investigated was determined.

The resources reviewed were treated on a species by species basis, with each species being allocated a chapter in the Workshop Proceedings. At the end of each chapter, a detailed list of monitoring and research directions and priorities are given. The authors present a major conclusions chapter which summarises some of the main recommendations, but these recommendations should not be interpreted as representing the exclusive list of proposals and time should be taken to read the full list of recommendations at the end of the report on each species.

Currently, the longest and, in most resources, the only time series available as an index of biomass is catch rate. However, in some species doubts were expressed concerning the validity of using simple catch rate data as an index of stock biomass. This is especially true for species such as spanner crab where complex animal behavioural patterns may affect catch rate and tailor which is highly aggregatory. In cases where the use of catch rate is more defensible, the series should be standardised to remove factors that affect catch rate other than biomass.

In many of the draft and new Management Plans developed by QFMA, performance indicators and trigger points are mentioned. In most cases, these indicators remain untested. In the workshop, the spanner crab TACC decision rules were tested using a delay difference model and highlighted many aspects of the shortcomings and strengths of the rules. This type of work should be extended to include other major species e.g. scallops and eastern king prawns.

The independent saucer scallops survey conducted in 1997 provided valuable information to the workshop. Although surveys are expensive, in many cases their usefulness far exceeds their cost. It was highly recommended that this particular survey should continue, but also that independent surveys should be extended to other major resources within Queensland.

Age data from otoliths were of varying value depending on the species concerned. For sea mullet, even though the data set was short, strong year classes were identified and were extremely useful for modelling purposes. There was some question as to the validation of rings in tailor as the Western Australians age the same otoliths differently to scientists within Queensland. Bream and flathead otoliths can be fairly easily aged, but there was much difficulty with the whiting species.

The resolution of the logbook database was often a major stumbling block in developing stock assessment models. Much of the data is still entered within the 30-minute square grids, whereas many management rules require at least 6-minute square or direct latitudes and longitudes. Furthermore, in many cases the data can not be resolved to species level. The most chronic of the species investigated was the inshore whiting. Gear type beyond net and trawl etc. is also not recorded even though, for example, in the net fishery, beach seine gear have extremely different catchability and selectivity functions compared to tunnel and gill nets.

Modelling techniques used within the workshop were extremely varied, from simple biomass dynamic models, estimation of total mortality from age information, generalised linear models to a full-scale relative age model using survey, tagging and catch rate data to estimate population size and recruitment indices. The workshop had limited success in estimating final population parameters to determine the health of the stocks. Mostly this was due to logbook problems (e.g. resolving whiting catches into species), lack of contrast in the data (e.g. eastern king prawns catch rate trends), defining effort (e.g. the multi-species and multi-endorsed net fishery) or unknown recreational catch (e.g. tailor and the inshore finfish species). However, of extreme use were the management questions that were addressed. The benefits of a winter closure for scallops, the benefits of opening for a short period the scallop preservation zones to catch senescent animals and testing the spanner crab TACC decision rules are examples. It can be argued, however, that the three greatest benefits of this workshop were:

- the collation of data, which prior to the workshop was either untraceable, on old computers, only on datasheets or in various files held by the scientists involved on the project at the time, and
- the communication between *all* interested individuals, be they biologists, stock assessment specialists, fishers etc., concentrating on species of relevance to south-east Queensland in a hands on forum, and
- a list of research priorities and monitoring directions for the future.

2. BACKGROUND

Our proposal used the FRDC funded NT Workshop ("Towards the sustainable use of NT fishery resources" FRDC 96/158) as a model so as to review the major projects funded by FRDC and DPI and to develop stock assessment models of the major resources. The workshop also tied in with a QFMA peer driven requirement to closely assess the status of the spanner crab fishery which is Queensland's only TAC-managed fishery, and the tailor fishery, a very important recreational fishery that is widely believed to be over-exploited.

Queensland's fishing industry is based on relatively small landings from a wide range of species. Total wharfside landings from the fisheries is valued at about $175 m annually. However, as most individual fish stocks contribute only modestly to this figure, fisheries tend to have a multi-species focus. This is reflected in a complex, multi endorsement licensing system.

The responsibility for managing Queensland's fisheries lies with the Queensland Fisheries Management Authority (QFMA). This organisation is responsible for ensuring the objectives of the Queensland Fisheries Act are met. One such objective relates to the use of fisheries resources in an ecologically sustainable manner. To achieve ecological sustainable development, the Authority uses a precautionary approach to management. The Authority is required to develop management plans for each fishery under its jurisdiction, and does so through Management Advisory Committees (MACs). MACs (and more broadly, the general community) have placed an increased demand for stock assessment and other scientific advice. Some MACs have already established Stock Assessment Groups for specific resources. Present assessment procedures are almost exclusively focussed on fishery-dependent abundance indices derived from commercial catch-effort statistics. Comprehensive daily statistics are available across the entire Queensland commercial fleet via a compulsory commercial logbook system, which has been in operation for about 10 years. While this is a relatively short time-series compared to those for some Northern Hemisphere fisheries, we believe that this should not be a barrier to the progress of serious scientifically based stock assessment work.

The application of fishery monitoring and assessment procedures is still fairly new in southern Queensland. Consequently the development of meaningful assessments for individual species has been limited by the availability of appropriate expertise and has been largely focused on per-recruit analysis. Given the increasing levels of concern about the status of fished resources being voiced by MACs and individual scientists, there is great demand on those scientists with mathematical and statistical skills. Rational allocation of scarce assessment skills is a matter to be addressed. A process of in-house resource prioritisation was completed by DPI stock assessment biologist Ms C. Dichmont in 1997. Several criteria were used to prioritise the more than 150 resources, including value of catch, size of catch, size of recreational component, level of conflict etc. This process identified the region's top 5 marine resources as being tailor, eastern king prawns, spanner crabs, blue swimmer crabs and scallops. As a result, most stock assessment work since this meeting has concentrated on these species. This has alleviated some of the problems of resource allocation, but has exposed stock assessment research to little peer review in terms of appropriate methodology.

It is important to note that most of the stock assessment and monitoring projects in this region are at or near completion, because they have been reliant on external (mainly FRDC) funding. As a result, further funding in the form of industry-based cost-recovery and further FRDC applications will have to be investigated within the 1998/99 financial year. These monitoring programs have been fairly broad-based, both in terms of species covered and techniques used, and will have to become more specific and less resource-intense to achieve industry funding.

The current FRDC funded stock assessment and monitoring projects which will be completed in 1998/99 in south-east Queensland are
a) "Integrated Stock Assessment and Monitoring Program" (FRDC T94/161) which investigates length- and age-based procedures for monitoring the stocks of several important recreational and commercial coastal and estuarine species in southern Queensland.

b) "Support of employment of Stock Assessment Biologist" which has assisted DPI in recruiting a qualified and experienced stock assessment biologist to the region and
c) "Stock Assessment and Management of Spanner Crabs in SE Queensland" (FRDC 95/022) which investigates the biological parameters for stock assessment and provides the platform for initial stock assessment attempts.

3. NEED

A number of introductory stock assessment and monitoring programs funded by FRDC will be completed within the next financial year. Most of this work has been undertaken with little peer review. There is a need for an external and highly competent stock assessment consultant to review present research and assessment procedures used for fisheries in southern Queensland, and to identify the direction of future research and monitoring. It is expected that future monitoring programs will be resourced through an industry based cost-recovery program. As a result, a narrowing of objectives and species is needed.

There is a need to look closely at the simulation models being developed by scientists for management use in south-east Queensland. For example, the State's only output-controlled fishery is subject to a TAC, which is set from sustainable yield estimates derived from models that are rapidly becoming outdated. Several monitoring programs, experiments and simulation models have been attempted with varying success. This work needs to be exposed to peer review as this fishery moves (probably) to an ITQ management system. These models should be updated and the present status of the resource needs to be examined, particularly in light of the situation in northern New South Wales as it is a shared resource.

There are a number of data sets on south Queensland fisheries that may be extensive enough to warrant further in-depth assessment. There is an opportunity for this work to be completed at the workshop while the expertise is available.

All the MACs are seeking information on the status of major fish resources for which they have management responsibilities. They are becoming increasingly aware of the need for objective and scientifically based assessment work and are slowly becoming aware of the costs and resource requirements associated with assessments. The supply of initial assessment reports from the proposed workshop will reinforce the move towards objective assessment and associated management recommendations.

Fisheries management in Queensland will be based upon Fishery Management Plans. There is a need to incorporate into these Plans much more robust and well-conceived monitoring and assessment strategies and decision rules than is occurring at present.

Stock assessment skills are scarce within south-east Queensland. An intensive workshop of most major species will include the majority of fisheries scientists and technicians within the region. This will expose them to stock assessment methods and their data requirements.

4. METHODS AND RESULTS

The project contained four basic components:
1. Training to expose Queensland scientists to stock assessment techniques,
2. Data collection and collation,
3. The Stock Assessment Review Workshop, and
4. Extension and publication of proceedings.

Training

The training of Queensland based scientists in stock assessment techniques were approached in two ways. A three day stock assessment course was held prior to the workshop. On the first day, Dr James Scandol presented the stock assessment computer based module from the Quantitative Training Unit for Fisheries, Sydney. Topics covered were:

- Simple population models,
- Parameter estimation,
- Growth of individuals,
- Standardised indices of abundance,
- Stratified random survey designs,
- Stock-recruitment relationships and
- Biomass dynamic models.

On the next couple of days, Dr Malcolm Haddon of the Australian Maritime College lectured on advanced biomass dynamic models and age-based modelling techniques. Scientists from Northern and Southern Fisheries Centre were sponsored to attend.

During the workshop, scientists were exposed to experts within the stock assessment field. Several Southern Fisheries Centre scientists had to verbally present their research for peer review. Each group that was compiled during the workshop always contained a stock assessment expert, a biologist, a person knowledgable with the database and an industry representative. The above format allowed scientists to expose their newly learnt theoretical knowledge to real life data and situations.

Data collection

Emphasis was placed on data collation into a central, easily accessible and well-described form that would be available to anyone in the future. This work had never been dome before at this scale. As a result, information and data was collated from various sources and in some cases was re-entered from datasheets. Also, information on an old out of date computer was transferred to more modern PC's. In some cases, data has been lost for various reasons and these situations have also been described. All data resides on a CD within the centre and the data is to be described in metadata format and placed in the Blue Pages as part of the Coastal Atlas.

The workshop

A Stock Assessment Review Workshop was convened by the project Principal Investigator Ms Cathy Dichmont and facilitated by Dr Malcolm Haddon from the Australian Maritime College over a two week period between Sunday 16th August and Thursday 28th August. Commercial fishers, recreational fishers, managers and scientists were all represented at the workshop. The workshop reviewed, analysed and commented on some of the major fishery resources of southeast Queensland. The resources chosen for review were determined through a series of Resource Priority Workshops held within the Department of Primary Industries. These are spanner crabs (*Ranina ranina)*, eastern king prawns (*Penaeus plebejus*), saucer scallops (*Amusium japonicum balloti*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*) and an inshore finfish component of bream (*Acanthopagrus* spp), whiting (*Siliago* spp.) (excluding the trawled stout whiting) and dusky flathead (*Platycephalus fuscus*).

The workshop sessions for each of these species and species groups had the same format and each session lasted between 1.5 and 2 days. The focus of the workshop was upon the stock assessment of each species and how this could be used to improve on management advice.

The first step was always an introduction to the biology of the species, its current management arrangements, the data available and the research that had already been conducted. From this exposition Dr Haddon, with the groups agreement and prompting, would propose four or five activities which could likely be profitably pursued by smaller sub-groups. The members of the workshop would then be sub-divided among these activities and each such sub-group would work on their particular problem for between four and six hours. Each sub-group would then report back to the complete workshop and from that and the ensuing discussion the final recommendations and suggestions of the workshop would be devised and agreed upon. This format was surprisingly successful and it is the opinion of the authors that the suggestions produced were a consensus of opinion.

Workshop extension and proceedings

The day after the workshop, an open seminar series was held within the centre. More than 50 people attended, mostly from the trawl and finfish commercial sectors, QCFO and Sunfish. The progress and results of each species group was presented in a half-hour seminar of which, 5 minutes of questions were allowed. Thereafter, a free BBQ lunch was provided to further discussions and interaction.

After the workshop, the group's models were in various stages of completion. Any incomplete work was finalised by Ms Dichmont and Dr Haddon. Furthermore, all results were checked. A Stock Assessment Review Workshop Proceedings was written in which all the work undertaken in the workshop was described (Appendix 4). Final recommendations were also collated therein. Transcripts of the discussions during the talks, the group reports and future research direction sessions were made. These are included as a disk in the Workshop Proceedings.

Results and recommendations of the workshop were reported to the relevant Management Advisory Councils. An article was published within DPI Prime News and Queensland Fisherman. Recommendations of research directions were made by

Dr Malcom Haddon to QFIRAC for the next round of FRDC project proposals. Of the four projects supported, two were subsequently funded.

5. ACHIEVEMENT OF OBJECTIVES

Objective 1. To review and evaluate existing stock assessment and monitoring programmes and methods relating to fishery resources in SE Queensland, with particular reference to eastern king prawns, spanner crabs, tailor and saucer scallops.

All available data collection and stock assessment research was reviewed within the workshop. Species coverage was increased to include spanner crabs, saucer scallops, eastern king prawns, sea mullet, tailor and an inshore finfish component of flathead, bream and whiting. The main method of review was through presentations following the general format of:

- Biology and world-wide distribution (presented by the relevant biologist)
- Description of the fishery (presented by a fisher),
- Present and future management (presented by a QFMA manager),
- Available data (presented by a scientists most familiar with the data),
- Present analysis and modelling (presented by a stock assessment modeller that has worked on the species), and
- Present monitoring program and its cost.

Recommendations were covered in sessions facilitated by Dr Haddon entitled:

- Discussions of possible models that could be developed,
- Explanation of models used/suggested in the workshop, their assumption and data needs, and
- Discussion of future monitoring program and possible stock assessment models.

Objective 2. Use existing data on eastern king prawns, spanner crabs, tailor and scallops to develop and test alternative assessment techniques.

All available data was collated for the workshop, which included spanner crabs, saucer scallops, eastern king prawns, sea mullet, tailor and an inshore finfish component of flathead, bream and whiting. Available data was presented and summarised for the participants so that full use of the data could be made. In the case of eastern king prawns, monthly catch rate data from New South Wales and in spanner crabs, tagging data from New South Wales's studies, were obtained. For the recreational species discussed, data from QFMA's recreational survey was presented and analysed. The Australian National Sportfishing Association tagging data and recreational club catch rate was also included.

Stock assessment models were successfully developed for eastern king prawns and saucer scallops. A monthly biomass dynamic model for eastern king prawn estimated recruitment levels for the New South Wales and Queensland resource. Unfortunately, the model could not estimate present biomass levels relative to virgin levels due to the lack of contrast in the data. A relative age model that incorporates catch rate, survey and tagging data was developed for scallops. A recruitment index was estimated in which the relatively low level of recruitment over the last few years can be observed. Modelling in the spanner crab section concentrated on the application and standardisation of catch rate and on developing a single growth curve incorporating all available dredge, tagging and size information. Sea mullet models concentrated on estimating total mortality and growth. Although estimates are provided, uncertainty in the estimates is high due to the short data series. The most important issue addressed by the tailor groups was directly or indirectly linked to the extremely high estimates of natural mortality obtained from catch-at-age curves. Several arguments against the conclusion that the resource is overexploited can be given. Most commonly voiced are that the ageing is incorrect and that large animals move offshore and thereby become unavailable to the fishery and bias the sample. In combination with the Western Australian scientists invited, several catch curves were produced. These investigated the bias and variance between readers from Queensland and Western Australia, between readers in Queensland and between multiple readings from a single scientist. Total mortality values could therefore range from 0.8 to 2 $year^{-1}$ depending on interpretation of otolith rings. The inshore finfish sessions were dominated by the lack in resolution of the data in terms of species, method of capture and location. In some cases, algorithms were developed to separate the catch by method or species, but in the case of whiting only rules of thumb could be developed.

Objective 3. To advise the Queensland Fisheries Management Authority and DPI Fisheries Group of the biological status of these resources, and make recommendations on future directions and/or priorities for research and monitoring.

The results of the proceedings have been presented to the relevant MACs within QFMA, being Crab, Trawl and Subtropical Finfish MAC. Furthermore, a report back seminar in which each section was given a 30-minute presentation was completed in the Centre, in which fishers, managers and executives from QFMA and DPI attended. The results of the workshop were also published in DPI Prime News and The Queensland Fisherman. Dr Malcolm Haddon wrote a recommendation for project research priorities to QFIRAC in which two of the four projects supported have subsequently already been funded. In the proceedings are clear sections recommending future research and monitoring directions and priorities.

Objective 4. To develop appropriate strategies for monitoring and assessment of southern Queensland fisheries resources at levels commensurate with the value of resources and risk of overfishing.

In each species section, a half-day session was dedicated to the discussion of monitoring and assessment priorities and research needs within southeast Queensland. As a result, in the proceedings, a heading in each resources section is dedicated to the appropriate strategies that should be taken both in the long and short term. Dr Malcolm Haddon wrote a recommendation for project research priorities to QFIRAC in which two of the four projects supported have already been funded.

Objective 5. To train Queensland based fisheries scientists in recently developed stock assessment procedures

As stated in the section of training within Methods, the training of Queensland based scientists in stock assessment techniques were approached in two ways. A three day stock assessment course was held prior to the workshop. On the first day, Dr James Scandol presented the stock assessment computer based module from the Quantitative Training Unit for Fisheries, Sydney. On the next couple of days, Dr Malcolm Haddon of the Australian Maritime College lectured on advanced biomass dynamic models and age-based modelling techniques. Scientists from Northern and Southern Fisheries Centre were sponsored to attend.

During the workshop, scientists were exposed to experts within the stock assessment field. Several Southern Fisheries Centre scientists had to verbally present their research for peer review. Each group that was compiled during the workshop always contained a stock assessment expert, a biologist, a person knowledgable with the database and an industry representative. The above format allowed scientists to expose their newly learnt theoretical knowledge to real life data and situations.

Objective 6. The consultant should report on workshop proceedings as well as limitations or bottlenecks to effective stock assessment in Queensland. The consultant should also offer recommendations which may alleviate such limitations to stock assessment in Queensland and improve stock assessment procedures in that state.

Appendix 3 is a document by Dr Haddon, which has also been given to QFMA and QDPI in which any bottlenecks and limitations to effective stock assessment in Queensland are discussed. Furthermore, the consultant has reported on the workshop and proceedings. It should be stated that the consultant, Dr Haddon, contributed enormously to the success of the workshop.

6. BENEFITS

This project consolidated the direction of future stock assessment and monitoring programs and is of high regional significance.

The project has in part or full produced the following benefits:

- A review of present stock assessment and monitoring research,
- A strategic plan for stock assessment and monitoring within the SE region,
- The status of major fishery resources or proposed research direction to achieve full assessment of the resource,
- Exposure of stock assessment techniques and their data needs,
- Stock assessment input into Fishery Management Plans,
- Peer review of mainly FRDC-based projects, and
- More robust advice to QFMA.

The major beneficiaries are the QFMA MACs who are responsible for the development of Management Plans. In the long-term, Management Plans based on objective assessment will be of major benefit to the commercial and recreational fishing sectors. Participating scientists and QFMA fisheries managers will benefits from exposure to stock assessment techniques and both QFMA and QDPI will benefit through the development of strategic research priorities.

7. ACKNOWLEDGEMENTS

The Fisheries Research and Development Corporation (FRDC), Department of Primary Industries (DPI) and Queensland Fisheries Management Authority (QFMA) funded this workshop. It was a major undertaking for several people, however, the largest contributions came from Dr Malcolm Haddon, workshop facilitator, Proceedings author and editor; Ms Kath Kelly, workshop coordinator and transcriptor of the audio tapes; Ms Kate Yeomans, data collector, collator and Proceedings editor. Your dedication is much appreciated. I would like to thank Dr Ian Brown and Mr Bob Pearson for convincing the various parties and interest groups that this workshop was essential and for securing financing from QFMA and DPI. Each session had an allocated coordinator, which really reduced my workload. They were; Dr Ian Brown for spanner crabs, Dr Tony Courtney for eastern king prawns, Mr Mike Dredge for scallops, Mr Ian Halliday for mullet and Mr Simon Hoyle for tailor and the bream/whiting/flathead sessions. Several scientists have reviewed the manuscript, but I would like to make a special mention of Mr Mike Dredge, Dr Ian Brown and Dr Daryl McPhee. I would also like to thank the laboratory for allowing me to use the tearoom and other facilities without complaint. Most of all, I really appreciate the help from the administrative staff for what was a difficult and diverse project.

APPENDIX 1: INTELLECTUAL PROPERTY

Based on the original agreement, FRDC's proportion of ownership of intellectual property, decided on financial contribution, is 45.1%. Proceedings of the workshop have been included in this project but will also be published independently as a document on its own. Results have been published in an industry journal. Some work has already been taken further, mostly by other FRDC projects. These are the effort standardisation components described in FRDC T94/161 and FRDC 95/022. It is the intention that other components may be written up in peer-reviewed journals. No commercial patents are expected from this project.

APPENDIX 2: PROJECT STAFF

Project staff	Name	Organisation
Principal Investigator	Ms C.M. Dichmont	DPI Queensland
Workshop facilitator and consultant	Dr M. Haddon	Australian Maritime College
Workshop coordinator	Ms K.E. Kelly	DPI Queensland
Co-investigators (alphabetically)	Dr I.W. Brown	DPI Queensland
	Dr A.J. Courtney	
	Mr M.C.L. Dredge	
	Mr I. Halliday	
	Mr S. Hoyle	
	Ms K.M. Yeomans	

Apart from the above scientists that contributed to all facets of the project, more than 45 people participated in the workshop itself. Drs James Scandol and Malcolm Haddon lectured during the three-day stock assessment course.

APPENDIX 3: CHAIRMAN'S COMMENTS - MALCOLM HADDON

Stock Assessment Review, Southern Fisheries Centre, Deception Bay.
17th and 28th August 1998

Summary and Recommendations

- The workshop, with its particular format, worked exceedingly well as a source of recommendations for identifying issues or importance and future research needs. It also acted as a detailed form of extension of ideas about stock assessment and permitted detailed discussion on all sides of the issues raised.

- The two weeks of workshops were very intensive and if future workshops are organised they should be limited to a maximum of a single week. The amount of work involved in preparing for the two weeks was onerous for the already busy staff of the Southern Fisheries Centre.

- The present commercial fisheries database is inadequate in many ways for the production of reliable stock assessments. The database itself has many errors and problems in relation to key stocks. With some urgency, the QFMA need to address the problems with the database. The data already available needs cross checking, the quality control on data entry needs to be improved, and the fisheries scientists who are expected to use the data to provide management advice should be consulted about the structural changes needed to the database and the reporting forms.

- The feasibility of conducting fishery independent surveys on suitable species, such as saucer scallops, spanner crabs, and Tailor, should be investigated to discover workable ways of funding such enterprises.

- An obvious threat to sustainability for some species, such as eastern king prawn and sea mullet, is the fact that these stocks extend and migrate across State boundaries. Until all States share a common set of management objectives for such species they will be vulnerable. Strategies need to be developed for improving and formalising inter-State communication with respect to shared or migratory species.

- The performance indicators being proposed for use in many of the Queensland fisheries considered were of varied nature but there were many which used a catch rate or assumed associated biomass relative to some earlier biomass level. Such performance indicators have their problems and need further investigation and development. In the workshop a modelling procedure was developed to test the efficiency of a set of such indicators. This approach should also be pursued further as being of general use across Australia. The relationship between fishery management objectives and their associated performance indicators needs to be tighter wherever possible.

The Workshop

The Executive Summary provides a description of the origin and development of the Stock Assessment workshop run at Deception Bay over the two week period Monday 17th to Friday 28th August 1998.

The species and species groups considered by the workshop were Spanner Crabs, Eastern King Prawn, Saucer Scallops, Sea Mullet, Tailor, and Bream/Whiting/Flathead. Particular details of the recommendations for each are included in the body of the text of the main report and the executive summary and will only be revisited here to illustrate particular points.

The Workshop Process

The workshop sessions for each of the species and species groups all had the same format and each session lasted between 1.5 and 2 days. The focus of the workshop was upon the stock assessment of each species and how this could be improved and, in turn, used to improve on management advice.

The first step of the process for each species or species-group was always an introduction to its biology, the operational practices of its fishery, the data available, the research that had already been conducted, and the current management arrangements for the fishery. From this exposition, input from workshop participants, and more detailed reading, I would formulate, with the groups agreement and prompting, four or five areas of analysis which were thought of as good candidates for providing an indication of future directions or even an answer to a particular research problem. The members of the workshop would then be organised into sub-groups and each would work on one of the particular problems for between four and six hours.

Each sub-group had members of all sectors represented at the workshop. They would first gather the data or information they required and then collect in a separate room or part of the main meeting room and push the work forward in a collaborative manner. After taking their particular problem as far as they could in the time available, each sub-group would report back to the complete workshop for discussion and commentary.

After all sub-groups had reported back to the workshop a discussion always followed during which the final recommendations and suggestions about issues of concern and future research priorities would be devised and agreed upon for the species or species group concerned. An objective of these discussions was to obtain a consensus but where that was not possible the different points of view were described.

The Benefits

1. The full-workshop/mini-workshop approaches, and the particular format used, were surprisingly successful at generating results of either immediate value or indicative value for future stock assessments. The discussions following the mini-workshops were often useful in clarifying issues considered important by the fishing industry representatives, clarifying management objectives, and

identifying actions which may improve the assessment and management of the different fisheries.

2. The workshop automatically acted as an extension process that described and explained many stock assessment methods to Industry and Management representatives. There was an exchange of ideas among all members of the workshop.

3. The open discussion and the opportunities given to everyone who wanted to contribute meant that the process was sometimes slower than was always strictly necessary. However, I believe everyone would agree that the suggestions and recommendations produced were a consensus of opinion, as far as that was possible.

4. The progress of the analyses in the mini-workshops also appeared slower than they could have been but by having the sub-groups made up of both scientists and fishers both sides often benefited from trying to explain to the other their perceptions of each fishery.

5. Preparing for the stock assessment workshop forced staff at the Southern Fisheries Centre, Deception Bay, to collate all available data and other information and raised their awareness of what historical information was available.

The Disadvantages

Preparing for the two weeks of stock assessment workshops forced staff at the Southern Fisheries Centre, Deception Bay, to spend much time in gathering and organising information into easily useable computer files. The step of organising the available information is undoubtedly a good thing but it exposed already busy people to further stress and aggravation. Undertaking a workshop with such an ambitious agenda is something that should not be undertaken lightly.

General Statements regarding Stock Assessment at Deception Bay.

Past Data Collection, its Analysis and Interpretation

Many Australian fisheries have a relatively low landed value and yet the size of the country and its coastline means that performing any useful assessment on the status of a fish stock can prove to be both difficult and expensive. The relatively low value means that the number of fisheries scientists also tends to be relatively low. It would be fair to say that at all fisheries research centers in Australia, and the Southern Fisheries Centre at Deception Bay is no exception, the scientific staff tend to be stretched to their limit in terms of workload.

The fisheries research carried out at the Southern Fisheries Centre invariably appears to have been executed as well as available equipment and funding would permit. There is a history of staff at the Southern Fisheries Centre formally publishing at least some of their studies of the biology of commercial species. Longer term stock assessment and monitoring has not fared so well although occasional, localised, population surveys of species such as saucer scallops were conducted. Voluntary logbook schemes were devised for selected fishers for a number of species and this was the start of attempts at stock monitoring. Such data proved very useful during the workshop process when discussing fishery performance now relative to earlier dates.

The Commercial Catch and Effort Database in Queensland

Every State in Australia appears to have its own set of fisheries assessment and management problems. To a large extent, Queensland's problems, in terms of its fisheries, derive from earlier attempts to encourage the development of the Australian fishing fleet. By the time restrictions on new fishing licenses were instigated in Queensland there were over 800 trawl licenses and hundreds of other licenses in the various fisheries. The logistic problems involved in collecting meaningful fisheries data from such a large set of fishers are enormous. This is reflected in the fact that except for a very few fisheries there are few useful fisheries statistics prior to 1990 or even later.

The current logbook scheme, while a great improvement over earlier schemes (especially when no data other than landings were collected), is still inadequate for many stock assessment purposes. Many of the fishery performance indicators suggested by the draft fisheries management plan, and for the individual fisheries, use catch-effort data in a comparison with earlier catch rates. Without proper error checking when the data are input, and without various design flaws being rectified, the proper functioning of the performance indicators would be compromised. One big problem is the poor resolution of species identification. For example, the use of "Bay Prawns" indicates a mix of prawn species by size rather than by species. A further example of a major problem is the mixing of ways of reporting catch in the scallop fishery. Catch is reported as both baskets and kgs weight, but sometimes only one is provided and then it can fall into the wrong database column (e.g. a 1,000 kg catch can be mis-labeled a 1,000 basket catch). Such problems make using the current database difficult. Potentially the errors could be very large making any stock assessments very confused.

The current commercial fisheries database of catch and effort information has some general uses. However, the problems which exist in relation to data quality, missing information, and confused data (species lumped together, search times not recorded, failure to separate effort types, mixing of catch reporting, etc, - see main report) mean that stock assessments based on this information could be flawed fundamentally. Under these circumstances the options are for scientists to introduce extra, voluntary log-book schemes or, for more detailed work, to conduct fishery independent surveys.

In Queensland, fishery independent research and monitoring has been patchy at best so there has been no consistent long term stock monitoring. However, there is a history of relatively continuous work on scallops, eastern king prawn, and spanner crabs. These works, however, are a reflection of the efforts of individual scientists or groups of scientists, not necessarily as a result of a conscious policy except an implicit one of investigating important fisheries. The intermittent nature of this work relates to a number of factors. First, the patchy history of the collection of centralised fisheries statistics, second, to the intermittent nature of funding for fisheries research, especially by way of setting in place routine stock monitoring, and third, the opportunities that arise for particular fisheries scientist to carry out assessment work on particular species.

With the relatively recent explicit adoption of sustainability as a key management objective there has been an increased emphasis towards research into long term monitoring of stock status. To expect there to have been more by way of stock monitoring in the past would be unjust.

Current Fishery Performance Measures and Reality

The stock monitoring or performance indicators, or both, for spanner crabs, eastern king prawns, and saucer scallops, all rely heavily on commercial catch effort data. Apart from the many problems which exist with this database, many people at the workshop expressed doubts about the validity of using such information to access stock performance; it was thought that simple catch effort data was not a good indicator of relative stock size. Thus, it is possible to use the current performance indicators but whether they reliably reflect nature is questionable.

The alternative suggested was, naturally, fishery independent surveys. The best examples of the value of such surveys were provided by the stratified random surveys for saucer scallops. During the workshop, the availability of the information gained from the first survey was used for a number of purposes and led to suggestions for adding up to $3 million of value to the fishery through the use of seasonal and spatial closures. To adequately manage a resource such as saucer scallops, which can have highly variable recruitment, such surveys are possibly the only viable option that could lead to optimal sustainable management.

Fishery Independent Surveys

The obvious disadvantage of such fishery independent surveys is that they are expensive to run. Such surveys have been suggested for saucer scallops, spanner crabs, and Tailor. The design of such surveys would be no problem with the present staff at the Southern Fisheries Centre. For example, the previous scallop surveys were nicely designed to cover the ground and provide the needed information in a valid way.

The funding of such surveys would be the biggest problem. Many options were discussed in the workshop ranging from a marine recreational fishing license, a further Industry levy, a system of charter for catch or effort rights, and combinations of such approaches. Which approach would work best in Queensland will probably vary by fishery.

The workshop demonstrated that for a few fisheries, such as Tailor, the recreational catch was higher than the commercial catch. Recreational fishers appeared not to be over troubled by the idea of a marine recreational license as long as it was guaranteed that any funds raised would be used for recreational fisheries research and compliance.

Whichever method for funding the fishery independent surveys is selected, the importance of such surveys, properly executed, can be tremendous. However, not all species are suited to such surveys. Just as with commercial catch-effort data, care must be taken to restrict such analyses to those species (such as scallops, spanner crabs, and Tailor) which might provide results of sufficient statistical precision to be useful as a basis for management advice.

Other General Problems

The Eastern King Prawn and Sea Mullet fisheries provide examples of where single stocks straddle the waters of more than a single State. As elsewhere, a disagreement between States, and sometimes the Commonwealth, over the management of fisheries resources sometimes acts against successful collaboration on stock assessment. The Deception Bay workshop was, for a short time, under threat of scientists from NSW not being allowed to attend. Fortunately, in Australia the community of fisheries scientists is relatively small and there is a history of a good level of collaborative work between people in different States.

The argument for the separation of the management from the assessment of fisheries is supported by such difficulties and will not be rehearsed here. Things would become easier for stock assessment, and hence sustainability, when all States have consistent management for cross-border species. Eastern King Prawn and Sea Mullet are two species which could be vulnerable to assessment in one State not accounting for all that happens to the stock in other States.

Performance Indicators

Performance indicators (PI) being suggested for the management of various fisheries in Queensland are often based upon catch-effort data. These types of PI are dangerous if, in fact, there is no relationship between the stock status and catch-rates.

There are a number of questions about performance indicators that should be addressed and these include such basic ones as whether performance indicators are an efficient way of managing a fishery. Certainly, when catch rates are used as limit measures of performance it must be recognised that we are only dealing with estimates of relative catch rate. We can thus never be 100 % certain that a trigger point has been reached. Any performance indicator which utilises a single number as a threshold would suffer from the same criticism.

Some PI measures are better than others but currently there are no agreed upon criteria for distinguishing good from bad. In the workshop a modelling procedure was used to test the efficiency of a set of proposed PIs which acted upon threshold catch rate levels being reached. This modelling test procedure worked well and should be pursued further as a means of comparing different sets of performance indicators.

It is of concern that PIs that use either catch rates or their assumed stock biomass levels relative to some selected reference year have an arbitrary nature. Such indicators or thresholds are difficult to relate to any specific management objective. Although the link can be made to sustainability if there is some notion of the biomass required to ensure reliable levels of recruitment (not known for any Australian fishery except empirically through comparison with seemingly equivalent fisheries elsewhere).

In the development of quantitative performance indicators (catch rates, economic performance, geographical extent of the fishery, etc) it is necessary that single year effects are not over-emphasised. There is much remaining to be done in the design and use of performance indicators when managing a fishery. In the workshop there was active discussion of performance indicators and their strengths and weaknesses. There is also active discussion continuing in a number of the stock assessment groups operating around the country, especially in the South East Fishery groups. Given Australia's and especially Queensland's extensive use of such management devices this discussion and development should be encouraged and monitored.

APPENDIX 4: WORKSHOP PROCEEDINGS

Attached are the Workshop Proceedings. Copies have been professionally printed and are available as a separate document (ISSN Number 0728-067X). A printed copy will be sent to each participant.

PROCEEDINGS

OF THE SOUTH-EAST QUEENSLAND STOCK ASSESSMENT REVIEW WORKSHOP

Southern Fisheries Centre
Deception Bay, Queensland

16 – 28 August 1998

Editors
C. M. Dichmont
M. Haddon
K. Yeomans
K. Kelly

QUEENSLAND GOVERNMENT

QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

QFMA Queensland Fisheries Management Authority

QC 99003

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Executive Summary

A Stock Assessment Review Workshop, funded by the Fisheries Research and Development Corporation (FRDC), Department of Primary Industry, Queensland (DPI) and the Queensland Fisheries Management Authority (QFMA), was held in August at the Southern Fisheries Centre, Deception Bay, Queensland. It was convened by stock assessment scientist Ms Cathy Dichmont of DPI, and facilitated by Dr Malcolm Haddon from the Australian Maritime College (AMC). Commercial fishers, recreational fishers, managers and scientists were all represented at the workshop. It should be noted that the workshop only reviewed, analysed and commented on some of the major fishery resources of southeast Queensland. The resources chosen for review were determined through a series of Resource Priority Workshops held within DPI. Those workshops concluded that the primary southeast Queensland resources are spanner crabs (*Ranina ranina)*, eastern king prawns (*Penaeus plebejus*), saucer scallops (*Amusium japonicum balloti*), sea mullet (*Mugil cephalops*), tailor (*Pomatomus saltatrix*) and an inshore finfish component of bream (*Acanthopagrus* spp), whiting (*Siliago* spp.) (excluding the trawled stout whiting) and dusky flathead (*Platycephalus fuscus*).

The workshop reviewed and evaluated present stock assessment and monitoring programs in order to investigate and develop alternative assessment techniques. A further objective was to make recommendations on the future directions and priorities for research and monitoring. Also, where possible, the biological status of the resources being investigated was determined.

The resources reviewed were treated on a species by species basis, with each species being allocated a chapter in the Workshop Proceedings. At the end of each chapter, a detailed list of monitoring and research directions and priorities are given. The authors present a major conclusions chapter which summarises some of the main recommendations, but these recommendations should not be interpreted as representing the exclusive list of proposals and time should be taken to read the full list of recommendations at the end of the report on each species.

Currently, the longest and, in most resources, the only time series available as an index of biomass is catch rate. However, in some species doubts were expressed concerning the validity of using simple catch rate data as an index of stock biomass. This is especially true for species such as spanner crab where complex animal behavioural patterns may affect catch rate and tailor which is highly aggregatory. In cases where the use of catch rate is more defensible, the series should be standardised to remove factors that affect catch rate other than biomass.

In many of the draft and new Management Plans developed by QFMA, performance indicators and trigger points are mentioned. In most cases, these indicators remain untested. In the workshop, the spanner crab TACC decision rules were tested using a delay difference model and highlighted many aspects of the shortcomings and strengths of the rules. This type of work should be extended to include other major species e.g. scallops and eastern king prawns.

The independent saucer scallops survey conducted in 1997 provided valuable information to the workshop. Although surveys are expensive, in many cases their usefulness far exceeds their cost. It was highly recommended that this particular survey should continue, but also that independent surveys should be extended to other major resources within Queensland.

Age data from otoliths were of varying value depending on the species concerned. For sea mullet, even though the data set was short, strong year classes were identified and were extremely useful for modelling purposes. There was some question as to the validation of rings in tailor as the Western Australians age the same otoliths differently to scientists within Queensland. Bream and flathead otoliths can be fairly easily aged, but there was much difficulty with the whiting species.

The resolution of the logbook database was often a major stumbling block in developing stock assessment models. Much of the data is still entered within the 30-minute square grids, whereas many management rules require at least 6-minute square or direct latitudes and longitudes. Furthermore, in many cases the data can not be resolved to species level. The most chronic of the species investigated was the inshore whiting. Gear type beyond net and trawl etc. is also not recorded even though, for example, in the net fishery, beach seine gear have extremely different catchability and selectivity functions compared to tunnel and gill nets.

Modelling techniques used within the workshop were extremely varied, from simple biomass dynamic models, estimation of total mortality from age information, generalised linear models to a full-scale relative age model using survey, tagging and catch rate data to estimate population size and recruitment indices. The workshop had limited success in estimating final population parameters to determine the health of the stocks. Mostly this was due to logbook problems (e.g. resolving whiting catches into species), lack of contrast in the data (e.g. eastern king prawns catch rate trends), defining effort (e.g. the multi-species and multi-endorsed net fishery) or unknown recreational catch (e.g. tailor and the inshore finfish species). However, of extreme use were the management questions that were addressed. The benefits of a winter closure for scallops, the benefits of opening for a short period the scallop preservation zones to catch senescent animals and testing the spanner crab TACC decision rules are examples. It can be argued, however, that the three greatest benefits of this workshop were:

- the collation of data, which prior to the workshop was either untraceable, on old computers, only on datasheets or in various files held by the scientists involved on the project at the time, and
- the communication between *all* interested individuals, be they biologists, stock assessment specialists, fishers etc., concentrating on species of relevance to south-east Queensland in a hands on forum, and
- a list of research priorities and monitoring directions for the future.

INTRODUCTION 1

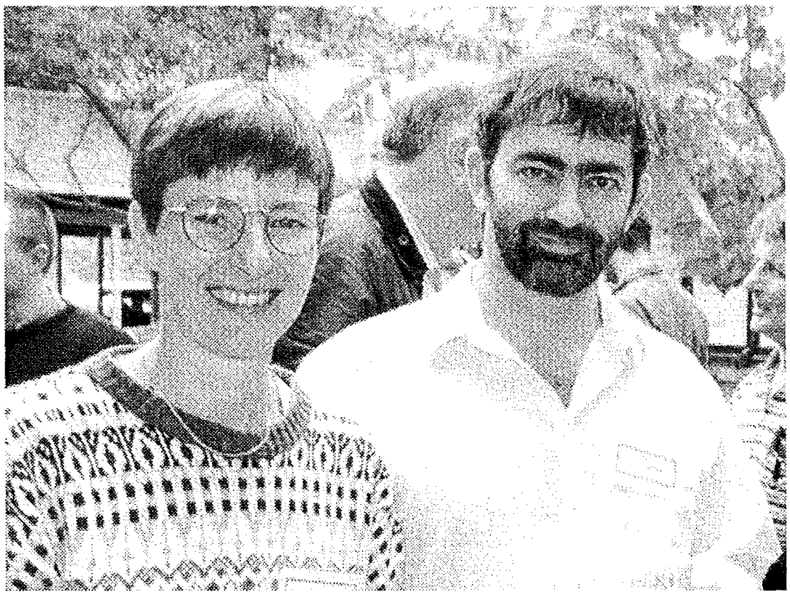


Figure 1.1. *Ms Cathy Dichmont (workshop convener) and Dr Malcolm Haddon (workshop facilitator)*

A STOCK ASSESSMENT REVIEW WORKSHOP was held from the 16–28 August at the Southern Fisheries Centre, Deception Bay, to investigate possible stock assessment techniques that could be applied to available fisheries data. The workshop was funded by the Fisheries Research and Development Corporation (FRDC), Department of Primary Industry, Queensland (DPI) and the Queensland Fisheries Management Authority (QFMA). It was convened by stock assessment scientist Cathy Dichmont of DPI, Southern Fisheries Centre and facilitated by Malcolm Haddon from the Australian Maritime College who is an expert in this field. Participants outside the Centre were invited from the fishing industry, SUNFISH, Queenslands Commercial Fishermen's Organisation (QCFO), Queensland Fisheries Management Authority (QFMA), DPI Northern Fisheries Centre, New South Wales Fisheries, Northern Territory Fisheries, Western Australia Fisheries and CSIRO in Cleveland and Hobart *(see complete list of participants and their affiliation in Chapter 11).*

The workshop had four major objectives:

- To review and evaluate existing stock assessment and monitoring programs and methods relating to fished resources in SE Queensland.
- Use existing data to develop and test alternative assessment techniques.
- Make recommendations on future directions and/or priorities for research and monitoring, and, where possible, to advise the Queensland Fisheries Management Authority and DPI Fisheries Group of the biological status of the resources to be investigated.
- To develop appropriate strategies for monitoring and assessment of southern Queensland fisheries resources at levels commensurate with the value of the resources and risk of overfishing.

The focus of the workshop was therefore upon the stock assessment of each species and how this could be used to improve on management advice.

The resources chosen for review were determined through a series of Resource Priority workshops held within DPI. Those workshops concluded that the primary southeast Queensland resources are spanner crabs (*Ranina ranina)*, eastern king prawns (*Penaeus plebejus*), saucer scallops (*Amusium japonicum balloti*), sea mullet (*Mugil cephalops*), tailor (*Pomatomus saltatrix*) and an inshore finfish component of bream (*Acanthopagrus* spp), whiting (*Siliago* spp.) (excluding the trawled stout whiting) and dusky flathead (*Platycephalus fuscus*). A final open-day series of seminars was held on 28 August reporting on the results of the workshop. All sessions were well attended especially the final seminar series.

The same format for proceedings was used for each species or species group examined. The first step was an introduction to the biology of the species, its current management arrangements, the data available and the research that had already been conducted. Following this introduction, four or five tasks were proposed which smaller sub-groups could most likely pursue profitably. The members of the workshop would then be sub-divided among these activities and each such sub-group would work on their particular problem for between four and six hours. Each sub-group would then report back to the complete workshop. On the basis of these reports and the ensuing discussion, the final recommendations and suggestions of the workshop would be devised and agreed upon. The workshop report follows the same structure.

The above approach was surprisingly successful. Efforts were made to ensure that everyone would agree that the recommendations produced were a consensus of opinion. Many of the sub-groups working on particular problems managed to produce useful results although time limitations within the workshop meant that none fully completed their tasks. The most promising of their analyses will be pursued further and results reported at a later date. The aim of this current report is to describe the workshop and its activities. Given the time available, all results in this document are of a preliminary nature.

1.1. WORKSHOP INTRODUCTION

Below is the transcript of the Workshop opening speech by Dr Barry Pollock, DPI Fisheries General Manager.

It is really a privilege to have a workshop like this at the Southern Fisheries Centre. This workshop is basically being funded by the Fisheries Research and Development Corporation (FRDC) and we really appreciate that funding. Queensland Fisheries Management Authority (QFMA) and Queensland Department of Primary Industries (DPI) have also been supportive financially, but I guess the participants will make it work. The workshop is going to look at stocks in south Queensland on spanner crabs, eastern king prawns, scallops, mullet, tailor and a finfish assemblage of bream/whiting and flathead. That is a big program you have given yourself and it will be interesting to see what comes out of it.

We are at a really interesting stage in Queensland with our fish stocks, in that at the moment the emphasis is for accurate more rigorous stock assessment. If you look at what has happened over the last 20 years or so, it has been a really interesting process in finding out about our fish stocks. I know when I was doing research, it was really exciting to find out about how these things migrate and I remember the first time people could pin up a life cycle of king prawns. We tried to understand the biology of these things.

We've come past that now and we have got a pretty good handle of the basic biology of most of these animals, but we are now being asked, through the management process particularly, what the status of these stocks are for example are they healthy or not so healthy. That is the challenge I guess for the scientists here. It is quite important to come to grip with this challenge.

Another thing developed over these last few years is that we now have a reasonably good commercial logbook program in Queensland. We understand that there are some problems and that it is not perfect, but at least we've got one we can work on and try to improve.

More recently, we've started to get a database on recreational fishing, but it has only been going for a year. We really need to get catch and effort statistics on that sector. Also, I guess, information from the charter sector and smaller sectors. We have to get the complete picture.

What we are not doing and therefore it is the challenge, is a more sophisticated or a more elaborate monitoring program. We don't have anything now. We've done some research in the last few years on stock like the finfish, scallops, barramundi, mud crabs and so on. FRDC has funded a lot of those short term, 3 year research projects. We need to make some important decisions now as to what we are going to do especially in terms of longer-term monitoring.

It has been quite exciting over the last couple of months. We have come up with a concept to get up a monitoring team, which will be a dedicated group of people who will monitor various indicators of key fish stocks. These indicators may be fishery independent or it may be fishery dependent. We haven't really worked out the details and that is why this workshop is important, because it will give us some clues as to what and how we might actually monitor.

We don't have a lot of resources, but at least it is a start and I am hoping that eventually we can entice some money from industry. We hope that this team would start in June of next year, so we have a year to work out exactly what we need to do.

The other thing that interests me about this type of work, is how we communicate the results to the fishing industry and the public. We are dealing with a public resource. In some studies, science that is quite complex have had a fantastic extension program. For example, scientists have built up a visual model of Moreton Bay and Brisbane River and tried to build the complex science into a simple model which is visually strong.

In terms of extending our assessment work, it is maybe not your role, but it certainly is something into which you should have input. How do we get information out to people who we may want to convince? I don't think we can just stop at the scientific, we need extension before people really accept a tough message.

The last thing I want to mention, is that we have already produced the 'Condition and Trend' document which is not aimed at the scientific community, but at a broader community and fishers particularly. We are committed to producing something like this every two or 3 years. It is a good start but the amount of modelling in the book is pretty minimal and that should be corrected in time.

I wish the workshop well. There will be some real implications for resourcing, especially the monitoring side and it will give us a picture of what we know about these really important stocks at this point in time and how good the data is.

1.2. AUTHORSHIP NOTE

Numerous people have contributed to these proceedings. Unless otherwise stated below, the authors are Cathy Dichmont and Malcolm Haddon, whereas the Proceedings was edited by Cathy Dichmont, Malcolm Haddon, Kate Yeomans and Kath Kelly.

CHAPTER 2 SPANNER CRAB

This chapter was written in collaboration with Ian Brown. Section 2.2 "Introduction" was written by Ian Brown and is a summary of workshop presentations given by Ian Brown, Cathy Dichmont, John Kirkwood, Richard Freeman and Mark Doohan.

CHAPTER 3 EASTERN KING PRAWNS

This chapter was written in collaboration with Tony Courtney. Sections 3.2.1 "Biology", 3.2.2. "Description of fishery", 3.2.2.a. "Introduction" were written by Tony Courtney on which he based his presentation given at the workshop. Section 3.2.2.b "The Development of the Fishery" was written by Peter Gaddes and was presented by Peter Gaddes and Peter Seib and 3.2.2.c "Management" was written and presented by Mike Dredge.

CHAPTER 4 SAUCER SCALLOP

This chapter was written in collaboration with Mike Dredge. Section 4.2. "Introduction" was written by Cathy

Dichmont and Mike Dredge and is a summary of presentations given by Cathy Dichmont, Mike Dredge and Richard Gilbert.

CHAPTER 5 SEA MULLET

This chapter was written in collaboration with Ian Halliday. Section 5.2 "Introduction" is an extract from the Draft Final Report to FRDC for Project No. 94/024 'Assessment of the Stocks of Sea Mullet in New South Wales and Queensland Waters'. The Queensland section was written by Ian Halliday and Kath Kelly and the NSW information was written by John Virgona, Kerrie Deguara and Darryl Sullings, NSW Fisheries. The workshop presentation by Ian Halliday was based on this report.

CHAPTER 6 TAILOR

This chapter was written in collaboration with Simon Hoyle. Section 6.2 "Introduction" is a summary of presentations by Simon Hoyle, Ian Halliday and Michael O'Niell and was written by Ian Brown and Simon Hoyle.

CHAPTER 7 BREAM, WHITING, FLATHEAD

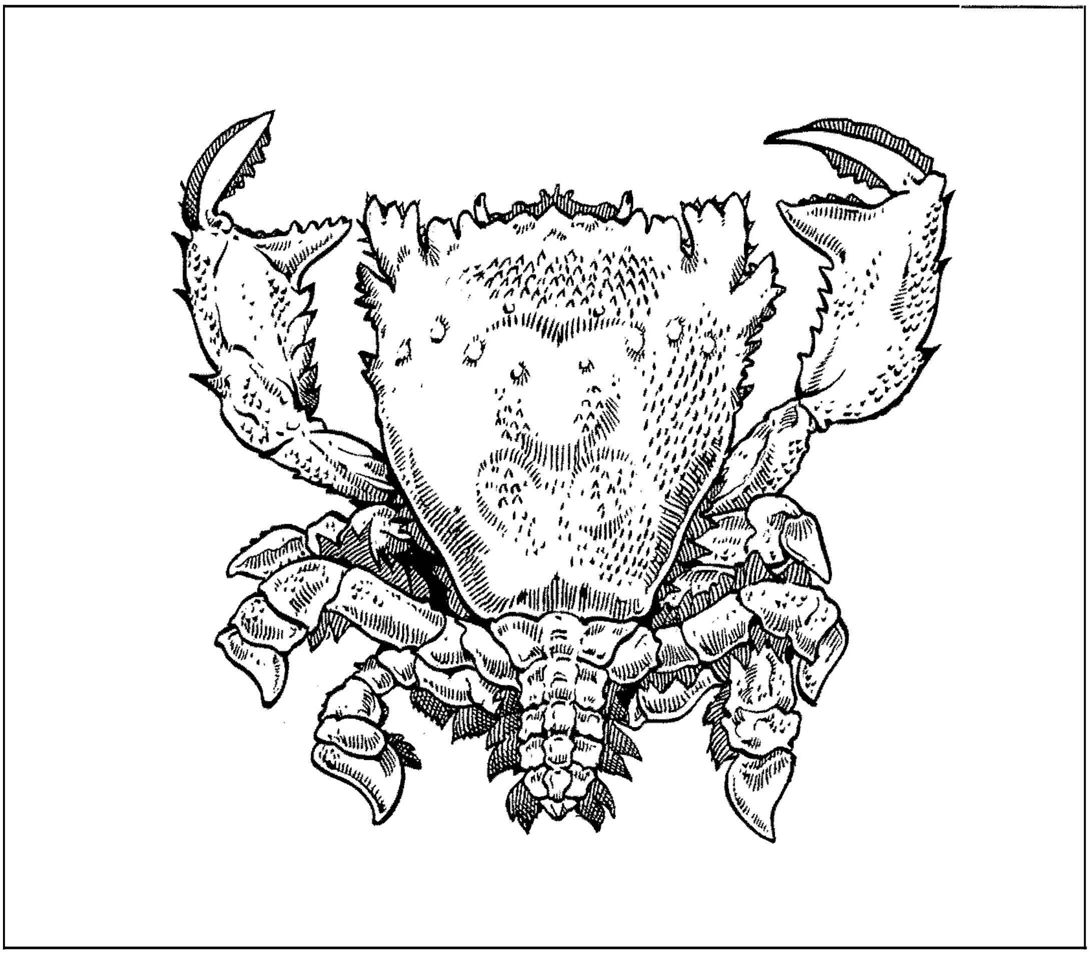
This chapter was written in collaboration with Simon Hoyle. Section 7.2 "Introduction" is a summary of presentations by Simon Hoyle, Ian Brown, Daryl McPhee and Darren Cameron and written by Ian Brown and Simon Hoyle.

CHAPTER 9 AVAILABLE DATA

This chapter was compiled and written by Kate Yeomans.

common name

SPANNER CRAB 2



Ranina ranina

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2.2. INTRODUCTION

Spanner crabs (*Ranina ranina*) are found throughout the tropical Indo-Pacific region from the eastern coast of South Africa through the Indonesian Archipelago to Japan and Hawaii. In Australia, the species occurs from the Abrolhos Islands (WA) through northern tropical and Great Barrier Reef waters and as far south as southern NSW. They have been fished commercially around the Hawaiian Islands since before the Second World War. Catch statistics compiled by the Hawaiian Division of Fish and Game indicated an average annual production before the mid-1980s of approximately 10 tonnes, with a peak of 35 tonnes in 1972. The species is also exploited to a minor extent around the Philippines and the southern coast of Japan (northwest Pacific Ocean) and in the Seychelles Islands (western Indian Ocean), but production figures for these regions are unavailable. A large spanner crab fishery which has recently developed in Thailand, is a significant competitor to the Australian fishery.

The fishery for spanner crabs in Australia has a relatively recent history, going back only two decades. It began to develop as a commercially viable operation around 1978–79 when it was found that crab ‘dillies’, previously used by recreational fishers to catch mud crabs (*Scylla serrata*) and sand crabs (*Portunus pelagicus*) in estuarine habitats, were a very effective means of catching spanner crabs in offshore waters. In the early days of the fishery, inverted dillies or ‘witches hats’ were used exclusively. This apparatus comprised a baited, conical, mesh net attached to a circular metal frame and supported at the apex by a small net float. Nets were set on the sea floor individually, each with a separate buoy-line and surface marker float. The equipment was simple to construct, inexpensive, easy to deploy from a small boat, and was therefore very attractive to potential crabbers.

The first significant commercial landings were made early 1979. However, it is difficult to establish precisely how the fishery began and who was involved, as a number of operators lay claim to having been the first to fish spanner crabs commercially. A considerable proportion of the initial landings is attributable to unlicensed fishermen, particularly in the Mooloolaba–Caloundra area where the fishing grounds were relatively close to the coast. As a result, early ‘official’ catch statistics, maintained by the Queensland Fish Board, are highly likely to have underestimated the actual landings. The total annual catch of spanner crabs in Queensland during 1983–84 was estimated to be around 300 tonnes. This is an order of magnitude greater than the highest annual catch reported from the Hawaiian fishery during its 35 year post-war history. The construction of the fishing gear used had by this time changed from the conical dilly to a very much flatter version, with the mesh stretched relatively tightly across the frame. This development resulted from the fact that the crabs became so entangled in the loose mesh that it was very difficult to extricate them without severely damaging the net.

With the influx into the fishery of more professional crabbers, who generally marketed their catch through the Board's regional depots, ‘official’ figures by the mid 1980s accounted for a more realistic proportion of the State catch. At that stage the recreational catch was believed to be small but still significant, and professional crabbers were starting to develop alternative outlets for their catch, including cooperatives, processors and dealers.

In the mid 1980s fishers in northern New South Wales began to realise the potential of the spanner crab resource, and significant landings began to be reported by several of the Northern Rivers fishermen's cooperatives. During the same period the Queensland fishery expanded south to the border and north to Double Island Point. The results of a voluntary logbook program, run during 1982–84 and 1987, showed an increase in individual effort and indicated a decline in catch rates. The average number of net lifts per boat per day increased from about 90 in 1982–83 to 198 in 1987, while the average catch rate, after an initial increase from 3.5 to 4.5 legal sized crabs/net between 1982 and 1983, declined steadily to about 1.5 crabs/net in 1987. Legal sized crabs have a minimum carapace length of 100 mm. This CPUE would translate to approximately 0.6 kg/net lift. This decline in CPUE was thought to have been due to a real decrease in stock density (particularly in the geographically 'central' part of the fishery that had been subjected to exploitation for the longest time).

The fishery has always been considered a convenient 'alternative' fishery to most of the active participants, many of whom hold net, line and crab licence endorse-ments. This means that under present regulations there is enormous potential for boats to move in and out of the fishery at will (e.g. from the sand crab, mud crab and reef line fisheries). As early as 1988 there was general agreement among those involved in the management of the spanner crab fishery, that the major management problem in the fishery was the lack of a practical way to reduce or even limit the number of actively participating vessels in the fishery.

In response to requests by interested fishermen for information on the northern distribution of spanner crab stocks, research staff at DPIs Southern Fisheries Centre conducted a 3 day survey in the northern Hervey Bay area in early November 1987. The survey revealed the presence of a potentially fishable stock of *Ranina ranina* in the area between Bundaberg, Lady Elliott Island, and Round Hill Head (Seventeen Seventy). This information was made available to a number of crabbers during the subsequent two or three years, and doubtless contributed to the northward expansion of the fishery.

In the late 1980s there was a major advance in the collection of fishery statistics in this State with the development of the compulsory CFISH logbook program by QFMA and DPI. This program is now incorporated into the Queensland Fisheries Information System - QFISH. Although the level of detail was less than had been obtained by the voluntary spanner crab logbook, there was at last a mechanism available for estimating total State catch with some confidence.

In response to concerns about the future sustainability of the fishery, a warning about further investment in the fishery was issued in January 1994. The fishery had faced an unprecedented increase in both the number of boats entering the fishery and the total number of fishing days, with a resultant increase in overall landings. In December 1995, two Management Areas were declared. Management Area A (South of 23S and east of 151.45E) was generally accepted as the developed fishery and was subject to a Total Allowable Catch (TAC) and a maximum daily catch limit of 300kg. Several changes to the daily catch quota have taken place and the fishery in this region is moving to an Individual Transferable Quota (ITQ) managed fishery. Management Area B (South of 23S and west of 151.45; north of 23S) is basically unrestricted as it is seen as a developing fishery. Closed seasons have been imposed over time, the most important of which is the spawning closure between 20 December and 5 January.

Attempts at production and size based modelling have not been immediately successful. This is mainly due to the unstandardised nature of the effort as well as lack of definitive growth information. Some growth analysis of the species in the Seychelles Islands have been attempted, but only with a very small data set. Analysis from a tagging study completed in New South Wales indicated that spanner crabs might be much longer lived than previously thought. However, little information is available on early growth. A recent study by DPI with dredges has had success in sampling animals smaller than 50 mm carapace length, which are assumed to be less than two years old. None of this work had been combined into a single model of spanner crab growth.

Management Area A was subdivided into five regions that emulate the expansion of the fishery. Due to a lack of an objective stock assessment method, which would guide the setting of the annual TAC, a 'ratio-metric' model was used to estimate the TAC. It assumed that the constant catch rates over the last few years in Areas 3,4 and 5 could be interpreted as indicative of sustainable catches. These catches per unit area were multiplied to the whole of Management Area A region. A set of decision rules have been developed by the Crab SAG in order to set the future annual TAC in a manner transparent to everyone. This process may become part of the Draft Crab Management Plan of QFMA.

2.3. SPANNER CRAB WORKSHOP TASKS

Five problems or issues were investigated by separate groups:

1. Effort standardisation.
2. Develop a YPR model to investigate evidence of growth overfishing.
3. Investigate the possibility of deriving a TAC from a review of the spatial development of the fishery and the expected yield per area.
4. Develop a simulation model to test the robustness of the proposed Decision Rules.
5. Examine all existing growth and mortality data and synthesise a growth curve.

2.3.1. EFFORT STANDARDISATION

Information from a questionnaire on vessel characteristics, gained from a section of the fishing fleet at the end of 1997, is now available for analysis together with the catch and effort data in CFISH. A GLM approach was applied using the statistical package GENSTAT. Some preliminary cleaning of the data was needed to remove suspect effort and catch records from consideration. The dependent response variate was *ln* (catch rate), where catch rates were kg of spanner per net lift. Catch rates were log-transformed as should be done with this type of analysis but also because the data clearly were lognormally distributed.

Catch rates are often assumed to be proportional to stock size. In a GLM, the year factor is treated as a surrogate for stock size. Unfortunately, many factors other than stock size can influence catch rates. The objective of effort standardisation is to account for the variation in catch rates introduced by factors such as 'skipper experience', 'vessel size', 'fishing region', etc. In this preliminary analysis the factors tested for influence upon catch rates were: year, management region, crew number, skipper experience, hull length and hull cruising speed. The data on navigational aides obtained from the questionnaire lacked contrast and had many missing records so these factors were not included in the analysis. Region, year and their interaction term dominated the analysis outcome. Skipper experience was a significant factor, with the adjusted mean catch rate amongst 'experienced' fishers (0.96 $kg.lift^{-1}$) being substantially higher than that of the 'novice' group (0.71 $kg.lift^{-1}$). Hull length may be a significant factor, but time prevented an in-depth analysis of this factor and of the effects of crew number and hull speed.

This preliminary analysis has been extended and completed by Ian Brown and David Mayer. Results have been reported on in detail in FRDC Report 95/002 (Brown, I.W. et al., 1999).

2.3.2. DEVELOP A YIELD-PER-RECRUIT MODEL TO INVESTIGATE EVIDENCE OF GROWTH OVERFISHING

This group completed two sub-tasks; an investigation of a depletion event and a YPR analysis.

2.3.2.a Depletion Event.

Discussions in the workshop led to industry members remembering a particular event where many fishers converged on a single area and fished it hard until catch rates declined markedly. It was considered that, if the data from this 'event' could be found in the database, then it might be possible to conduct some form of DeLury depletion analysis on the decline in catch rate through time. The database was investigated and the 'hot spot' was discovered to be near North West Island reef. This area was fished very heavily by the commercial fleet over an eight week period during October–November 1996. During that time, some 40 tonnes of spanner crabs were taken out of an area approximating a 6 minute grid square. The appropriate catch and effort data were retrieved and fitted to a standard Leslie depletion model (Figure 2.1), which provided a catchability coefficient and an estimate of biomass in the depletion area. The regression parameter estimates are given in Table 2.1.

The negative of the slope of a linear regression of the graph provided a catchability coefficient of 0.000034. This means that one unit of effort (a dilly lift) captures, on average, 0.003% of available biomass in this particular aggregation of spanner crabs. Whether this figure is typical of all Queensland spanner crab fishing grounds needs further investigation.

Table 2.1. Linear regression parameter estimates used in the Leslie analysis of the commercial depletion off North West Island reef in Management Area B

Parameter	*Estimate*	*Std. Error*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.736	0.142168	6.75E-15	1.448063	2.023187
Slope (-q)	-0.000034	0.000005	8.58E-08	-0.000044	-0.000023

The estimate of total biomass available in the depletion area is calculated by extrapolating the regression line to the point where it would cross the x-axis (total catch). In this case, an estimated pre-exploitation biomass of 58 tonnes was calculated. It should be remembered that this was considered an exceptional aggregation of spanner crabs and so might best be viewed as an estimate of the upper limit of crab biomass.

The Leslie depletion analysis assumes that the average catchability remains constant for the duration of the depletion event. It also assumes that no immigration or emigration of spanner crabs occurred during the fish down. This analysis may therefore have a positive bias because of the method of capture uses bait so the area of influence may expand through time. Any immigration into the depletion area would falsely increase the estimates of the total biomass and decrease the estimate of the catchability coefficient.

2.3.2.b Yield-Per-Recruit

The second task of this group was to develop a standard equilibrium-based YPR model of the resource. Input parameters were:

- natural mortality (M $year^{-1}$) of 0.38 $year^{-1}$ based on the results of the group reported in Section 2.3.5,
- age at recruitment to the fishery (t_r) of 1.5 years,
- weight at L_∞ (W_∞) of 1.5 kg and
- intrinsic growth rate, K, of 0.28 $year^{-1}$ (from group results reported in Section 2.3.5)

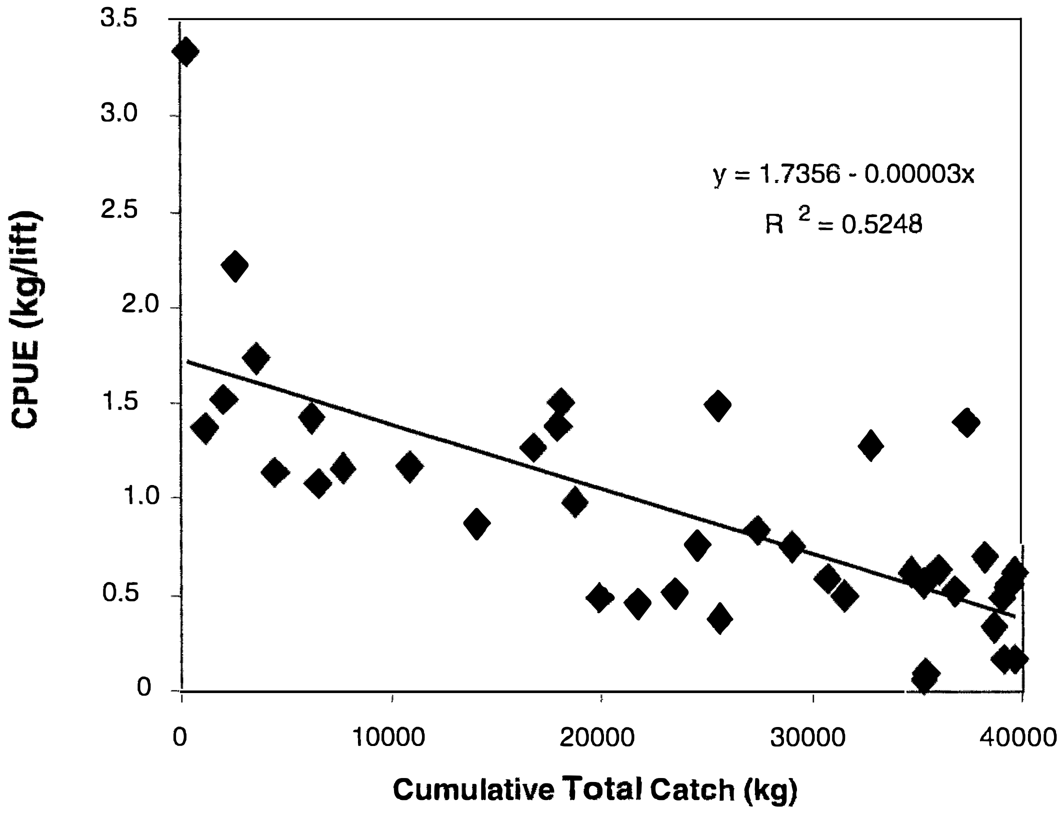


Figure 2.1. *Commercial depletion of a newly discovered area off North West Island reef in Management Area B between 1 October and 2[illegible] November 1996 using CFISH logbook data.*

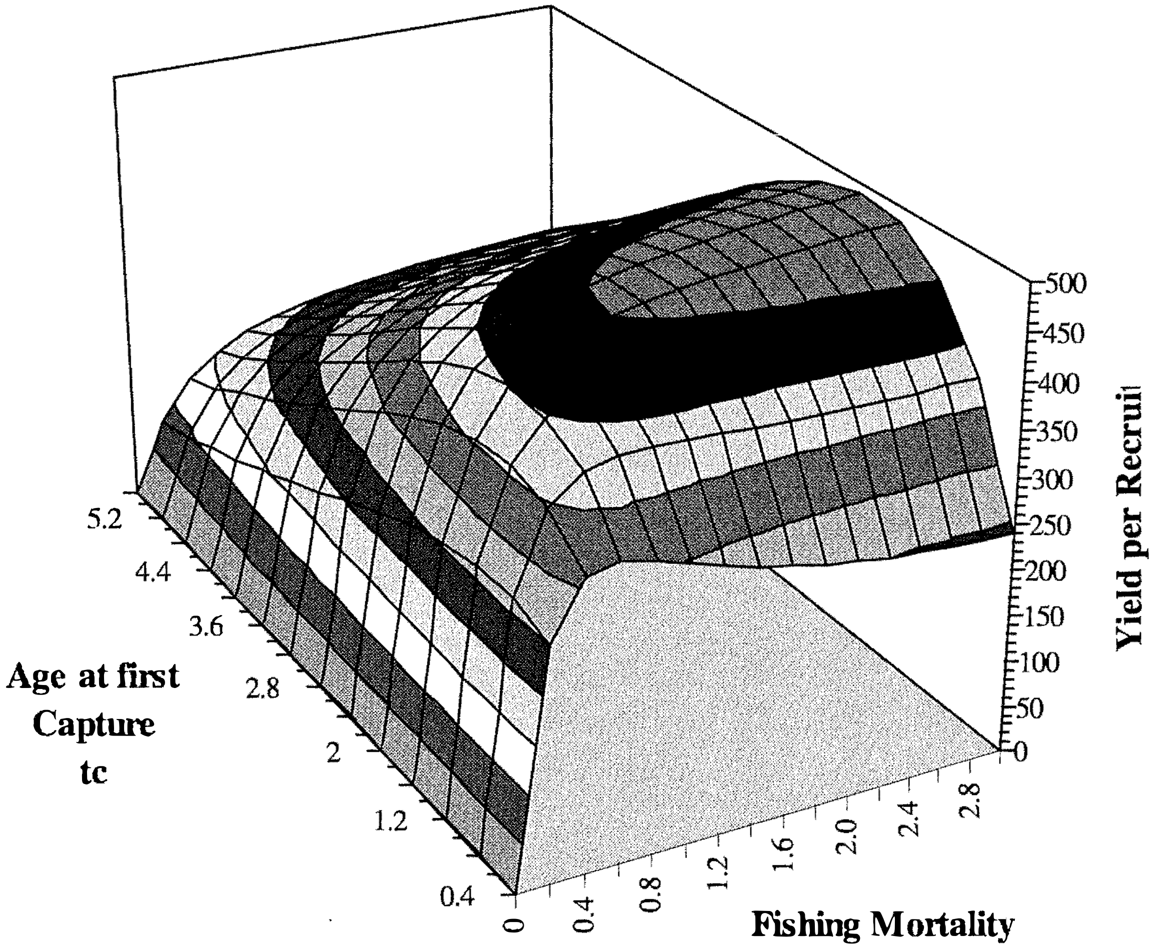


Figure 2.2. *Plot of yield-per-recruit of spanner crabs for a range of fishing mortalities (year^{-1}) and age-at-first capture (t_c) in years.*

A three-dimensional plot of YPR for various combinations of age-at-first capture (from 0.4 to 7 years old) and fishing mortality (from 0.2 to 3.0 year^{-1}) is in Figure 2.2. Indicated maximum YPR occurred at an age of first capture of about 2.4 years over a wide range of fishing mortality rates (F) from 1.2 to 3.0 year^{-1}. This is consistent with our understanding of the age of a spanner crab at the minimum legal size. It can therefore be concluded that growth overfishing is not likely to be a potential problem in this fishery, subject to present uncertainties associated with estimated growth parameters and natural mortality rate.

2.3.3. INVESTIGATION OF THE APPLICATION OF A PRODUCTION/YIELD MODEL

This group's objective was to determine whether a defensible TAC could be estimated. The approach used was to consider the spatial development of the fishery and find those areas fished the longest. If the level of yield taken from those areas had remained relatively constant through time one can assume that such yields could continue to be taken on an on-going basis i.e. the present yields are sustainable. If there is no evidence of serial depletion, then the average yield per spatial unit may provide an estimate of TAC.

The ESRI GIS package ARCVIEW was used to plot the yearly catch and effort by 30 minute square grid. These clearly demonstrated the expansion of the fishery and the establishment of key ports (e.g. Figure 2.3 **a** and **b** and 2.4 **a** and **b**).

The work attempted by this group was ambitious in its scope and they ran out of time. To complete the work, the frequency distribution of daily catch rates in particular space units should be determined. A highly skewed lognormal distribution would indicate depletion over time. Also, if this distribution were compared from one year to the next, then a truncation of the upper catch rate levels would again indicate depletion. However, the degree of this depletion may not be established.

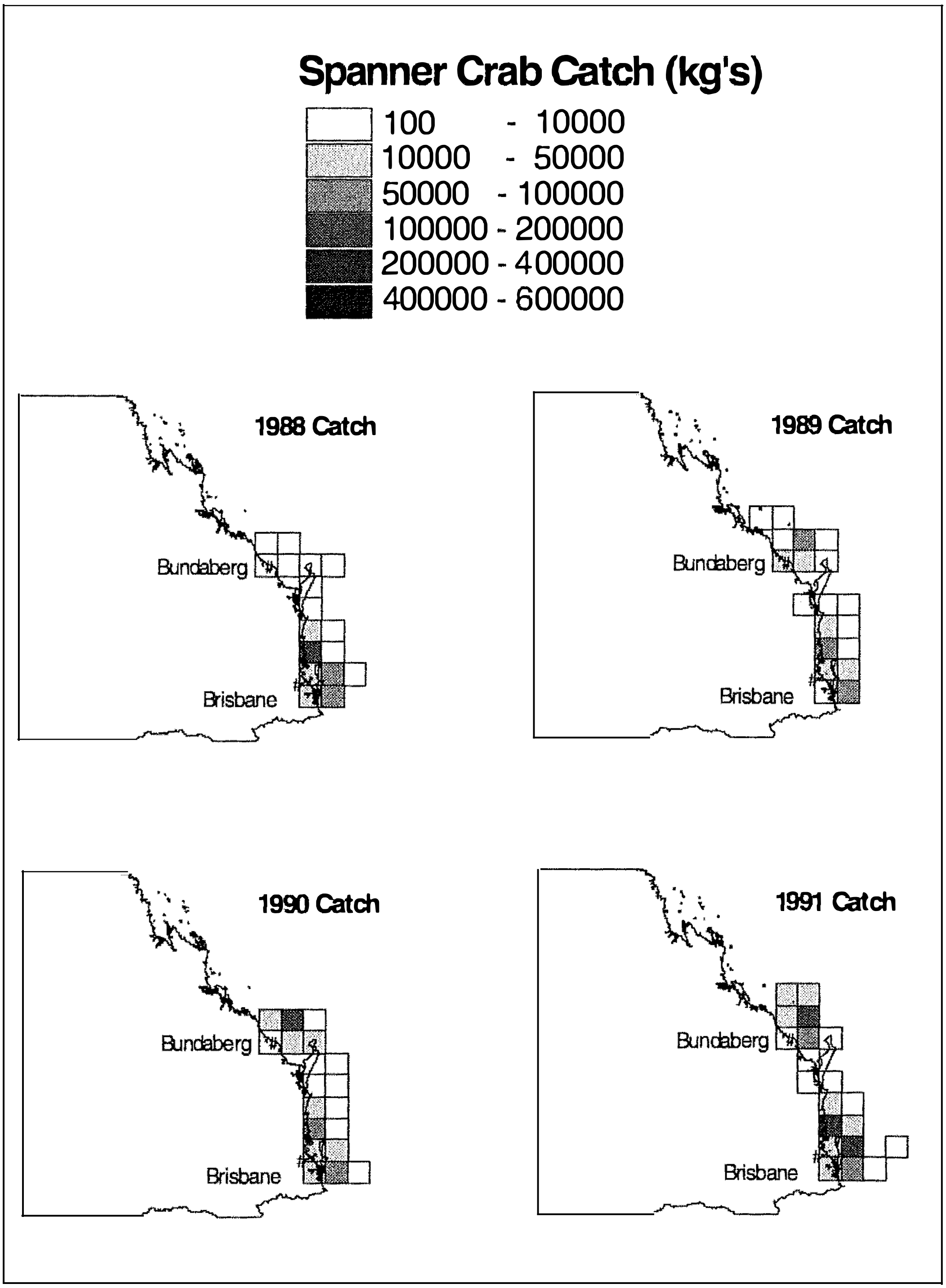


Figure 2.3 a. *Spanner crab catch (kg) distribution over the Queensland coast for years 1988 to 1991 using the raw data from CFISH.*

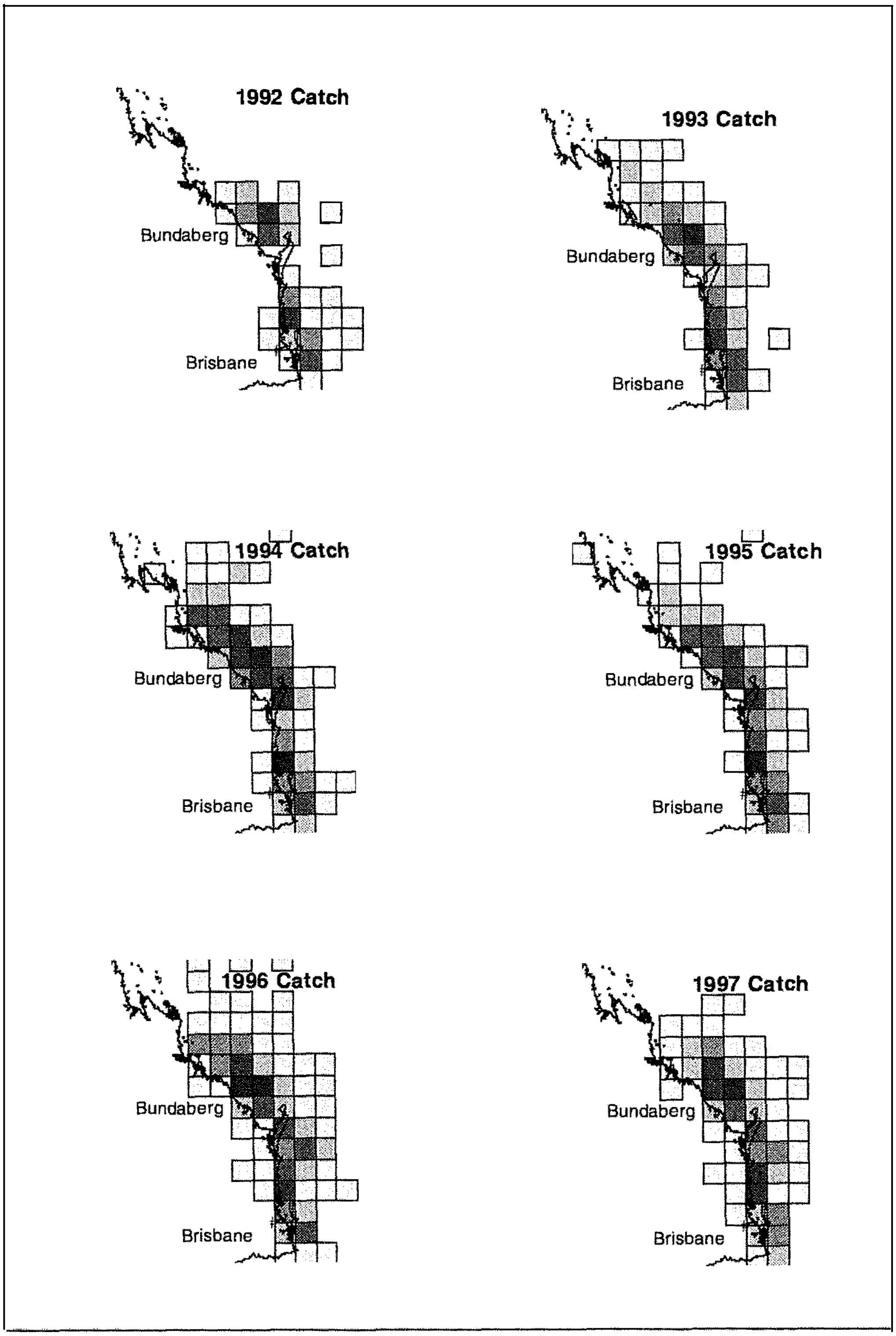


Figure 2.3b. *Spanner crab catch over the Queensland coast for years 1992 to 1997 using the raw data from CFISH. Legend as per Figure 2.3a.*

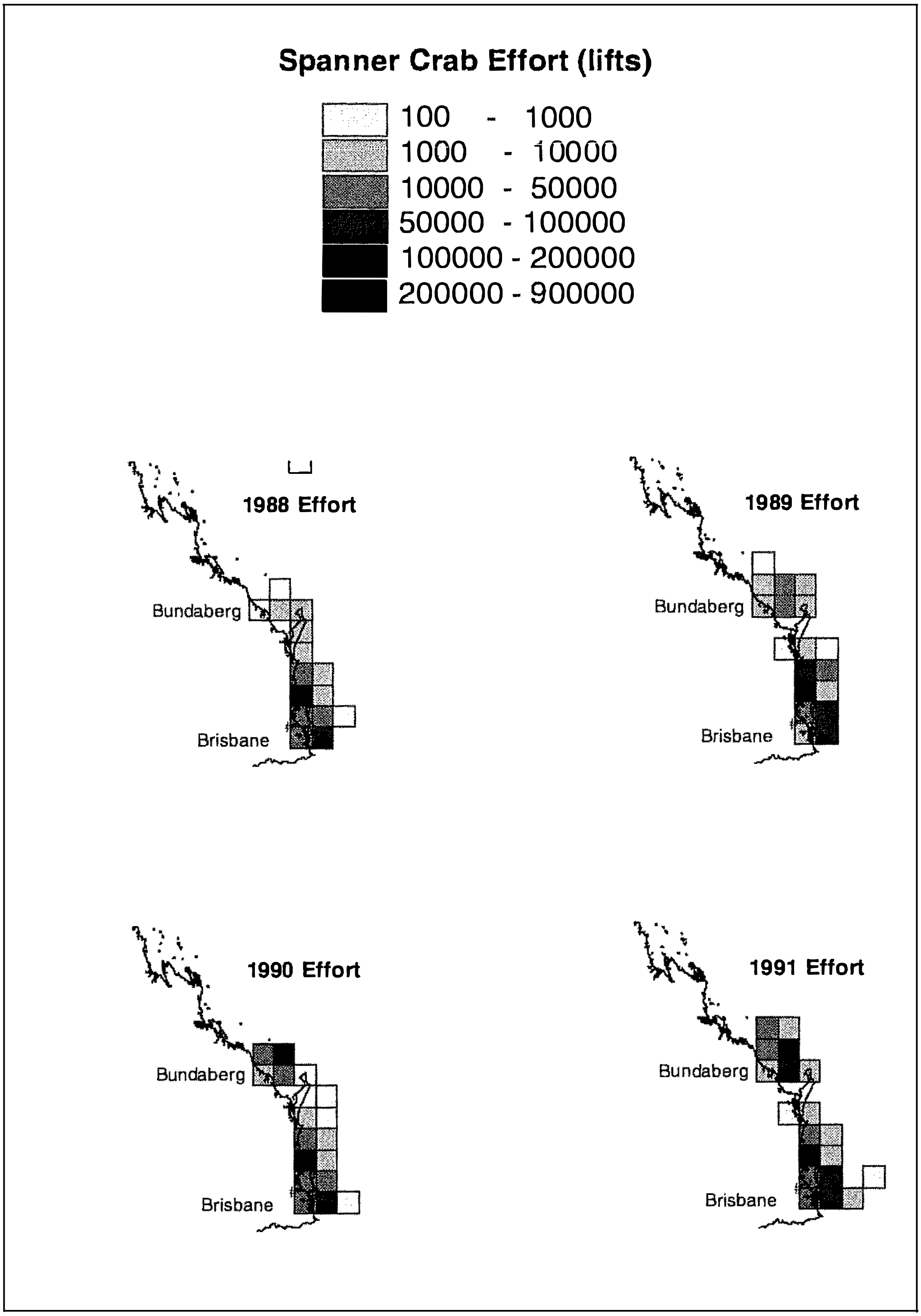


Figure 2.4 a. *Spanner crab effort (lift) distribution over the Queensland coast from 1988 to 1991 using the raw data from CFISH.*

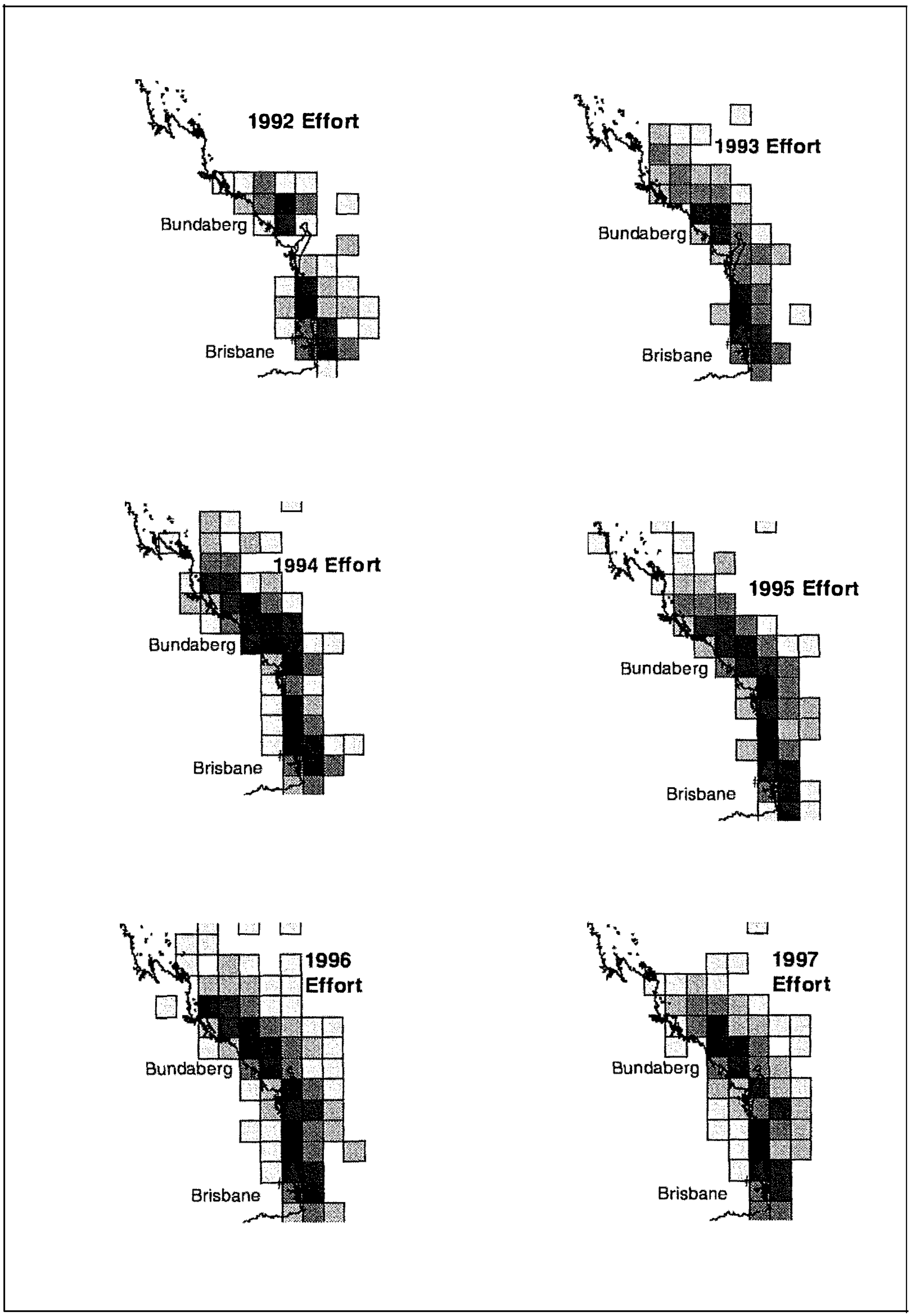


Figure 2.4 b. *Spanner crab effort (lifts) distribution over the Queensland coast for years 1992 to 1997 using the raw data from CFISH. Legend as per Figure 2.4a.*

2.3.4. DEVELOP A SIMULATION MODEL TO TEST THE ROBUSTNESS OF A SET OF DECISION RULES

This group had the objective of developing a strategy and algorithm for testing the operational characteristics of sets of decision rules, such as found in Fishery Management Plans. A set of decisions rules, as developed by the Crab Stock Assessment Group, were tested with a number of sources of uncertainty and error:

1. highly variable recruitment;
2. inaccurate estimates of catch rates (i.e. large observation errors);
3. inappropriate management regions with respect to the actual stock structure;
4. a model assumption was that catch rate was proportional to biomass, whereas, in reality, catch rates were only proportional to biomass at low density — They then remained relatively constant at increasing densities (i.e. hyperstable).

The decision rules were vigorously tested using a model with 21 input parameters (Table 2.2).

The strategy used to test the decision rules was to develop an operational model describing a hypothetical population which was effectively sampled to provide catch and effort data. The management decision rules were applied to the information deriving from the operational model and the resulting global TAC was fed back into the operational model for another year's activity (Figure 2.5). The rules were tested over a 25 year period.

2.3.4.a Operational Model

The system was modelled to have four management areas and four stocks. The management areas did not align, however, with the biological stocks: stocks 1 and 2 were regarded as being a single management area; stock 3 was regarded as two separate management areas, and stock four was correctly identified as a single management area.

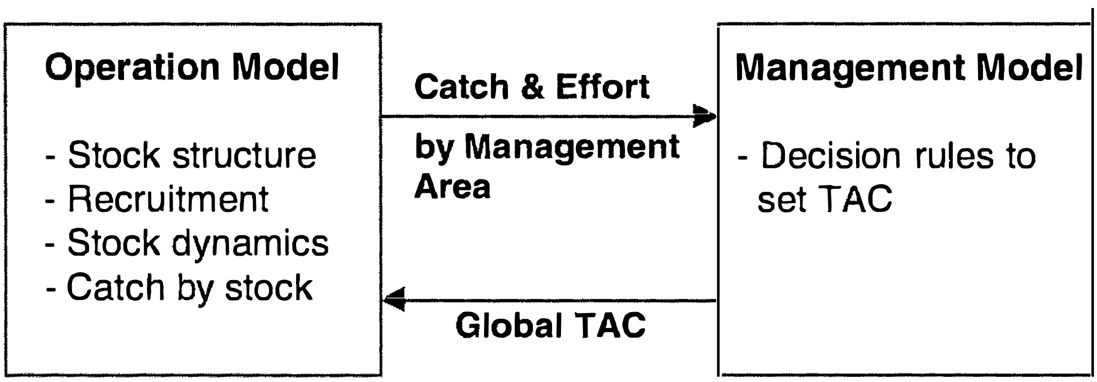


Figure 2.5. *Schematic describing the relationship between the operational model used to define the hypothetical population and the management regime imposed.*

A first order difference model was used to describe the dynamics of the resource from one year to the next:

$$B_{t+1,s} = \rho e^{-M} B_{t,s} - C_{t,s} + \frac{e^{Rand\,\sigma_r}\alpha B_{t,s}}{\left(\beta + \frac{B_{t,s}}{K_s}\right)}$$

: 2.1

where $B_{t,s}$ is the biomass at time, t, of stock, s,
ρ is a proportional constant,
M is natural mortality
$C_{t,s}$ is the catch taken from stock s, at time t,
Rand is a random normal deviate (Z),
σ_r is recruitment variance,
α is a stock-recruit parameter,
β is a stock-recruit parameter and calculated by:

$$\beta = \frac{(1-\delta)0.2}{(\delta - 0.2)} \qquad : 2.2$$

where δ is the steepness of the recruitment relationship
K_s is the stock carrying capacity.

Catch rates of each management area were defined as:

$$CPUE = B_{t,z}^{\gamma} e^{rand\sigma_q} + 0.00001 \qquad : 2.3$$

where $B_{t,z}$ is the biomass at time t for the management zone, z,
γ is the index of hyperstability,
rand is a random normal deviate (Z)
σ_q is the variance of the catchability coefficient.

A small number (0.00001) was added to equation 2.3 to avoid taking the natural log of zero. The effects of different degrees of hyperstability (γ) were tested.

Since only a global TAC is set by the decision rules, within the operational model a rule was applied to divide the catch taken from each stock:

$$C_{t,s} = \frac{B_{t,s} e^{rand\sigma_U} TAC_t}{\sum_s B_{t,s} e^{rand\sigma_U}} \qquad : 2.4$$

where TAC_t is the Total Allowable Catch that was set for year t,
σ_U is the variance of fisher knowledge.
$B_{t,s}$ is the biomass at time t for the biological stock, s.

This implies that the fishery takes the most yield from the areas with the highest levels of biomass (despite having incomplete knowledge of the biomass level). The initial stock biomass in each area was defined as an input parameter (Table 2.2).

2.3.4.b Management Model

All the decision rules that could potentially alter the TAC were driven by catch rate trends. Three of the selected decision rules recommended that the TAC should be reviewed. As a direct decision was required by the model, deterministic decisions about TAC levels were defined. Consequently, if one of these three decision rules was triggered, a change in TAC was agreed upon. In reality, this may not always be the case.

2.3.4.c Testing the Decision Rules

Several scenarios were tested. In one case, a seriously depleted resource was simulated. In this case, the decision rules performed extremely well. They did not allow the stocks to go extinct and reversed the downward trend of population biomass.

A second scenario described a resource in which one of the four stocks was severely depleted and/or had a much smaller carrying capacity with respect to the others. The decision rules saved the other stocks, but were unable to prevent the extinction of the seriously depleted stock.

A further extreme case of the resource being extremely large and the TAC being well below sustainable levels were tested. In this case the decision rule did not respond well at all and were unable to take advantage of the good resource biomass and production characteristics.

The simulation model indicated that the set of catch rate based decision rules which were tested were very conservative, precautionary and risk-averse. They are likely to perform extremely well in a declining fishery, but may underutilise the resource when it is in good condition. Further modelling of this type will be needed to do a more in-depth analysis of these rules, but some modification of these rules is needed.

An example of a single run is given in Table 2.2 below. The resultant catch rate, stock recruit relationship, annual TAC and biomass trend for each stock are given in Figure 2.6.

Table 2.2. Parameter values for an example run testing the Spanner Crab Draft Management Plan TAC setting decision rules.

Parameter	Value	Parameter	Value
ρ	1.4	K1	10 000
M	0.38	K2	10 000
γ	0.5	K3	10 000
δ	0.8	K4	10 000
α	0.045	$R_{1,1}$	425.9
β	0.067	$R_{1,2}$	425.9
B1,1	100	$R_{1,3}$	425.9
B1,2	400	$R_{1,4}$	425.9
B1,3	400	σ_α	1
B1,4	5 000	σ_r	0.2
		σ_u	0.2

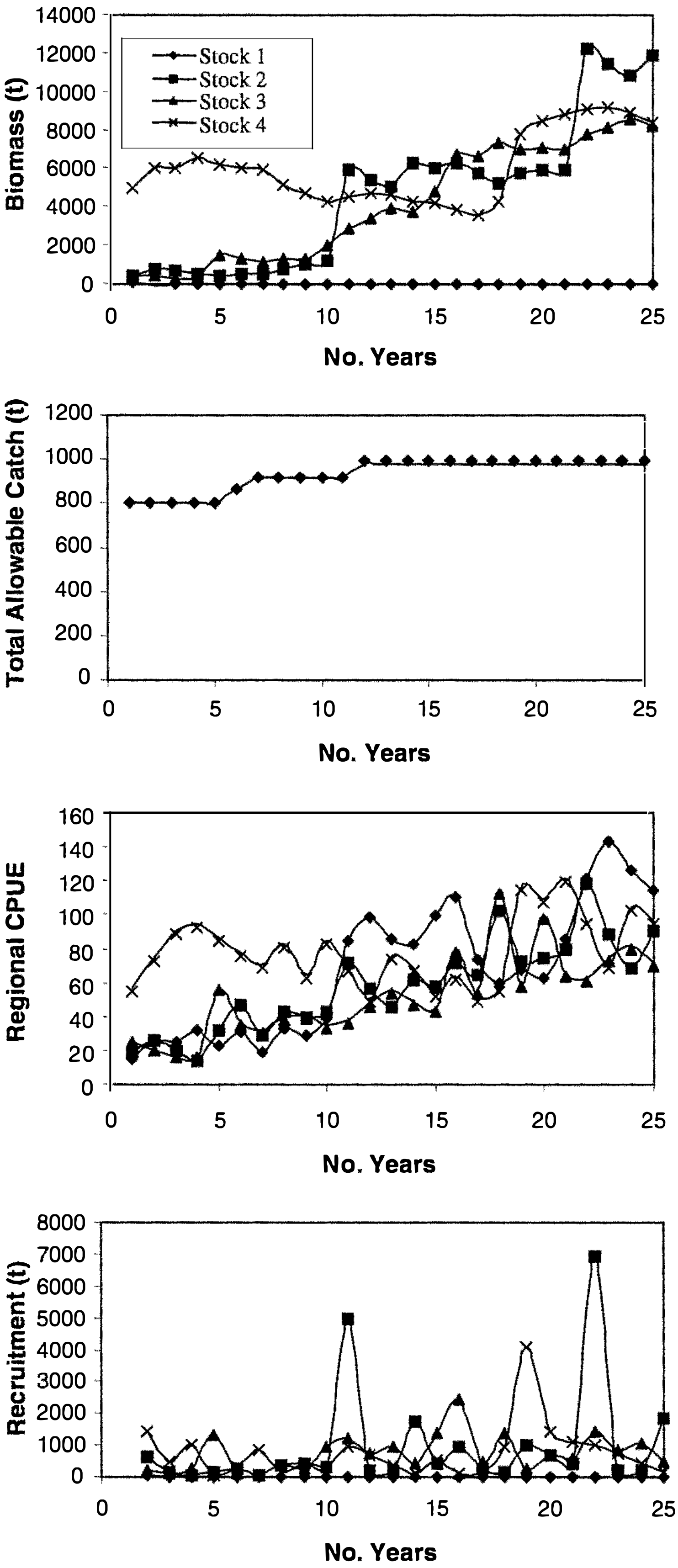


Figure 2.6. *Stock biomass, annual TAC, regional catch rates and stock recruitment for a single example run that test the hypothetical set of Decision Rules.*

2.3.4.d Conclusions

The strategy of using an operational model to interact with a selected management procedure/plan was easy to implement, simple to manipulate and the outcomes were straightforward to interpret. This approach provides a relatively simple mechanism for conducting a heuristic search for an optimal set of decision rules. Such an heuristic search was not carried out but should be done for a true life Fishery Management Plan.

2.3.5. EXAMINE ALL EXISTING GROWTH AND MORTALITY DATA

Each analysis of growth of spanner crabs throughout the world and in Australia uses different data and has produced very different growth curves. No complete growth curve is available for use in Australia. Information about growth can affect one's view of the animal's longevity, which, in turn, affects one's view of its ability to sustain a certain level of exploitation. This group tried to find a way of linking the NSW tagging data (which only includes crabs about 65 mm carapace length and larger) with the Queensland dredge data (which samples animals smaller than 60 mm in carapace length). A conversion factor (John Kirkwood *personal communication*) was used to convert orbital carapace length, used in NSW, to rostral carapace length, used in Queensland. The dredge data, arguably, shows two distinct cohorts (Figure 2.7). There was consensus that they were not two or more years apart, as there are no intermediate values. One cohort is therefore assumed to be less than 1 year old (0+ old) and the other between 1 and 2 years of age (1+ old).

The only available adult data for Australia is from a tagging study completed in New South Wales. This clearly showed that males and females have different growth rates. Three different plots of mean growth from the tagging model developed by Chen and Kennelly (1999) on the NSW tagging data, superimposed with the dredge data were attempted with all combinations

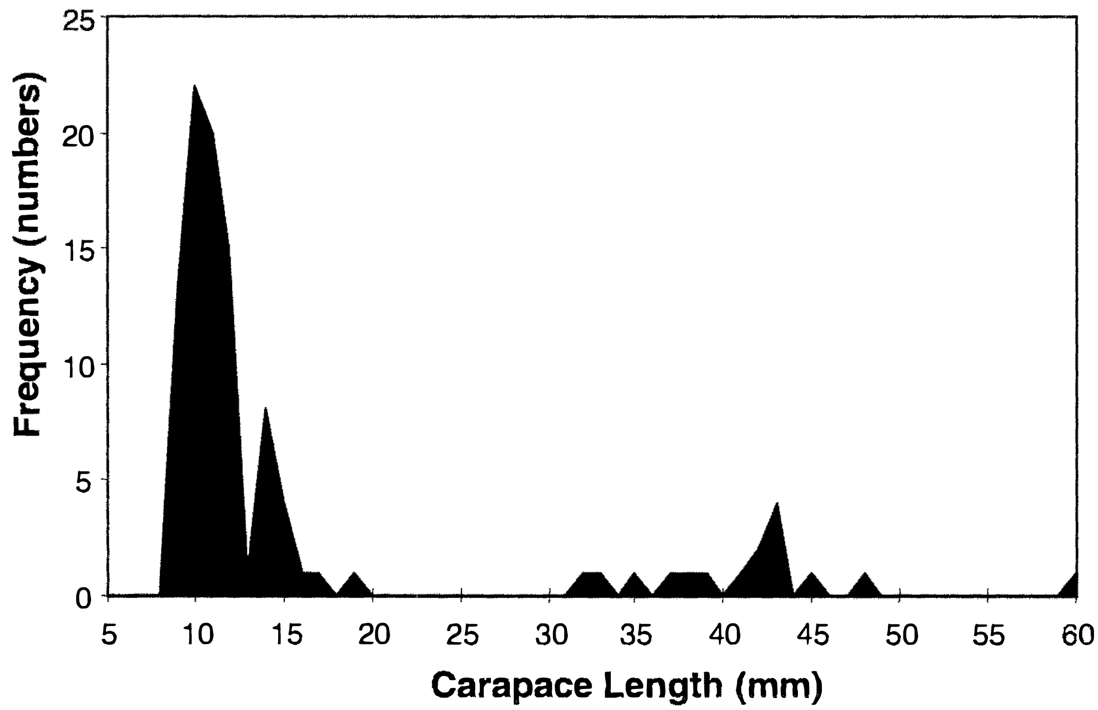


Figure 2.7. *Size-frequency distribution of juvenile spanner crabs caught in a Queensland dredge.*

from the tagged animals being 1+ year old to 4+ year old were considered (Table 2.3).

It is clear that the sum of squared residuals were minimised when the tagged animals were assumed to start as 2+ animals for each gender (Figure 2.8). When a search is made for the exact age increment (between the oldest dredge animals and the youngest tagged animals) which produces the smallest sum of squared residuals, approximately 2.4 years results for both males and females.

The average von Bertalanffy curve for both sexes combined, using a lead age of 2.4 years, leads to an L_∞ = 141.1, a K = 0.270, and a t_0 = -0.21 (a lead time of 2 years gives L_∞ = 142.2, a K = 0.279, and a t_0 = -0.20).

Ideally, each sex should be treated separately. However, if one assumes that the averaged curve gives a meaningful representation of average size at age, natural mortality is likely to be in the range of 0.31 to 0.46 $year^{-1}$, equating to a maximum age of 15 to 10 years of age. These analyses are preliminary and require more data on juvenile growth rates and more information on the moulting frequency of the adults.

	Different assumptions concerning the start age for youngest tagged animals							
	Males				Females			
	1+	2+	3+	4+	1+	2+	3+	4+
L_∞	170.3	168.5	166.0	162.4	119.9	117.6	114.8	111.7
K	0.258	0.229	0.205	0.190	0.348	0.334	0.324	0.324
T_0	-0.161	-0.201	-0.248	-0.294	-0.188	-0.206	-0.226	-0.237
SSQ	3100.6	1504.0	1561.5	2190.6	2166.3	1311.2	1316.3	1582.4

Table 2.3. Von Bertalanffy growth parameter estimates of Queensland dredge and NSW tagging data given different assumptions of start age for youngest tagged animals. All curves were obtained by including the dredge samples as unsexed juveniles.

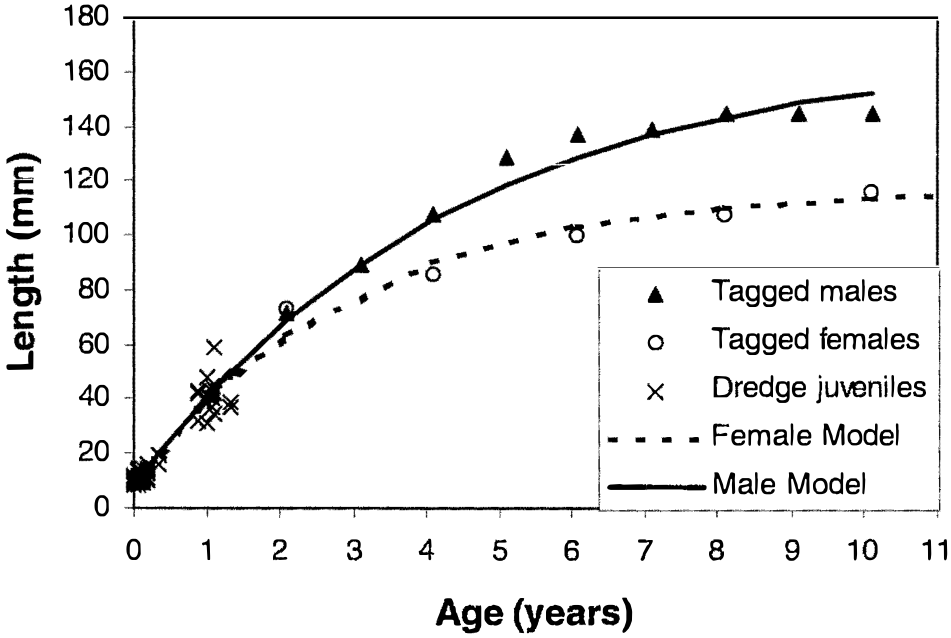


Figure 2.8. *Spanner crab growth data from two combined sources (Queensland dredge and NSW tagging data) for males and females.*

2.4. CONCLUSIONS

2.4.1. GROUP REPORTS

Much of the discussion centred on the possibility that catch rate is not proportional to biomass in this fishery. Preliminary analysis at the workshop using a generalised linear modelling approach showed that effort standardisation of regional and temporal changes, vessel characteristics and level of skipper experience could explain about 27% of the variance. There was general agreement that animal behaviour in relation to the baited dilly and oceanographic factors would greatly influence catch rates. Furthermore, the move to an ITQ system could affect the temporal integrity of the catch-effort data series. A fishery-independent survey was seen as essential, but would not be entirely without the problems above unless an active sampling method is used to catch spanner crabs.

A small-scale depletion event was discovered in the database and a Leslie depletion analysis estimated a pre-exploitation biomass over the area at the time. There was agreement that this result could not be extrapolated over the whole fishery area, but could be seen as an example of high biomass areas. Yield-per-recruit analysis demonstrated that growth overfishing is not likely to be problem in the spanner crab fishery, subject to uncertainties associated with estimated growth parameters and natural mortality rate.

An analysis of the spatial distribution of catches through time highlighted the expansion of the fishery and supported the approach in which different "assessment regions" within Management Area "A" are analysed separately.

The spanner crab TACC decision rules were tested using a model population, which was harvested and then managed in accordance with the decision rules.

To provide a stringent test the model included high variability in recruitment and catch rates errors, incorrect assumptions concerning stock structure relative to management regions and non-proportionality of catch rate relative to biomass. This testing strategy demonstrated that the decision rules perform well under adverse conditions to protect the regions from collapse, but tended to underexploit recovering or healthy regions.

An attempt was made to combine the Queensland dredge samples of juveniles with the NSW tagging data of adults into a single von Bertalanffy growth function. Based on an assumption that two clear modes in the dredge data are from animals that are o+ and 1+ old, results of a least squares approach is given. Time did not allow bootstrapping for error analysis.

Analyses to estimate ecological sustainability indicators have been attempted prior to the workshop, but the findings of this work was confirmed in the workshop. Lack of understanding of the complex dynamics of the resource means that interpretation of catch rate, size-frequency, sex ratio, tagging, dredge and other sources of data are difficult to interpret.

2.4.2. OVERALL PROGRESS TO DATE

A summary of progress to date in terms of data quality, research and stock assessment knowledge is given in Table 2.4. *(see over)*

2.4.3. MONITORING, RESEARCH DIRECTION AND PRIORITIES

a. Currently, spanner crabs are monitored solely through the use of commercial catch rate data. During the workshop, there were many doubts expressed concerning the validity of using simple catch rate data as an index of stock biomass. These doubts stemmed from the complex interactions between the crab behaviour relative to the baited dillies, between fishers and crab aggregations, and the impact of changes of current speed and direction. The workshop strongly recommended that independent surveys of spanner crab biomass were needed for long term monitoring in order to provide an alternative, more defensible index of abundance.

b. The institution of an ITQ management system is likely to cause further problems with using and interpreting the catch rates of spanner crabs for assessment purposes. The introduction of ITQs will break the continuity of the time series by changing the behaviour of the fishers. It was strongly recommended that fishery independent surveys of relative abundance, be conducted both pre- and post-ITQ implementation. This was seen as the highest priority for this fishery.

c. Since growth rates are still the source of greatest uncertainty in our knowledge of spanner crab biology, further study needs to be undertaken to improve the understanding of the growth of spanner crabs. Normal fishing gear only captures larger animals and thus tagging experiments would not include juveniles. Without information relating to the initial elements of the growth curve (involving juvenile crabs), it is only possible to estimate L_∞ but there is insufficient information to estimate the growth rate parameter K with any precision. Although the dredge gear only caught low numbers of juvenile animals, the data improved the growth curve estimation. Given the improved growth curve, approximate estimates of natural mortality could be made. Continued dredging for juvenile crabs was considered to be essential by the Workshop.

d. The possibility of using lipofuscin (a brain pigment which accumulates with age) as an ageing method should also be investigated as an alternative approach to generating a precise growth curve.

Category		Comments.
Commercial	Catch	Relatively reliable.
	Effort	Relatively reliable. Effort as dilly lifts less reliable prior to 1994 .
	Catch rate	Standardised catch rate by region. Assumption that catch rate proportional to biomass under debate.
Recreational	Catch, effort and catch rate	Probably not significant in comparison with commercial catch, but has not been not estimated.
Independent index of biomass		Commenced 1999.
Estimates of natural mortality		Only highly preliminary analysis completed in workshop, but not accepted due to *ad hoc* nature of estimation procedure. Difficult to measure, as the animal has not been aged, length frequencies are highly variable and growth rate is still unknown.
Estimates of fishing mortality or biomass		None.
Input controls		Limited entry, size limits, spawning closure.
Output controls		Two Management Areas. Management Area "A" has TACC, daily bag limit and non-fishing days.
TACC Decision rules		Objectively tested and performs relatively robustly under adverse conditions.
Performance indicators		Included in above decision rules.

Table 2.4. A summary of progress in research, data and stock assessment modelling.

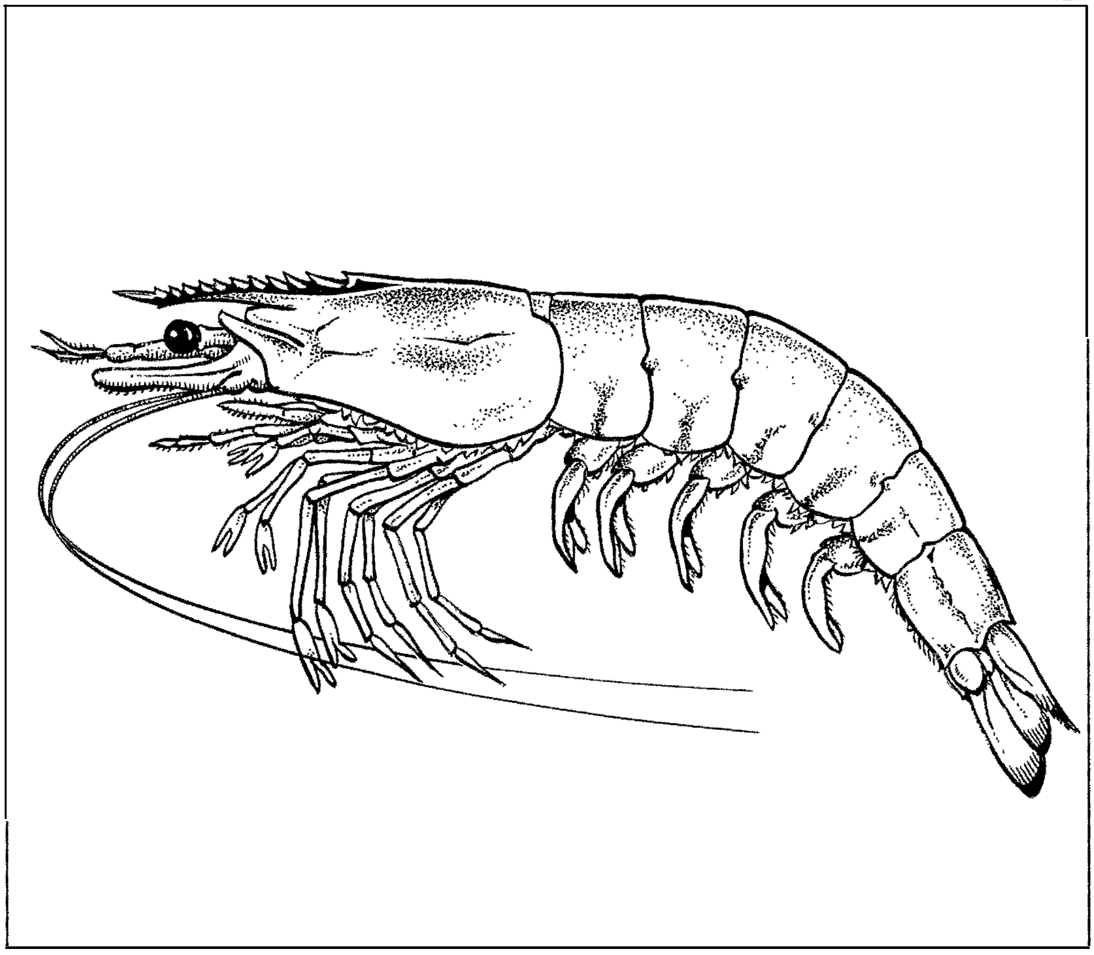
2.5. REFERENCES

Brown, I.W. Kirkwood, J., Gaddes, S., Dichmont, C.M. & Ovenden, J. 1999. Population dynamics and management of spanner crabs *Ranina ranina* in southern Queensland. FRDC Report 95/002.

Chen, Y. and Kennelly, S.J. 1999. Growth of spanner crabs, *Ranina ranina*, off the east coast of Australia. *Journal of Marine and Freshwater Research.* **50(4):** 319-25.

common name

EASTERN KING PRAWN 3



Penaeus plebejus

3.1. PARTICIPANTS

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3.2. INTRODUCTION

3.2.1 BIOLOGY

3.2.1.a. General Biology and Distribution

The eastern king prawn, *Penaeus plebejus*, is endemic to the east coast of Australia from central Queensland (20°S) to north eastern Tasmania (42°S) (Kirkegaard and Walker 1970; Ruello 1975a). It is the largest of Australia's endemic penaeid prawns in the genus *Penaeus*; females can reach 300 mm total length and exceed 150 g (Grey et al. 1983). Juveniles occur in shallow embayments and estuaries, while adults commonly occur in oceanic conditions to depths of 250 to 300 m. Commercial fishing is restricted to the continental shelf and shelf break from Lakes Entrance, in Victoria, north to the Swain Reefs adjacent to the central Queensland coast. In the central Queensland region the shelf and the fishery extend approximately 200 km out from the coast. Elsewhere, the shelf narrows and the spatial distribution of the fishery is limited to a maximum distance of approximately 60 km from the coast.

Penaeus plebejus display a seaward and northward migration of sub-adults as they mature. Adult females release eggs that sink to the bottom and hatch within about 24 hours, producing a pelagic larval stage. Larvae remain in the water column for 3 to 4 weeks, using tidal and diel behaviour to assist them undertake a general shoreward migration. Postlarvae then enter the benthic phase of their life cycle, settling on shallow coastal nursery grounds, where they remain as juveniles for 1 to 2 months before commencing a seaward migration to grow, mature and reproduce. *Penaeus plebejus* differs from most other prawns in that it is more oceanic and migratory, remaining in shallow estuarine areas for only a few weeks before undertaking an extended seaward, northerly migration.

An early tagging study (Ruello 1975a) suggested that there was a single adult population consisting of prawns from many estuarine habitats. This was independently supported by allozyme studies that showed genetic homogeneity for samples from south-east Queensland (27°S) to Victoria (38°S) (Mulley and Latter 1981). In NSW, additional tagging experiments confirmed the northward migration and mixing of prawns, thus supporting Ruello's single-stock concept (Montgomery 1981, 1990).

It has been argued that, for stock assessment purposes, two substocks exist based on the origin of recruits. These were referred to as the Moreton Bay–Mooloolaba substock, which had recruits principally from Moreton Bay, and the NSW–Southport–Mooloolaba substock which derived recruits principally from NSW estuaries.

The two substock theory was challenged by the expansion of the fishery in the mid 1980s to include fishing grounds further north and offshore, near the Swain Reefs (22°S). Preliminary examination of mitochondrial DNA from *P. plebejus* and other penaeid prawns from Australian coastal waters, including the Swain Reefs, indicate that *P. plebejus* has low genetic variation compared with the other species, with no clear spatial pattern of genetic differentiation (Lavery & Keenan 1995). It has been suggested that the results were consistent with the highly migratory behaviour of *P. plebejus*.

Although the eastern king prawn fishery is generally considered to be a single stock, in the past it has been compartmentalised for modelling and assessment purposes in alignment with state boundaries.

3.2.1.b. Growth and Mortality

Several scientists have described the growth rates of eastern king prawns. Lucas (1974) and Glaister et al. (1987) fitted von Bertalanffy growth curves to data obtained from tag-release experiments (Table 3.1). Lucas' estimates of the growth coefficient (*K*) for males were higher than those produced by Glaister et al (1987), possibly because Lucas tagged smaller, faster-growing individuals. The quantity t_0 is generally assumed to be zero as tagging data does not give an indication of t_0. Growth is modelled from the size at recruitment, estimated at approximately 20 mm CL. Ruello (1975a) also used tagging data from experiments conducted on the NSW coast. He found growth rates were similar to those of Lucas (1974) but could not produce a growth parameters due to insufficient data. Somers (1975) used both monthly length frequency distributions of post-larvae and juveniles (2.5 mm CL–11.0 mm CL), and tag-release data from prawns larger than 19 mm CL. He concluded that growth of post-larvae and juveniles could be described exponentially and that the von Bertalanffy expression adequately described growth in the larger prawns.

An estimate of the instantaneous rate of natural mortality *M* for *P. plebejus* in Moreton Bay and offshore waters adjacent to Mooloolaba is 0.11 week^{-1} and 0.05 week^{-1} offshore (Lucas 1974). Other estimates, of 0.0621and 0.0810 week^{-1} for 1979 and 1980 respectively have been published, but these were biased upwards as they include other mortality sources (Glaister et. al. 1990).

3.2.1.c. Migration and Movement

In southeast Queensland, the emigration rate for *P. plebejus* migrating from Moreton Bay to adjacent offshore waters was high ($E = 0.17$ week^{-1}) (Lucas 1974) - about 4 times the fishing mortality rate ($F = 0.04$ week^{-1}). When the combined effects of emigration and mortality were considered, an initial population in the Bay was reduced to about half in two weeks. Several studies suggest that *P. plebejus* utilise nursery areas and estuarine embayments for only a few weeks before undertaking migrations to deeper, oceanic waters.

A compartmental model has been developed of the northward migration of eastern king prawns in NSW. They concluded that emigration rates varied with location, and may actually reduce with increasing water temperature (Gordon et. al. 1995).

Catchability of eastern king prawns varies with lunar phase, however, sub-adults and adults appear to be affected differently. In estuaries and shallow oceanic areas (< 30 m) catch rates of sub-adults increase in the period leading up to and including the new moon, while in the deeper oceanic areas (> 100 m) catch rates of adults peak shortly before the full moon and decline over the following

Reference	K (week^{-1})		L_∞	
	MALES	FEMALES	MALES	FEMALES
Lucas (1974)	0.10	0.10	40.0 mm CL	49 mm CL
Glaister *et al.* (1987)	0.0595	0.0483	45.4 mm CL	59.5 mm CL

Table 3.1. Von Bertalanffy growth parameter estimates for *P. plebejus*.

seven days. Consequently, the activity patterns of trawl operators targeting eastern king prawns in shallow (< 30 m) and deep (> 100 m) water regions of the fishery differ according to lunar phase. Fishers operating relatively small vessels in shallow water prefer fishing in the period leading up to and including the new moon, while those operating larger vessels targeting adults in deeper waters prefer fishing in the period leading up to and including the full moon. The catchability of adult males and females in offshore waters (160 m) also changes over the lunar cycle. As a consequence, the relative contribution to the catch from each gender differs over the lunar cycle. Lunar phases also affect the incidence of mature and ripe females. During the main spawning season, two periods of increased spawning activity occur in each lunar cycle. Lunar phase effects need to be considered whenever indices of spawning stock size are examined (Courtney et. al. 1996).

Adults are oceanic and are among the most migratory of the Crustacea. Several tag-release studies in NSW and Queensland have confirmed a general northerly migration along the coast and into deeper water (e.g. Ruello 1975b; Glaister et al. 1987; Potter 1975). Tagged individuals have been recaptured over 1000 km from their release location. This has been referred to as a spawning migration, emphasising the importance of the northern parts of the fishery as the source of spawning stock, however, recently the significance of such a spawning migration have been questioned.

Barber and Lee (1975) and Rothlisberg et. al. (1995) have shown planktonic larval stages of *P. plebejus* enter Moreton Bay with the flood tide during both day and night. Post-larvae typically settle on bare substrates and seagrass areas, with fewer individuals settling in areas that have a freshwater influence (Young and Carpenter 1977, Young 1978). Although Young and Carpenter (1977) concluded abundance peaked between July and September in Moreton Bay, post-larvae were abundant year-round and seasonal trends were weak. The aversion that *P. plebejus* exhibits to areas with a freshwater influence was supported by Coles and Greenwood (1983) who found that, in the Noosa River system (approximately 150 km north of Moreton Bay), post-larvae only settled at sites near the river mouth, and only for brief periods.

3.2.1.d. Fecundity and Spawning

The spawning stock dynamics of *P. plebejus* are poorly understood. Dakin (1938) and Racek (1959) used field observations of the distribution of inseminated adult females, eggs, and larval stages to infer reproductive activity. Racek (1959) observed the population between 27°S and 36°S and suggested the 'period of maturity' was from March to June and that breeding grounds were in depths of 100 to 140 metres, but warned his results were inconclusive due to difficulties in identifying larvae to species level. Laboratory experiments indicated spawning and maximum hatching success for *P. plebejus* are likely to occur in oceanic salinities (30–34 ppt). Based on the recapture of tagged prawns, Ruello (1975a) suggested the coastal area between Fraser Island and Southport (Figure 2.1) was the most important spawning area for the species. However, this was prior to the establishment of additional trawling grounds for this species north of about 26°S.

Fecundity ranges from 350 000 eggs for 40mm CL females to 885 000 eggs in 60 mm CL females. When the effects of growth, mortality and fecundity are considered simultaneously, the size range of females that are responsible for most egg production is 35–48 mm CL. Large females (>50 mm CL) as a whole contribute little to egg production because there are very few such large individuals left in the population, due to the high mortality rates. The capacity of very large individual females (≥ 60 mm CL) to produce and fertilise eggs is reduced apparently by reproductive senescence (Courtney et. al. 1995a).

The spatial distribution of mature females was investigated in southeast Queensland using measures of ovary weight and histological condition. Ovary weight and the incidence of mature or ripe females did not vary significantly between areas. No obvious temporal patterns in spawning activity were apparent. The main spawning period appears to be June (winter). Mean ovary weight measures, and the incidence of histologically mature females are slightly elevated at this time. However, the main spawning period of June has been largely deduced by back-calculating from the time of the pulse recruitment using the growth curve and age at length estimates (October–November each year). There is likely to be a significant level of egg production outside the main spawning period that does not contribute to stock renewal (Courtney, 1997).

The significance of the northerly spawning migration has been challenged. Given the low speed of cross-continental shelf currents, it seems that many of the larvae spawned offshore and in the northern regions of the fishery have little chance of renewing southern coastal populations. It has been suggested that localised near-shore spawning stocks may be more important to the stock-renewal process than first considered (Rothlisberg et. al. 1995).

3.2.1.e. Biological Recruitment

The annual timing of biological recruitment in Moreton Bay is distinct and restricted largely to October–November. Individuals recruit at the relatively small size of 14–15 mm CL. Selectivity ogives for a 1 5/8" mesh net indicate that very few individuals (<10%) are retained in the gear. Recruitment to the fishery occurs 1–2 months after this period as individuals grow and migrate offshore. Approximately 50% of 19 mm CL individuals are retained.

The main abiotic factor affecting the distribution of recruits in Moreton Bay is depth; recruits are negatively correlated with depth. Two areas in Queensland are considered to be major sources of recruitment; Moreton Bay and the Great Sandy Strait–Wide Bay Bar region. The relative contribution to recruitment in Queensland from NSW is unknown (Courtney et. al. 1995b).

3.2.2 DESCRIPTION OF FISHERY

3.2.2.a. Introduction

In the order of 200 vessels land 1,500–2,000 tonnes of eastern king prawns annually in Queensland. The catch is restricted to the south-east corner of the state. An additional 800–1 000 tonnes are landed in NSW annually. Retail prices for the product vary with prawn size and season. Small or 'Bay' eastern king prawns (100 per kg) retail for about $6–8 per kg, while larger 'Ocean kings' (10 to 20 per kg) retail for about $20 per kg, although ocean king prawns retailed for $40 per kg over the 1997 Christmas season in Sydney markets. The majority of the product is sold on domestic markets, mainly in Sydney. A very minor component of the overall catch is landed in a recreational fishery in NSW.

In Moreton Bay the annual pulse of recruits is fished heavily from November to January. *P. plebejus* migrate rapidly through the Bay to deeper oceanic areas. The range of mesh sizes allowed in the Bay is 38–60 mm, with most vessels using the minimum size allowable.

Maximum head rope length is 32.5 m, (deployed usually as twin gear) and maximum vessel size is 14 m. Depths range from 4–35 m with trawl shot duration of 1–2 hours.

Outside the Bay, larger mesh size (50 mm, 2") is deployed. Maximum vessel size in the offshore fishery is 20 m. Trawling occurs in depths to about 300 m and shot duration increases to 3–4 hours. In the Swain Reefs region, fishing trip duration increase to approximately 12 days before returning to port. Logbook data indicate average nightly catches in the order of 50–120 kg per vessel with strong seasonality.

From December to May the annual pulse of recruits is fished down; monthly effort and catch decline over this period. The spatial distribution of effort moves offshore and northward, following the migration of prawns. By May, natural and fishing mortality rates dictate that only about 5% of the annual recruitment remain to contribute to spawning in June.

3.2.2.b. The Development of the Fishery

The development of the fishery was well described by Peter Gaddes. His involvement with the prawn fishery started as a deck hand in 1972 in the Moreton Bay and adjacent deep-water fishery off Cape Moreton. At that time, a 14-metre trawler was considered to be a large boat. On Moreton Bay, one 8 fathom net or two 4 fathom nets were allowed as is still the case today. In the offshore fishery, one net between the sizes of 10 to 15 fathom was used depending on the horsepower of the vessel. There were few refrigerated boats and ice was mostly used keeping the maximum time spent at sea to below four days and even shorter if the wind reached 20 to 25 knots. At that time, he did not recall any boats with radar. An unsophisticated echo sounder was the only hi-tech piece of equipment on board. The Moreton Bay fleet tended to fish in the bay in summer and the deep-water fishery in winter. The fleet rapidly grew in numbers as the northern tiger and banana prawn fishery developed. The inshore nature of the fishery with calmer waters and protected anchorages lent itself to fast development. At that time, government was giving encouragement by way of a 25% investment allowance on the construction of new boats. The red spot king and bug fishery had not been established at that time.

As the fleet grew, so did the average horsepower and boat size, net size and catching efficiency. The catching ability of a modern prawn trawler relative to its earlier counterpart, is far greater than we realise. Sonar, GPS and plotters make it possible to catch prawns in areas that were once protected by reef and obstacles. Once a concentration of prawns is found it is easily pinned down to the exact co-ordinates with the aid of a try net and GPS with plotter. Mr Gaddes, a professional fisher, believes that the increase in catching efficiency is highlighted by the fact that the catch rate of a concentration of prawns now declines rapidly over one, possibly two nights working. Increased horsepower and the use of multiple net rigs (e.g. 4 nets and try net or 3 nets and try net) have also contributed to the increased catching efficiency of the fleet. The duration of a trip has been greatly increased by the introduction of freezer rooms and larger hull capacity, most boats being able to achieve two weeks at sea and some even 4 weeks.

The unfortunate reality in this fishery is that increased catching ability has not meant increased profit, because the stocks are depleted and running costs are increasing. This declining trend is reflected in the fact that more new trawlers with large fuel capacities are being built. More fuel means more time at sea.

The geographical distribution of the eastern king prawn fishery is from Sandy Cape to the Queensland–NSW border. In November, new recruits begin to be caught in the shallows (40 to100 metres), close to the bars and northern outlet of Moreton Bay e.g. Cape Moreton to Mooloolaba. These prawns migrate into deeper water as they grow and are fished from March through to December in the 100 to 200 metres depth range. Scallops are fished all year round in Hervey Bay and off Yeppoon. The trend to date is for boats to migrate south into the scallop and king prawn fishery while the tiger grounds are closed.

3.2.2.c. Management

The objectives of the *Fisheries Act 1994* (Qld) are to ensure that fisheries resources are used in an ecologically sustainable way, to achieve optimum community, economic and other benefits obtainable from fisheries resources, and to ensure access to fisheries resources is fair.

The eastern king prawn fishery forms part of an overall east coast otter trawl fishery, which is managed by restricted entry (about 800 boats). Other than size restrictions applied to boats in Moreton Bay, all trawlers are entitled to access all trawl species. A further 200 odd licence endorsements allow small boats (< 10m) to use beam trawl in specific estuarine areas of the state's waters. Eastern king prawns are fished sequentially, from the inshore nursery areas to the offshore adult animal. There are different gear restrictions for the inshore and the offshore fleet. Beam trawlers in the rivers are restricted by a maximum 5 metre beam and footrope and the close inshore fleet, in the bays, by a maximum of 8 fathoms of headrope. The inshore fishery (less than 100 metre deep) and offshore (greater than 100 metres) are limited to a maximum of 88 and 84 metres of headrope and footrope respectively.

Near bar closures have been used as a form of spatial yield optimisation in Southport, Jumpinpin, Amity and Tincan Bay. At present, there are no clear targets, reference points or measures directed towards achieving the Act's objectives but these are being developed in a new Management Plan. Key issues that are being addressed in this Management Plan include:

- The current vessel replacement policy discourages vessel replacement and has resulted in the average vessel being 25 years old;
- There is an enormous amount of latent effort. The fleet of about 800 boats now apply about 90 000 night's work, which could be readily increased by 30–40%;
- There is a belief that the industry is running under a very low profit regime;
- The stocks are fully exploited and chronic recruitment overfishing is a possibility.

The key elements of the proposed Draft Management Plan are:

- Restricted access, but under certain conditions, all licensed trawlers can access all trawl resources;
- A complex effort capping mechanism which involves boat units and historical performance;
- Seasonal closures in north and south Queensland;
- Bycatch reduction devices and a turtle protection mechanism;
- Limit reference points; if catch rates decline below 70% of the long-term average, within key life-cycle periods, then spatial closures are triggered. If catch rates decline below 60% of the long-term average a more significant response is proposed.

Compulsory VMS for monitoring will be phased in, starting with the scallop fleet.

3.3. EASTERN KING PRAWN TASK GROUPS

1. Characterisation of catch rates in the Fishery:
   - amalgamate NSW and Queensland data;
   - investigate the influence of geographical and temporal scale on catch rates;
   - regionalisation.
2. Distribution of effort:
   - development of the fishery;
   - level of reporting scale in terms of 6 minute and 30 minute grids.
3. Evidence and arguments for recruitment or growth overfishing.
4. Establishment of a recruitment index through simulation models.
5. Location and size.

Common Name	Elsewhere	Moreton Bay
Banana	18.36	3.52
Bay	1.71	48.53
Clicker	0.00	0.14
Coral	3.57	0.22
Eastern king	0.00	0.00
Endeavour	3.21	1.38
Greasy	0.01	1.71
Hardback	0.00	0.05
King	62.80	25.28
Leader	0.01	0.00
Mixed	0.39	5.35
Mixed bait	0.09	0.40
Pink tailed	0.01	0.00
Pistol	0.00	0.01
Red spot king	0.69	0.01
Royal red	0.09	0.00
Sand	0.01	0.00
Scarlet	0.08	0.00
School	0.56	0.50
Tiger	8.03	12.28
Unspecified	0.37	0.62
Western king	0.00	0.00

Table 3.2. The relative proportion of the different prawn species/categories in the CFISH data-base inside Moreton Bay and Elsewhere (south of 20°S). The zero values are either truly zero or an extremely small amount landed. Note that the species category Eastern King Prawn receives no use.

3.3.1 CHARACTERISATION OF CATCH RATES

NSW catch and effort data was very kindly made available for this workshop. For confidentiality reasons, this data was summarised by month, unlike the Queensland logbook data, which was at the record level. This made it impossible to combine the data without losing the resolution necessary for effort characterisation. In this group, therefore, work was restricted to the Queensland data-set.

There was much discussion about data quality and the difficulties in separating the species of interest from one another. A major source of noise and error is the category 'bay prawns' which can contain any small prawns including eastern king prawns, greasyback prawns (*Metapenaeus bennettae)*, school prawns (*M. macleayi*) and red-spot king prawn (*Penaeus longistylus*). Fishers often classify prawns as 'bay prawns' when they have not sorted their small prawn catch. A further problem stems from the category 'king' as used on the East Coast Otter Trawl Fishery Logbook. This is used to represent eastern, red-spot and western king prawn (*Penaeus latisulcatus*). The problem of 'bay prawns' was considered to be mostly confined to Moreton Bay (Table 3.2). The difference between Moreton Bay landings and landings from elsewhere (but south of 20°S) are primarily related to differences in banana prawns, 'bay' prawns and 'king' prawns (Table 3.2). It was clear that Moreton Bay and elsewhere should be treated separately to other oceanic waters.

Owing to the problems in identifying the eastern king prawns within the database in the time available it was decided to limit analyses to relatively simple summary methods. Given the doubts about the nature of the data they were working with, the group recommended that the data-set be cleaned using an agreed upon algorithm designed to select records which would be mostly eastern king prawns. For example, it was suggested that the category 'king' could be divided into eastern king and red-spot king prawns using locations defined by latitude. To deal with the problem of 'bay prawns', especially in Moreton Bay, the group recommended that such landings be sampled to determine the proportional species composition.

As the data did not lend itself to detailed standardisation, it was decided to characterise seasonal changes in catch rates on a broad spatial scale (inside Moreton Bay and elsewhere). At the same time long term trends were considered by using twelve month moving averages to remove the strong seasonal signal from the data from both inside Moreton Bay and elsewhere. This group did not have details of the characteristics of the vessels in the eastern king prawn fishery, however, the offshore vessels are larger and have higher catch rates.

Inside Moreton Bay, the twelve-month moving average within years was less than expected. Across the period 1988 to 1997 there were relatively low catch rates in 1993 (Figure 3.1). On a shorter temporal scale, there were clear peaks in catch rate over new year periods (November, December and January which were consistent with the expected periods of recuitment. However, there was also an unexpected peak in catch rates occurring in mid-year (June and July) which was of variable magnitude (Figure 3.1). This mid-year maximum had not been mentioned before and the group felt it was an interesting and repeatable phenomenon that needed an explanation. (The FRDC 97/145 Project 'Developing indicators of recruitment and effective spawner stock levels in eastern king prawn' will investigate this phenomenon further). The suggestion that it was a reflection of spawning aggregations was countered by the statement that the observed peaks were too small. Another suggestion was the mid-year peak could be simply a

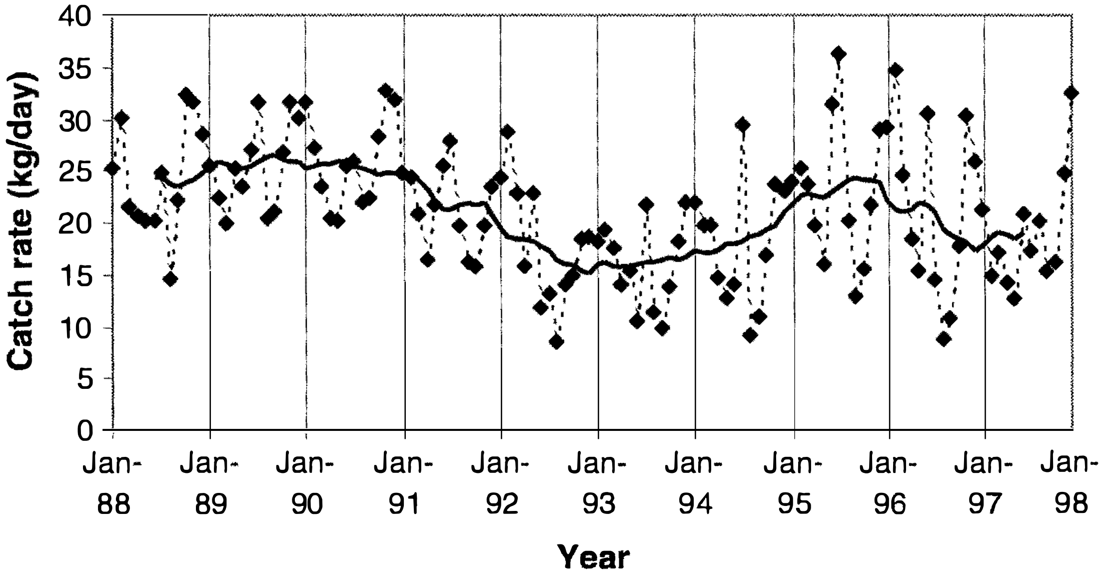

Figure 3.1. *Catch rates of the category king prawns inside Moreton Bay (points with dotted line) with a twelve month moving average (solid line). Note that there is a peak every January/February and another every June/July.*

reflection of that time having the best weather conditions for trawling. It was also pointed out that the 30 minute grid block used to define Moreton Bay includes a small offshore segment and this might influence the results observed.

The eastern king prawn catch rate outside Moreton Bay is also clearly affected by season (Figure 3.2). Catch rates peak over the new year corresponding with recruitment and subsequent decline through to late winter. It was suggested that there may be additional recruitment to the fishery from southern immigrants moving north. Outside Moreton Bay there was no evidence of a mid-year spike in catch rates as observed inside the bay (Figure 3.2). The twelve-month moving average showed a clear and smooth trend that was flat through to 1994 with a peak in 1995 and 1996 which then declines to the 1988–1994 level.

Even though the catch rate data for eastern king prawns have many problems, the information obtained from the simple analyses above identified a number of interesting patterns of activity within the fishery. The group recommended that following data clean-up, as described above, the mid-year spike in catch rates within Moreton Bay should be investigated further.

3.3.2 DISTRIBUTION OF EFFORT

The objective of this group was to investigate the spatial resolution of the logbook data and how the spatial distribution of effort has changed over time. There was a known expansion in the distribution of the fishery during the middle 1980s. However, this occurred before the logbook database was established. The resolution in the data-set is low, mainly reporting at 30 by 30-minute grids, but has improved over time to 6 by 6-minute grids. Some precise latitudinal and longitudinal data are being logged. An animated EXCEL sheet that scrolled through the effort distribution by depth and latitude was created. An example of 1989 and 1997 effort is given in Figures 3.3 and 3.4.

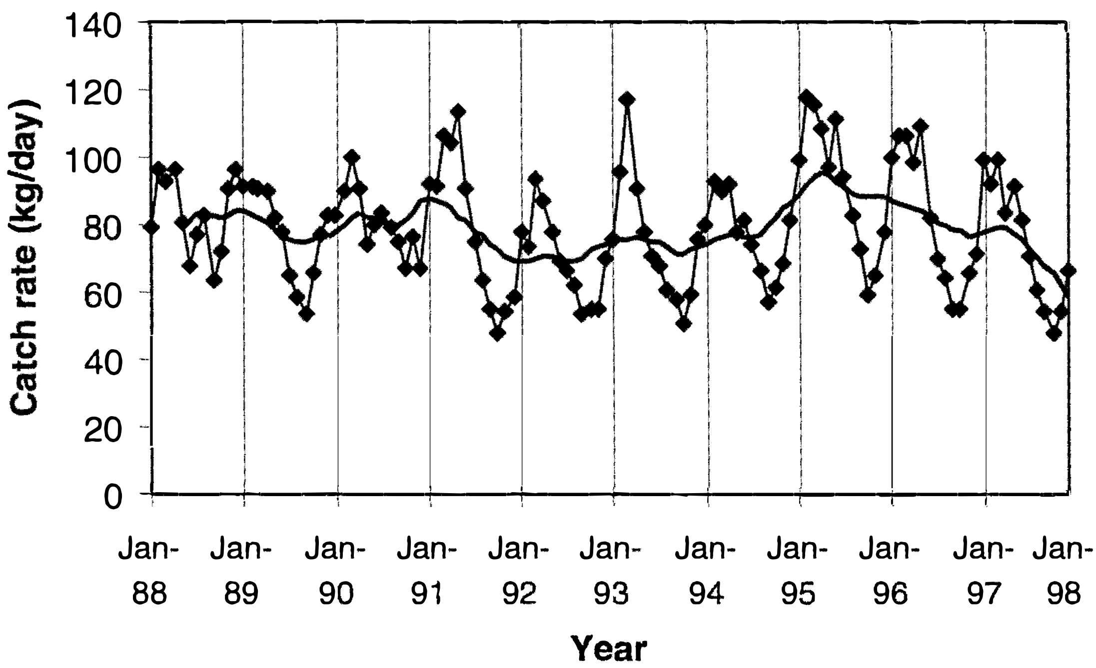

Figure3.2. *Monthly commercial catch rate of category king prawns caught outside Moreton Bay. The solid line is the 12-month moving average.*

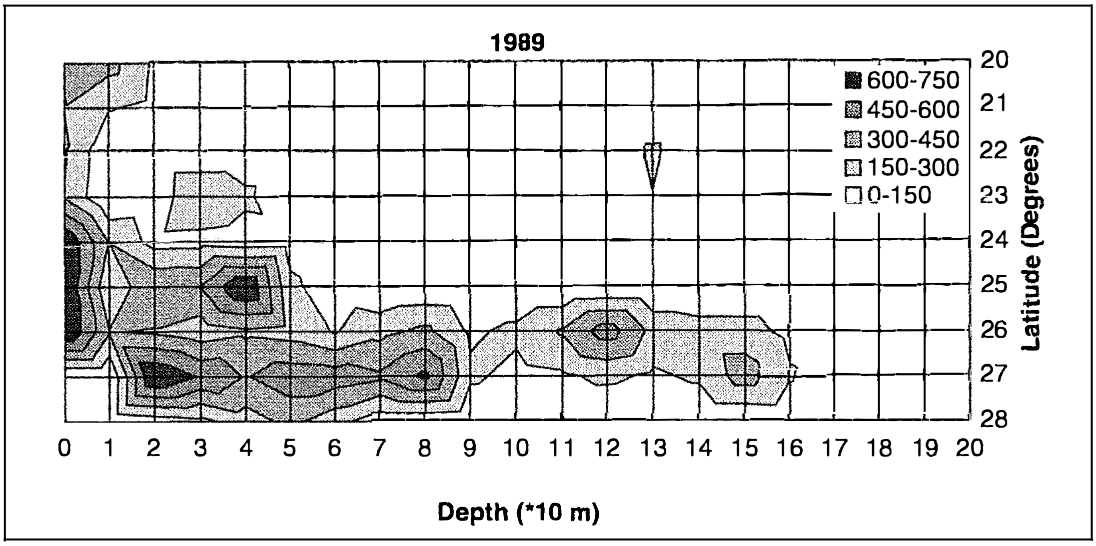

Figure 3.3. *Distribution of effort, as number of boat nights, by latitude and depth for eastern king prawns in 1989, excluding Moreton Bay.*

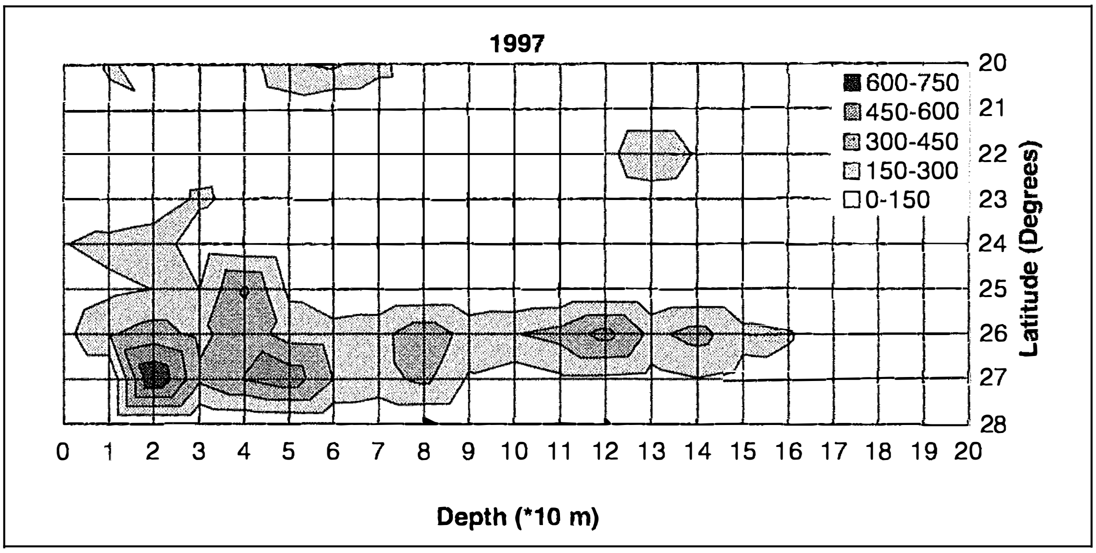

Figure 3.4. *Distribution of effort as number of boat nights, distribution by latitude (degrees) and depth (m) for eastern king prawns in 1997, excluding Moreton Bay.*

In the two figures above, about 33% of the data include zero and null depth or latitude values. The Moreton Bay effort data are not included. The extremely high effort within this region would remove contrast in the non-Moreton Bay areas. With those records having a null depth and precise latitude and longitude, it should be possible to infer depth. Unfortunately, the group did not have the time to attempt to include such records in their analyses. The group suggested that this work be pursued when possible.

Using the distribution of catch by month, the group identified three areas (Figure 3.5):

a. shallow recruitment (Moreton Bay);
b. offshore spawning (>100m depth) ;
c. intermediate areas (<100 m depth excluding Moreton Bay).

There is a clear reversal of seasonal catch levels between offshore spawning areas and elsewhere. Catches peak in Moreton Bay and the intermediate areas during the new year period, there is

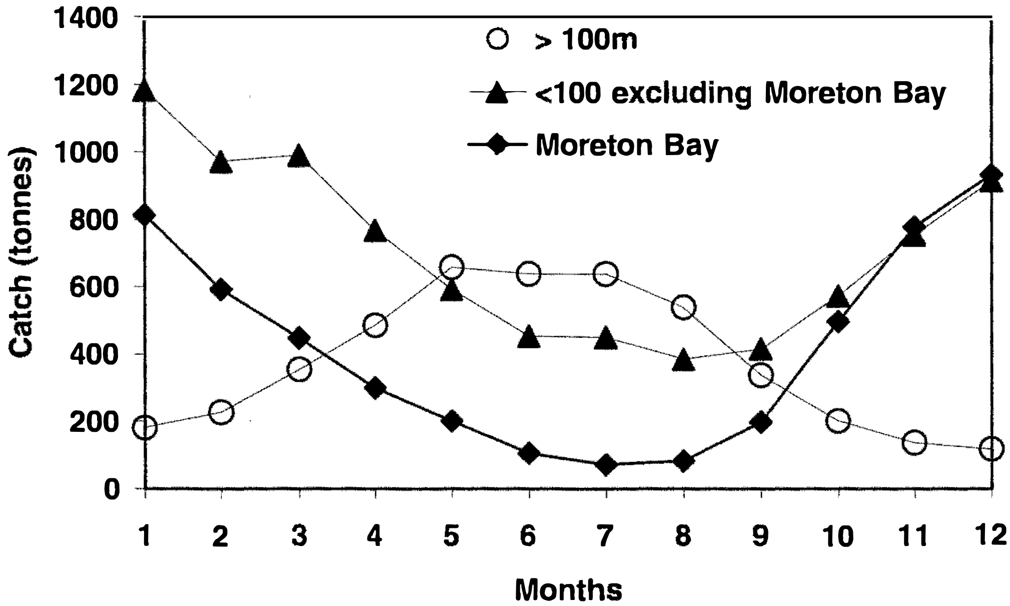

Figure 3.5. *Catch levels of eastern king prawn in different areas and depths. The changing seasonality with location, relating to migration with growth, is clear.*

some evidence of catches being maintained for a longer time in the intermediate areas. The offshore spawning adults exhibit the highest catch levels in the mid-year winter months (Figure 3.5). This pattern reflects the offshore migration of small prawns as they grow. This could be confirmed by examining these patterns through a season. It was considered by the group that such seasonally structured maps would also illustrate the general northwards movement of small prawns as they grow.

The group made the following recommendations:

a. When mapping effort distribution, effort should be sub-divided by season;
b. Estimate where possible, null depth values by using latitude and longitude data;
c. The offshore spread of effort should be linked to migration and tagging information, using both NSW and Queensland data.

3.3.3 EVIDENCE OR ARGUMENTS FOR RECRUITMENT AND/OR GROWTH OVERFISHING

The group used the qualitative ranking process by Penn (1984), which considers the life history characteristics of each species to determine whether it will be vulnerable to overfishing; the implication was that *P. plebejus* has a low risk of overfishing. This is due to its highly dispersed nature, that it is only active (and fished) at night and that it seems to be buried through most of the night, a behaviour most likely to reduce its catchability.

Logbook data from two possible sites were suggested for investigation of information on a recruitment index. The first is Moreton Bay, but the inability to distinguish between bay prawns and eastern king prawns in the database makes analysis difficult. The second area is the Wide Bay Bar area (Grid W34). The average of the catch rates for January and February were used as a recruitment index, consistent with life history patterns. This index does show a decline over time. If some indirect attempts at effort standardisation are attempted, then the decline becomes more marked (Figure 3.6). After the workshop, it was suggested that recruitment might occur over the whole of October through to the end of January and that the average across these dates would provide a better recruitment index.

The three series of catch rates were produced with the following assumptions:

'Nom' : Unstandardised mean January and February catch rates.

'1%' : Triple quad gear was introduced in 1976 to 1978 and introduced an estimated 20% increase in efficiency to the effort. In the mid-1980s, the introduction of try gear was thought to increase effective effort by 5% and GPS in 1990 resulted in an increase of 10%. On top of these increments , a yearly geometric effort increase of 1% was also assumed.

'5%' : Same as for '1%' but higher increases. Thirty percent for Quad gear, 10% for try gear and 15% increase for GPS. Also, the overall geometric increase on top of the incremental changes was assumed to be 5% per year.

The 5% series was clearly the worst case scenario. The industry members in the workshop generally agreed to the figures. The consensus was that the true scenario would be between the 1% series and the 5% series. Factors not included would be recruitment changes associated with climatic changes, random noise and changes in broodstock availability, for example, due to recruitment overfishing.

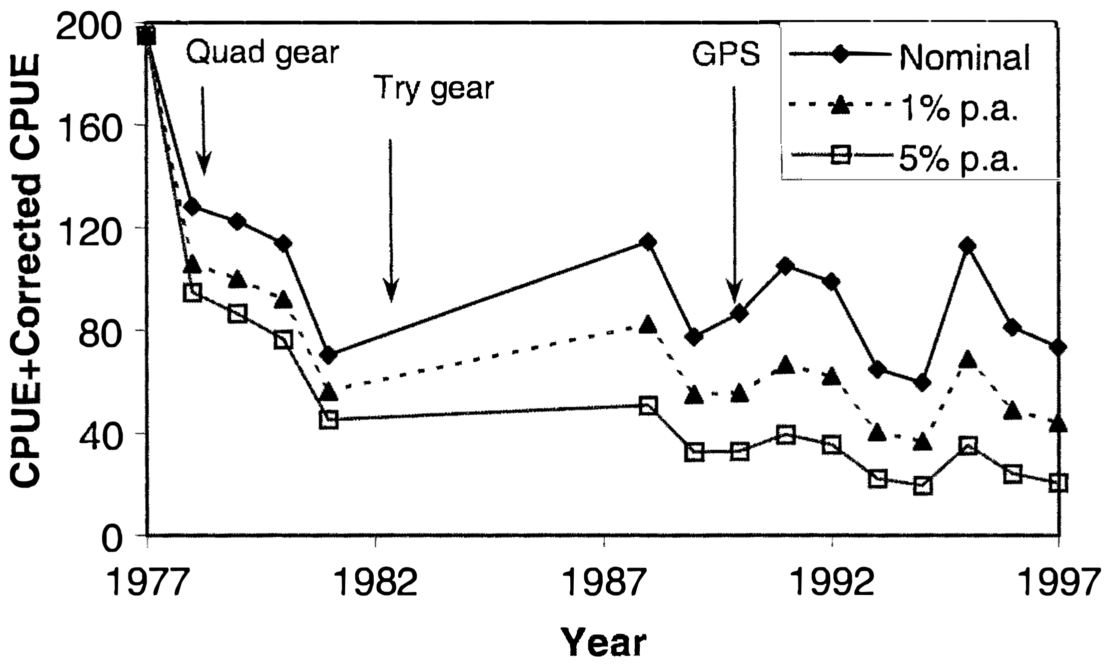

Figure 3.6. *Eastern king prawn corrected and uncorrected catch rates (kg. boat nights^{-1}) of January and February from 1977 to 1981 (voluntary logbook data collected by M. Dredge, DPI, SFC, Deception Bay) and from 1988 to 1997 (CFISH database, QFMA) for Tincan Bay. Arrows indicate years in which a technological improvement, assumed to effect fishing efficiency, was added to the fleet. An optimistic and pessimistic cumulative annual effort increase of 1% and 5% has also been added.*

3.3.4 ESTABLISHMENT OF A RECRUITMENT INDEX THROUGH SIMULATION MODELS

A monthly least squares biomass dynamic model was fitted to monthly catch rate data from Queensland alone, NSW alone and a combination of the two data-sets. The available data set and recruitment patterns of the prawn differ by state, so the NSW model and the Queensland model start in October 1985 and 1989 respectively. In both cases a strong seasonal trend is apparent. In Queensland, the highest catch rates (and, it is assumed, peak recruitment) occur from December to March. The pattern is slightly different in NSW, with highest catch rates being observed between January and March.

A simple variation of structure permitted the behaviour of two models to be investigated. The first model assumes that the increase in catch rates is due to recruitment and that the decline in catch rates is due to commercial catches only. The second model has an additional term to reflect the changes in biomass due to natural mortality and individual growth. Recruitment is uniformly distributed between the relevant months.

The biomass dynamic equation for Queensland is:

February to December

$$B_{y,m+1} = \gamma B_{y,m} - C_{y,m} + \rho_m R_y \quad : 3.1$$

where B_t is the biomass (t) in year y, month m,

γ is the growth and natural mortality term, set at 1 in the first model and estimated in the second,

C_t is the catch (t) in year y, month m,

• $_m$ is the proportion annual estimated recruitment that occurs in month m

R_t is the recruitment estimate in year y.

And January

$$B_{y+1,1} = \gamma B_{y,12} - C_{y,12} + \rho_1 R_y \quad : 3.2$$

Due to differences in the catch rate datasets between NSW, Queensland and both states combined, the equations above have to be adjusted to align with the observed recruitment periods for each State or combinations of States.

The relationship between catch rate (kg. boat night^{-1}) and biomass was modelled as:

$$\left(\frac{C}{E}\right)_{y,m} = qB_{y,m} \quad : 3.3$$

where $E_{y,m}$ is the effort in year y, month m, and

q is the estimated catchability coefficient.

A recruitment index was estimated for each year. A single global catchability parameter was estimated assuming catch rates were directly proportional to biomass. A further parameter, initial biomass, needed to be estimated. In the first model, the γ parameter was set to one, cancelling its effect. In the second model, it was estimated directly. The model fit to each data-set are given below (Figure 3.7).

The resultant recruitment index for the Queensland data shows a decline from 1990 to 1993 followed by a recovery until a maximum in 1995, followed once more by a decline. In NSW, there is an initial period starting in 1986 when recruitment is highly variable but from 1990 recruitment is relatively stable with only a slight peak in 1995. The combined data was dominated by the much higher catch rates in Queensland and exhibited an even more marked pattern than found in Queensland alone (Figure 3.8).

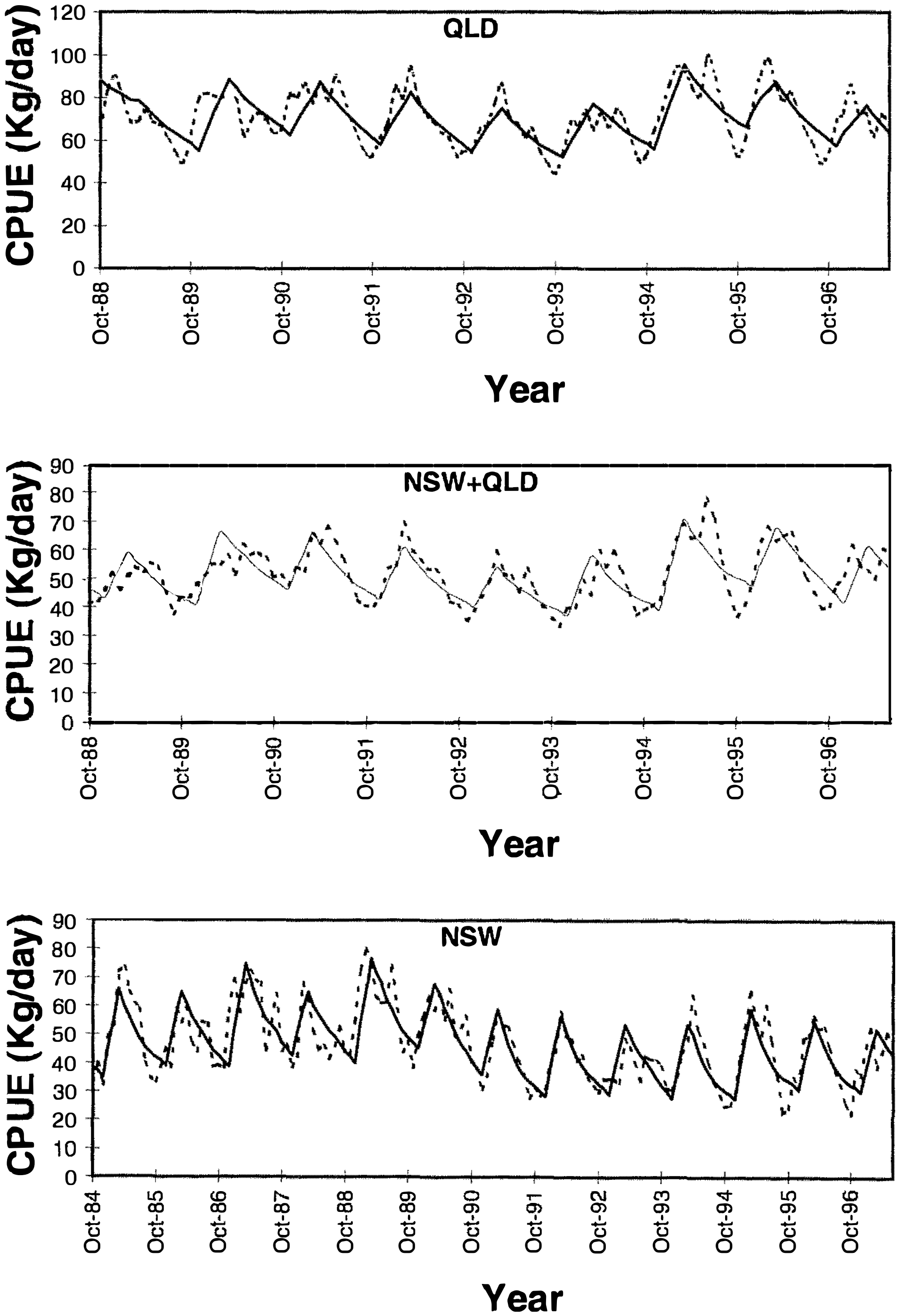

Figure 3.7. *Model (solid line) fit to the Observed (dashed line) catch rates for the off-shore fleet of i) Queensland (QLD), ii) Queensland and NSW fleet combined and iii) NSW*

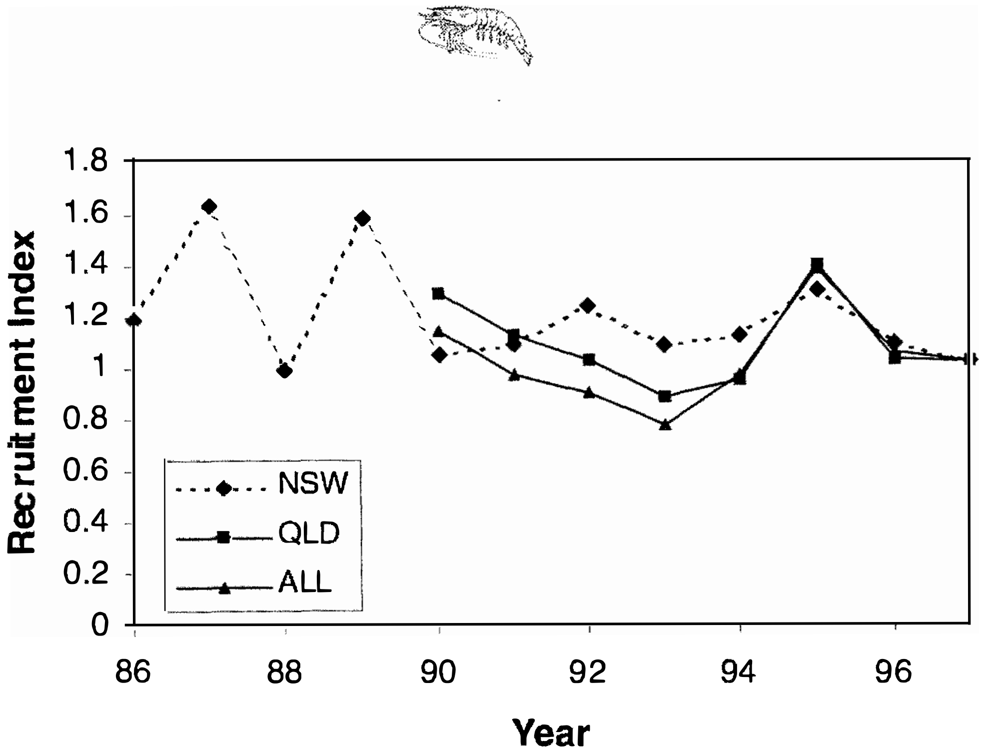

Figure 3.8. *Recruitment indices for NSW, Queensland and both combined for the offshore fleets.*

3.3.5 LOCATION AND SIZE DISTRIBUTION

This group argued that if recruitment overfishing occurs, then closures should be designed to maximise egg production. This would be affected by abundance, animal's size, timing of spawning and level of fishing effort. Pervious YPR studies on eastern king prawns have indicated that the optimal egg production size classes are females 35–45 mm carapace length. This is due to a combination of the fecundity-length relationship and number of females alive at a certain size (Courtney et al. 1995a).

Biological recruitment occurs in October to November. Based on the growth rates of these animals, the effective spawning period should therefore be between June and July. If the commercial catch for the months of June and July are plotted in the GIS package ARCVIEW (Figure 3.9), it is possible to locate four main fishing areas. These are the Swain Reefs (U28, V28, W28, W27), Lady Elliott Island region (V30), off Mooloolaba (W36) and offshore of Moreton Island (X37).

Monthly size-frequency and depth data from both selected fishers and a DPI research vessel were available for these four regions. Size-frequency plots of June and July prawn sizes at each of these regions are plotted below (Figure 3.10 a–d).

Prawns in the Swain Reefs region are extremely large and not many are within the optimal spawning size range class. As one progresses south, however, the relative size decreases. Although several animals between sizes 35 to 45 mm CL are present within the Lady Elliot and Mooloolaba region, it is clear that the highest abundance of these females are outside and adjacent to Moreton Island.

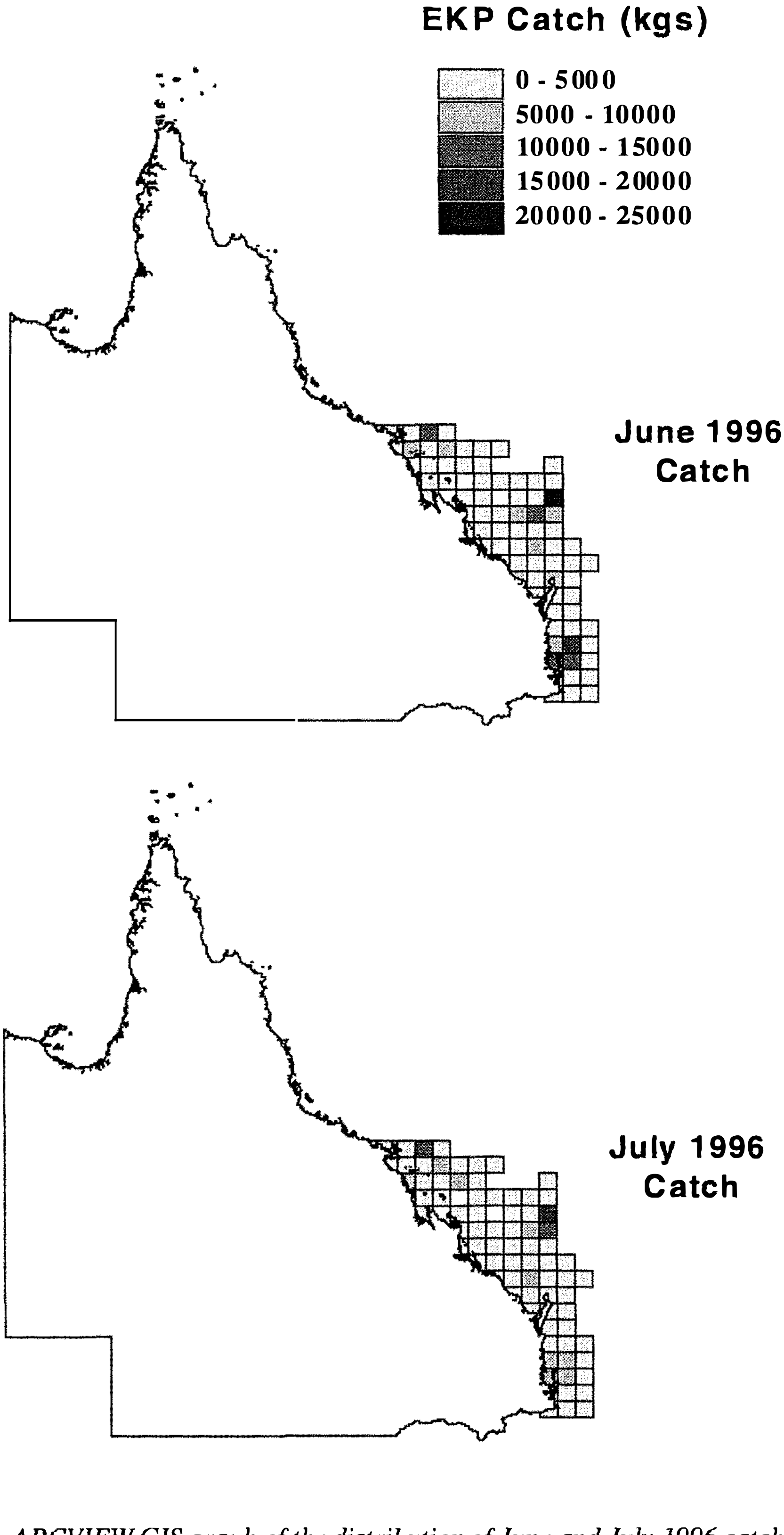

Figure 3.9. *ARCVIEW GIS graph of the distribution of June and July 1996 catch (kg).*

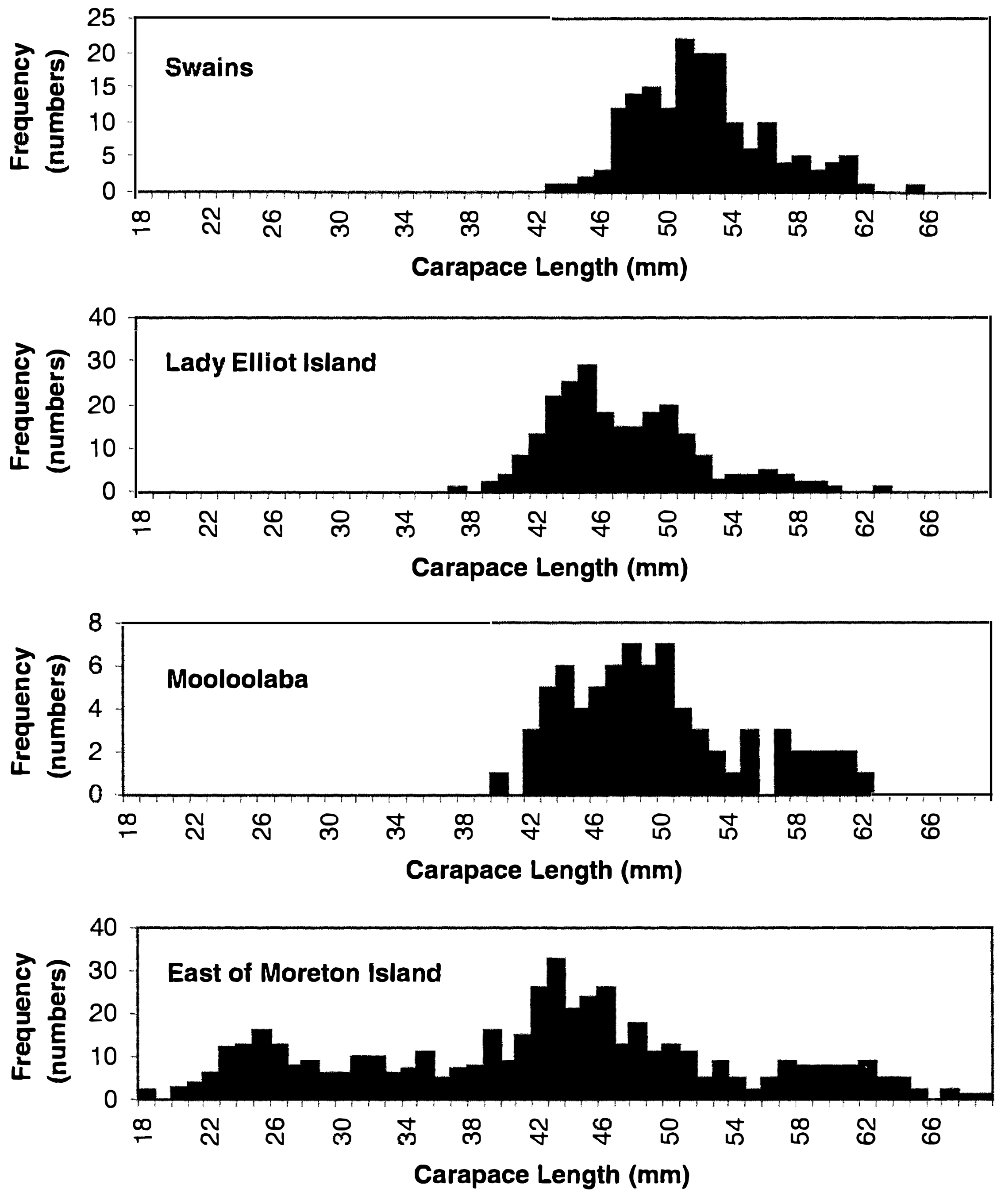

Figure 3.10. a–d: *Size frequency distribution of eastern king prawns from June and July survey data in 1991 and 1992 using 3 commercial vessels and 1 DPI vessel for a) Swain Reefs Area, b) Lady Elliot Island region, c) off Mooloolaba coast and d) east of Moreton Island.*

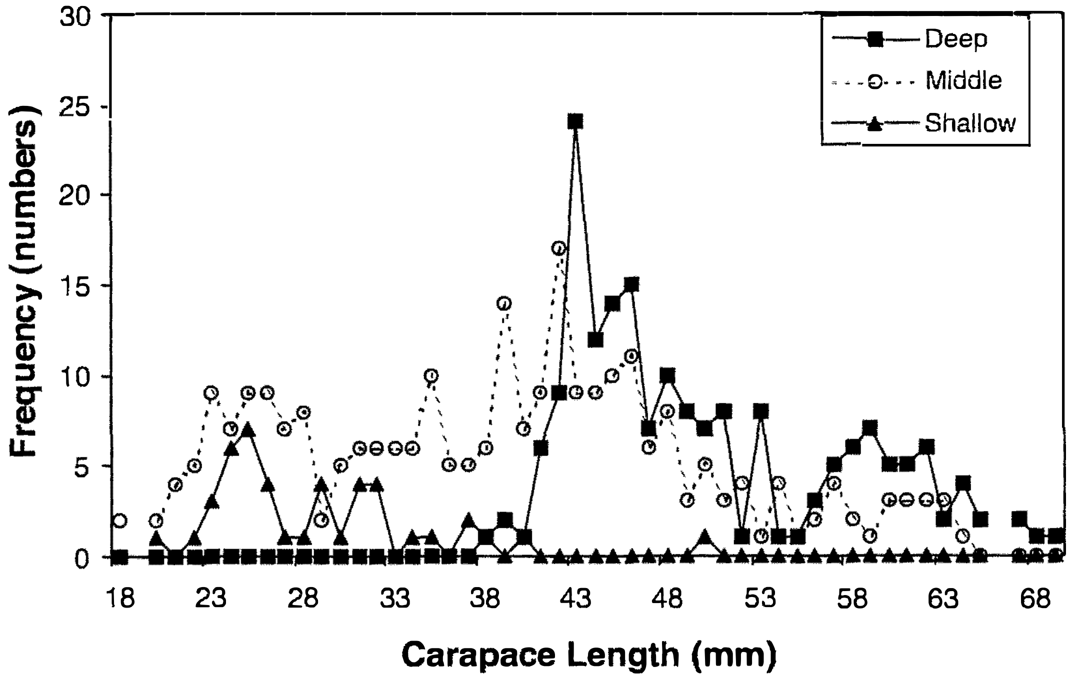

Figure 3.11. *Size-frequency by depth of eastern king prawns caught off Moreton Island during a survey in 1991 and 1992.*

If the size frequency distribution of eastern king prawns in waters off Moreton Island is related to depth, then the animals between 35 to 45 mm CL seem to occur in the medium depths of about 90 meters (Figure 3.11). In conclusion, any spawning closure should aim at the region offshore of Moreton Island in depth greater than 85 meters during the months of June and July.

In terms of growth overfishing, juvenile closures would be necessary. The obvious area would be Moreton Bay as this area is a major source of juvenile eastern king prawns. However, the social and political cost would be enormous and, possibly, small areas or night-time closures could be considered. Previous YPR work on these closures has shown that assumptions about migration rates greatly affect the duration of closures. Also, there is generally only a 5–10% increase in value.

Any potential closure should be carefully investigated in terms of risks and benefits. A simple table was produced by this group identifying these possible actions to be taken, their risk and benefits (Table 3.4).

3.4. CONCLUSION

3.3.6 GROUP REPORTS

Species identification problems exist in the database and algorithms that were used in the workshop to isolate eastern king prawn (*Penaeus plebejus*) catch and effort. The biggest problem exists in the Moreton Bay area, however 80-90% of the fishery's catch and effort occur offshore from Moreton Bay. The catch rate data reflects a distinctive pattern of high values between November to January, consistent with documented periods of recruitment. This is followed by a decline towards mid-year. A small and unexpected mid-year peak of variable magnitude can also be observed. This may reflect a second minor recruitment pulse, possibly as a result of northward migrations from New South Wales and is currently being investigated.

The spatial resolution of the data in the commercial logbook system is coarse with most fishers reporting at the 30 by 30-minute grid scale. This has improved over time to 6 by 6-minute grids. The larger grid level in Moreton Bay also includes a small offshore section. Some attempt at using depth to further segregate the catch spatially was promising, but about 33% of the offshore data included zero and null depth or latitude values. Three biological areas were identified, being shallow recruitment (e.g. Moreton Bay), offshore spawning (>100m depth) and intermediate (<100m depth, but excluding the bay).

A yearly recruitment index was established, using the average catch rates for January and February in the Wide Bay bar area. The historical data between 1977 and 1981 and the logbook data from 1988 to present were used. Factors that may affect the catch rate e.g. quad gear, try gear and GPS were considered and their possible effects included in the analysis. An overall 1% or 5% per year effective effort creep factor was added. Both the worst case and best case scenarios of the index demonstrated a decline in recruitment over time.

A monthly least squares biomass dynamic modelled fitted to Queensland, New South Wales and combined catch rate data was developed. The catch rate data were unstandardised. The model fitted the data well. The resultant recruitment index for the Queensland data shows a decline from 1990 to 1993 followed by a recovery until a maximum in 1995, followed once more by a decline. For reasons related to degrees of freedom, the present biomass relative to virgin biomass was not estimated. It will be important to consider the effect of effort creep in the future development of this model.

Commercial catches during the main spawning period (June and July) were investigated. Based on prior per-recruit analysis, the optimal egg production size classes are females 35 to 45 mm carapace length. As a result, any possible spawning closures to avoid recruitment overfishing should aim at the region offshore of Moreton Island in depths greater than 85 metres during the months of June and July.

The working groups were unable to determine whether the eastern king prawn catches were or were not sustainable. Attempts at effort standardisation were *ad hoc*, but demonstrated a significant effect on catch rate. An objective method for measuring effective effort changes should be utilised in future. Furthermore, the varying spatial and species resolution of the data adversely affects confidence in the results. An historical database, currently managed by QFMA, may be extremely useful for extending the series back to 1977, but was not available to the workshop. Successful modelling and management of eastern king prawns relies on good collaboration between New South Wales and Queensland.

3.3.7 PROGRESS TO DATE

A summary of data quality, research and stock assessment knowledge to date is presented in Table 3.3.

Category		Comments
Commercial	Catch	Problems in identifying eastern king prawn catch data within the Bay and King prawn CFISH categories.
	Effort	As above.
	Catch rate	CFISH data tends to have little year to year contrast. Within years there is a marked seasonal pattern. Historical data from voluntary logbook programs and other studies would extend the data to about 1970, but is unavailable for analysis because the database entry is incomplete and unchecked. Data resides with QFMA. There is an urgent need to have the data developed and made available.
Recreational	Catch, effort and catch rate	Minor in New South Wales and insignificant in Queensland. Not estimated.
Independent index of biomass or recruitment		Present FRDC project to establish appropriate methodology.
Estimates of natural mortality		Good estimates using various data sources in various studies, however few recent estimates.
Estimates of fishing mortality or biomass		Good estimates using various data sources in various studies. Workshop model estimated yearly recruitment.
Input controls		Limited entry, gear restrictions, inshore seasonal and area closures, hull unit controls.
Output controls		None.
TACC Decision rules		N/A.
Performance indicators		Broad and untested performance indicators in draft Management Plan.

Table 3.3. A summary of progress to date with respect to data quality and research knowledge.

3.3.8 MONITORING, RESEARCH DIRECTION AND PRIORITIES

a. The workshop considered it very necessary to improve our understanding of the relation between fishery performance indicators and CPUE data. In the current management plan it is proposed to utilise catch rate to act as performance indicators. However, the usefulness of this approach has yet to be demonstrated because catch rates may not be closely related to stock abundance. Effort should be standardised. This project should have a high priority.

b. VMS data capture should be used to provide detailed stock assessment information. With the introduction of VMS to the inshore trawl fleet the

Scenario	Risk	Cost/Benefit
• Recruitment protection closures	1. Growth overfishing. 2. No growth overfishing	• Increased number and price of large prawns. • Loss of small prawns for no benefit.
• Night-time area closure within Moreton Bay (2–3 months)	1. Juveniles fished on movement out of bay.	• Loss of tiger and small eastern king prawn catch. • Reduced growth overfishing.
• Extension and linkage of two mile closures in areas where juveniles move out of bay.	1. Insufficient protection of juveniles (within bay)	• Loss of small eastern king prawn catch. • Reduced growth overfishing.

Table 3.4. Possible actions to be taken to the management of eastern king prawns, their risks and benefits.

potential for its use to gather information on fleet dynamics and the distribution of effort would be of tremendous value in monitoring the status of the stock. This will be difficult to develop but should have a high priority as if it proves successful could in the long run have a high return for a low cost.

c. A fishery independent recruitment index from surveys is being developed and could substantially improve the sustainable management of this resource. Tony Courtney is undertaking this project, but some concern was expressed as to the high coefficient of variation of his index. It is recommended that a review of the sampling intensity is made and, if more resources are not available, that the time and spatial scale of the project be redesigned e.g. only survey Moreton Bay during November.

d. After much discussion on whether catch rates are representative of the fishery and good for performance indicators, the consensus was that there was no other likely approach available at this stage. Assessing juvenile eastern king prawn catches is not possible. The ‘bay’ prawn category used by fishers for any species of small prawn needs to be broken down to the species level. This could be done by catch sampling the ‘bay’ prawn to determine relative proportions of each prawn species at different times of the year. Another problem is that eastern king and red-spot king prawns are entered as one category of ‘king’ prawns in the logbook. This could be solved by adding another column in the logbook or catch sampling in areas where both species are known to occur.

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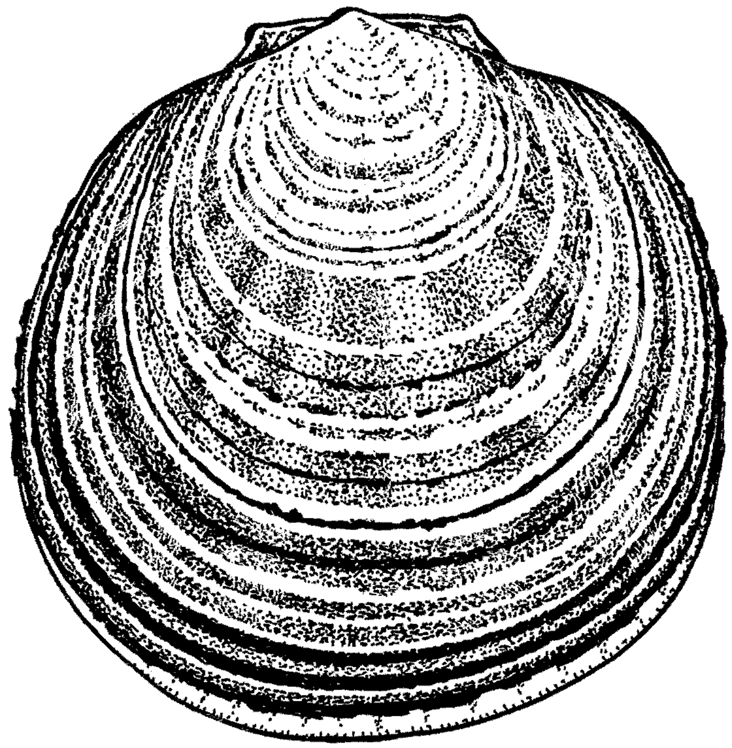
common name

SAUCER SCALLOP 4



Amusium japonicum balloti

4.1. PARTICIPANTS

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(No Trawl MAC Chair was allocated at the time of the workshop due to a secondment)

4.2. INTRODUCTION

The fishery for saucer scallops, *Amusium japonicum balloti*, is an important component of a multi-species trawl fishery on the East Coast of Queensland. Annual landings average about 1 200 tonnes of adductor meat, with a landed value in excess of $25 m (Williams 1997). The scallop fishery takes place mainly between 21°S and 27°S, in depths ranging from 20 to 60 metres. It is regulated through input controls, which include limited entry (which applies to the entire Queensland east coast trawl fishery) and size limits designed to optimise yield per recruit (Dredge 1994). The fishery was characterised by 24 hour fishing operations until 1988, but was limited to night-time only operations thereafter. Three 10-minute by 10-minute areas were closed to trawling so as to act as broodstock reserves in 1989, but were repealed 15 months later due to policing difficulties. Similar closures were again introduced in 1997 as a response to serious declines in catch rates which were observed in late 1996. These closures were re-gazetted in early 1999.

Saucer scallops have been shown to spawn in winter and spring, coinciding with water temperature change. It is probable that saucer scallops are serial spawners, with females spawning more than once in a season (Dredge 1988). Growth is rapid, with animals attaining sexual maturity at a shell height of 90 mm or larger towards the end of their first year of life (Williams and Dredge 1981; Dredge 1981). Natural mortality rates of adults are high, between 0.020 and 0.025 week^{-1}, suggesting that few saucer scallops survive more than 3 years (Dredge, 1985a; Heald & Caputi 1981). It is also assumed that the bulk of the fishery catch and the spawning biomass relies on a single year class based on the recruits into the fishery that survives into their first year.

Queensland's saucer scallop stock was first fished in the mid-1950s, when prawn trawlers working out of Hervey Bay took appreciable quantities (Ruello 1975). While annual landings have not shown the spectacular variation often associated with scallop fisheries (Hancock 1979), catch rates declined by an order of magnitude in the period 1980 – 1988 (Dredge 1988) and declined further in the mid 1990s (Williams 1997). The fishery is seasonal. Maximum catches and catch rates occur in early summer months, when young of year scallops recruit into the fishery and adductor condition are at its peak (Williams and Dredge 1981). Variable size limits apply to the fishery. A minimum size of 95mm shell length applies during winter and is decreased to 90mm during the summer months (1 November to 1 April). This has the effect of amplifying the early summer effort pulse (Dredge 1994).

Average catch rates observed in late 1996 and early 1997 were less than half of the 1988-1995 average for that time of the year. This decrease in catch rates was of sufficient concern to managers and fishers that emergency broodstock closures were gazetted. Resources were allocated for a large-scale survey designed to establish a baseline recruitment index of the saucer scallop resource. Additionally, data on scallop densities, size composition and distribution information was obtained. By the time of this workshop only one of these surveys have been completed.

4.3. SAUCER SCALLOPS WORKSHOP GROUP TASKS:

1. Value and cost of present preservation closures.
2. Value and cost of a possible winter/spring closure.
3. Standardisation of effort.
4. Stock assessment model.

4.3.1. VALUE AND COST OF PRESERVATION ZONES

This group was asked to investigate the long-term benefits of the preservation zones as well as the possibility of opening these preservation zones annually for a short period to remove old, senescent animals. The preservation zones have been introduced as spawning stock protection areas. The fishing industry has argued that, given the mortality rate of these animals, few of the adults that have spawned in one year would live to spawn in the next. In order to preserve these animals subsequent to the spawning period would therefore constitute a financial loss to the industry without benefiting egg and larval production. This group therefore investigated the value of the legal catch in the preservation zone at the time of the October 1997 survey and subsequently, also at the end of December as December was the proposed month for opening the zones. The October survey had sampled sites at intensities somewhat higher than the main fishing grounds and all scallops taken were measured to the nearest millimetre.

The length-frequency (in 10 mm classes, taking the mid-length of the class interval as the actual length of individuals within that class) summed over all trawl sites within the three preservation zones were calculated from the scallop data on size composition from the October 1997 survey. Since the length frequency of the total numbers in the preservation areas was required, the above measured frequencies were scaled to the proportion measured relative to total numbers caught. Total length-frequency over the whole zone would therefore be calculated as:

$$N^{T}_{l,October,r} = \frac{C_{l,r} A_r^{total}}{q A_r^{sampled}} \qquad : 4.1$$

where $N^{T}_{l,October,r}$ is the total number of scallops in size class *l*, in October 1997 in preservation zone, r,

A_r^{total} and $A_r^{sampled}$ are the areas (m^2) trawled (sampled) and the total area (total) of preservation zone, r,

$C_{l,r}$ is the number of scallops caught in size class *1*, in preservation zone r, and

q is the constant of proportionality, or catchability coefficient, estimated at 0.5 from Leslie-Delury experiments in Western Australia using similar gear (Joll & Penn, 1990)

Total meat weight (kg) was therefore calculated from month-specific length-weight conversions using Williams and Dredge (1981):

$$W^{T}_{l,October,r} = \frac{5.23E^{-6} l^{3.154}}{1000} N^{T}_{l,October,r} \qquad : 4.2$$

The value ($) of this meat weight per length class and region was calculated using Table 4.1.

Mid-length (l)	October Price ($)	December Price ($)
5	0	0
15	0	0
25	0	0
35	0	0
45	0	0
55	0	0
65	0	0
75	0	15.00
85	15.00	15.00
95	17.00	17.00
105	18.00	18.00
115	18.50	18.50

Table 4.1. Value of meat weight ($) defined for each length-class. This table was obtained from consultation with industry members within the group.

The resultant value of the resource was about $158 000, $1 581 000 and $310 000 for Yeppoon, Bustard Head and Hervey Bay preservation zones respectively. However, if the 90 mm minimum legal size were to apply, then the catch would be worth about $114 600, $1 330 000 and $238 000 for Yeppoon, Bustard Head and Hervey Bay respectively.

A von Bertalanffy growth function to convert length, *l*, to age, *a*, was used to calculate age structure of the October population in each class:

$$a_{October,l} = -\frac{1}{K}\ln\left(1-\frac{l_{October}}{L_\infty}\right) \qquad : 4.3$$

where K, the intrinsic growth rate was 0.05 week^{-1}, and L_∞, the asymptotic maximum length was 105.5 mm (Dredge, 1985b).

Animals in each length class that survive to December, would therefore be 9 weeks older and have grown in length from the von Bertalanffy formula:

$$l' = L_\infty\left(1-e^{-Ka_{December,l}}\right) \qquad : 4.4$$

where l' is the December length of length class, *l*.

Numbers in each length class in each preservation zone in December are therefore calculated by:

$$N^T_{l,December,r} = N^T_{l,October,r}e^{-9M} \qquad : 4.5$$

where M is the intrinsic natural mortality of 0.025 week^{-1} (Dredge 1985a).

As a result, the December meat value for each class can be calculated using data in Table 4.1. The resultant value of the resource in Yeppoon, Bustard Head and Hervey Bay was about $255 000, $2 115 000 and $434 000 respectively. However, if the 90 mm minimum legal size would apply, then the catch would be worth about $132 000, $1 538 000 and $274 000 for Yeppoon, Bustard Head and Hervey Bay respectively. The total legal standing stock value increased from $1 683 000 at the time of the October survey to $1 944 000 in the beginning of December. This means that the legal standing stock value at the time of the October survey was 86% of the standing stock value in December.

In this analysis, the cost to the fishery of the preservation zones has been interpreted as the loss of the legal standing stock value. Other costs have not been included. The value of the preservation zones has been introduced as a spawning stock refuge that will maintain the fishery through the maintenance of recruitment. The group concluded that it would be very difficult to assess the dollar value of the zones over the long-term as they did not know the relationship between the amount of stock preserved and the effect this has on the number of recruits the next year. However, they did propose that exposing the preservation zones to fishing pressure from 1 December could produce a $2.4 million dollar benefit to the fishery provided all the legal size scallop in the preservation zones were captured. Since most of these animals would not survive to spawn next year, it was proposed by this group that the fishery be allowed to fish animals larger than 90 mm shell length during December of each year in the preservation zones.

The group recommended that more in-depth analysis of this work would be beneficial. It would be necessary to simulate:

- the effects of handling induced mortality and shrinkage through chipping during the catch process;
- the possible level of recruitment that might be supplied by the preservation zones, given various spawner-stock-recruitment relationships;
- inter-year variability and the replenishment potential of various 'closure' areas;
- variation in meat value and meat quality through the months;
- changes in fishing pattern outside closure areas.

A large-scale simulation exercise would therefore be able to address these issues.

4.3.2. VALUE OF A POTENTIAL WINTER/SPRING CLOSURE

The issue under consideration by this group was that, while legally fishing for scallops greater than 95mm (the legal size during the winter months) the fishery catches large amounts of undersized scallops that must be returned to the water. This lead to undersize animals being damaged by shell chipping during catch sorting, which has two negative implications. First, the handling and chipping may result in the mortality of some of these small scallops. This is not considered to be a major problem (M. Dredge personal communication). The second, potentially more serious problem for the fishery, is that chipping to the shell could artificially decrease their size below the legal minimum, thereby increasing the period in which they are unavailable to the fishery.

The proposal being considered was that there be a winter/spring closure from 20 September to 1 November. The advantages include:

- A cessation of chipping by the high levels of effort required to capture the minimum legal size of 95 mm. This also implies there would be uninterrupted growth of animals and a consequent increase in meat yield;
- An improvement in the condition of the meat with a consequent improvement in the price (winter meat tends to have the poorest and lowest value);
- A financial gain from having no fuel costs incurred to take scallops in the closure;
- An increase in the number of animals greater than the 90 mm minimum legal size after November 1.

The disadvantages would include:

- a loss of revenue from the legal sized scallops captured during the proposed closed period;
- potential for harming the market share by failure to provide product during the closed period;
- natural mortality during the closed period would mean there would be some population decline.

The problem becomes one analogous to an analysis of yield-per-recruit. The industry would forego some earnings through the reduction in landings during the closed period. However, the potential exists for an increase in overall earnings through an increase in yield deriving from scallop growth and the avoidance of high levels of shell chipping, and the increase in the value of the catch through the improvements in meat condition.

To investigate whether the closure would be advantageous to the fishing industry required the group to determine the size distribution of scallops at the start of the proposed closed season. This then had to be projected forward the necessary six weeks first while omitting fishing mortality and the effects of chipping, second while including fishing as usual. By comparing the outcomes and value of the potential yield in each of these cases the merit of the proposed closure would be indicated.

The group used data from the October 1997 scallop survey within the preservation areas, which provided data from approximately the middle of October. This information was used to project the population backwards in terms of both relative numbers and growth to calculate the number and sizes of animals available at the beginning of the proposed closure. To project numbers backwards over time required estimates of natural mortality (because the original numbers were from inside the preservation areas fishing mortality could be ignored). To project the size structure backwards required growth data (L_∞ and K) and the repeated application of Equation 4.6, which describes inverse von Bertalanffy growth.

$$L_t = \frac{L_{t+1} - L_\infty\left(1 - e^{-K}\right)}{e^{-K}} \qquad : 4.6$$

where L_t is the length of an animal at time t,
L_∞ and K are the asymptotic constant, and the growth constant from the von Bertalanffy.

Once the starting position in terms of relative numbers in each size class was determined, the population was projected forward, again both in terms of numbers and size structure, using standard equations for growth and the application of natural mortality rates and fishing mortality rates. To follow changes in size structure required data on both the growth characteristics and also estimates of the probability of being chipped and by how much. In consultation with industry members, rough estimates on the extent of chipping from tagging data were used in the analysis to demonstrate the method. Once the forward projection was completed the relative numbers in each size class were translated into meat weight and their relative value determined and summed. Comparing the relative value from the population under conditions of closure and without the closure demonstrated that the total value of the fishery increased if a winter closure was put in place.

The analysis was carried out for the northern and the southern area separately as the growth characteristics of the scallops differs between the two areas. Data used was that collected from the preservation areas so as to have a sample of animals that had not been affected by fishing mortality. Without the existence of the preservation areas this analysis could not have been produced.

The assumptions about chipping and its prevalence mean that the particular conclusions of the analysis are only suggestive of the losses or benefits from the proposed winter closure. With the approximate calculations the analysis suggested that by closing the fishery for those 6 winter-spring weeks, the fishery would be enhanced in value by approximately $1 million. This figure ignores the savings introduced through the fishery not incurring fuel and crew expenses. This suggests that, as a minimum, more detailed investigation of shell chipping should be made to remove the crude approximations assumed by this initial analysis. The financial benefits to the fishery are, potentially, considerable.

This group concluded that a late winter-spring closure appeared to enhance the value of the fishery by approximately $1 million. It was recommended that the real value to the fishery be determined. To do this the impact of repeatedly landing the same undersized animals on their extent and degree of shell chipping should be investigated. Also, the relative value and condition of animals taken in September and October, relative to those taken in November should be formalised. Care must be taken to translate the research cruise measurements into those used by the commercial fishery. In the workshop, a rapid set of measurements provided an approximation of the relationship between the research and the commercial data.

4.3.3. EFFORT STANDARDISATION

Effective fishing effort continually increases in most fisheries, even though the number of licence holders or total number of days fished each year may remain constant. This continual 'effort creep' is characteristic of trawl fleets and is due to fishers adopting technological improvements in fishing practices, such as GPS and plotters. A recent study of the northern prawn fishery indicated that when GPS and plotters are used concurrently, relative fishing power increased by 7% over boats without such equipment (Robins et al. 1996). This technology creep will also apply to the scallop fishery and therefore affect the CPUE data. For this effect to be quantified, vessel characteristic information is required, including when certain technologies were incorporated into the fleet. In this study, vessel information was not available and therefore a number unique to each vessel ('vessel sequence number') was used as a surrogate.

A General Linear Modelling approach was applied to daily catch and effort records. Daily catch and effort data from 1988 to 1997 was extracted covering the area from 25° to 22.5°S. Factors that were considered to affect catch rate (baskets.day^{-1}) were year, month, vessel-sequence-number and year-month interaction. The preliminary result is presented in Figure 4.1 below and shows that the real decline in recent years is greater than the unstandardised data exhibits. The decline in standardised catch rates over time is not significantly different from zero. Furthermore, several highs and lows are not emphasised in the standardised data. It should be pointed out that this analysis is severely restricted by the lack of specific vessel characteristic data and it was recommended that this information be obtained.

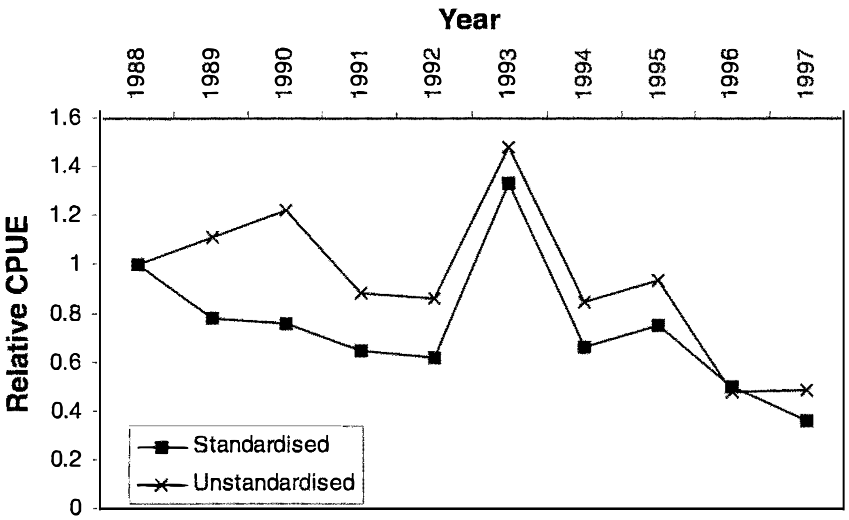

Figure 4.1. *Unstandardised and standardised relative catch rates of scallop data from 1988 to 1997. Factors considered were year, vessel sequence number, month and year-month as an interaction.*

Due to the size of the database and the restricted time, a larger, more detailed model was only proposed. For this model, it was recommended that the fishing year should start in November since this is the month at which the legal minimum size decreases to 90 mm shell height. Total effort in a month should also be included as it was considered possible that fishing effort becomes less efficient as competition for the resource increases i.e. catch sharing. The year-month interaction should be replaced with month as a factor nested in year. Vessel characteristic data, especially GPS with plotters (guessed as a 10-20% effect over the total period), try gear (≤ 25% over the period), engine power (about 20% difference) and net size/configuration changes (which could have affected the catch rate by 25%, but would have been a factor prior to this database in the late 1970s), should be considered. Further factors that could have affected the catch rates are responses to management and spatial effects (which could be captured by QFISH Grids). This larger model is more likely to capture the complexities of the catch rate data.

Although most of the daily catches recorded are ≤ 50 baskets (a 'basket' contains about 500–600 scallops which is 3–7kg of meat depending on season and meat condition), some large daily catch values were noted. These should be investigated (Figure 4.2). It may be necessary to remove some of these extremes, as they may actually be data recorded in kilograms rather than baskets. Due to historical problems in the CFISH database, all catch data entered into the 'weight' column of the CFISH system have been combined with those in the 'number' column and interpreted as being in the units basket. At present, we are unable to discern between records that may be in kilograms or in baskets, although the majority of the data are most likely to be baskets. This problem was highlighted to QFMA prior to the workshop.

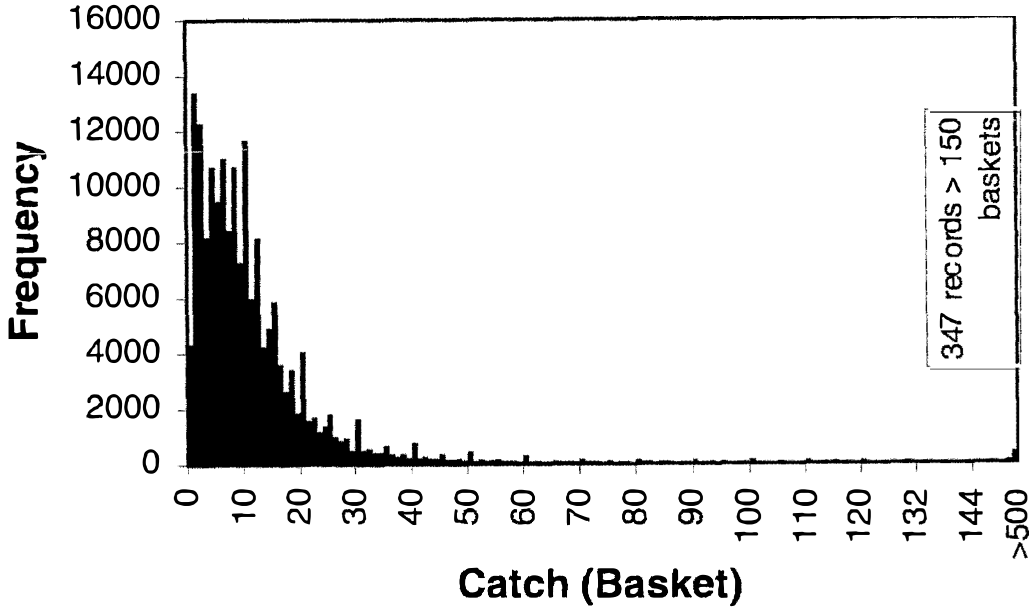

Figure 4.2. *Frequency distribution of daily catches in baskets. This data is a combination of catch in the CFISH 'weight' and 'number' column. Catches greater than 150 are more likely to be incorrectly assumed to be in baskets. Note that there are 347 records with catches greater than 150 'baskets', with two records being greater than 1000 'baskets'.*

4.3.4. STOCK ASSESSMENT

This group had to provide an estimate of biomass and yearly recruitment given available data of commercial catch and effort, the October 1997 survey estimate of total numbers, and tagging information from the same survey. Catch was converted from baskets to numbers using 500 as the conversion factor (Dredge personal communication.). An age-based model was developed keeping track of 1,2,..,12 month old animals and thereafter older animals fall into a 1 plus group (a=13). The latter group was seen as being fully recruited to the fishery.

The full model fits eighteen parameters, minimising the negative log-likelihood:

$$L_{total} = L_f + L_c + L_s = L_t \qquad :4.7$$

where each of the components are described below.

4.3.4.a Initial numbers

Initial numbers for ages 1 in January 1988 is:

$$N_{1988,1,1} = \Phi_1 \hat{R}_{1988} \qquad :4.8$$

where $N_{1988,1,1}$ is the total population in year 1988 for the month January of age 1,

Φ_1 is the birth patterns in month 1 (described in sub-section 'recruitment pattern'), and
$\hat{R}_{1988}$ is the estimated recruitment for year 1988.

Numbers for ages 2 to 12 were calculated as follows:

$$N_{1988,1,a} = \hat{R}_{1987}\Phi_m e^{-M(a-1)} \qquad : 4.9$$

where $N_{1988,1,a}$ are the total population numbers in year 1988 for January age a,
$\hat{R}_{1987}$ is the estimated recruitment for year 1987,
Φ_m is the birth pattern in month m described below (m = a), and
M is the natural mortality,

and for the 1+ group:

$$N_{1988,1,13} = N1 \qquad : 4.10$$

where N1 is the estimated numbers of age 1+ in 1988.

4.3.4.b Dynamic processes

The time dynamic component was calculated by:

$$N_{y,m,a} = \begin{cases} R_y\Phi_m \text{ for a} = 1 \\ N_{y,m-1,a-1}e^{-M}\left(1 - S_{m-1,a-1}F_{y,m-1}\right)\text{for a} = 1..12 \\ N_{y,m-1,12}e^{-M}\left(1 - S_{m-1,12-1}F_{y,m-1}\right) + N_{y,m-1,13}e^{-M}\left(1 - S_{m-1,13-1}F_{y,m-1}\right)\text{for a} = 13 \end{cases} \qquad : 4.11$$

Annual fishing mortality, $F_{y,m}$ was calculated as:

$$F_{y,m} = \frac{C_{y,m}}{\sum_a S_{m,a}N_{y,m,a}} \qquad : 4.12$$

where $C_{y,m}$ is the catch for year, y, and month, m, taken from CFISH, and
$S_{m,a}$ is the knife-edge selectivity by age and month, which includes the change in minimum legal size over the year.

If $\sum_a S_{m,a}N_{y,m,a} < C_{y,m}$, then $F_{y,m}$=0.999 and added to the likelihood as:

$$L_f = L_f + \left(\sum_a S_{m,a}N_{m,a} - C_{y,m}\right)^2. \qquad : 4.13$$

4.3.4.c Recruitment pattern

$$\Phi_m = e^{\left[\frac{-(m-mean\_r)^{2slope\_r}}{(2\,var\_r)}\right]} \qquad : 4.14$$

where mean_r, slope_r and var_r are recruitment parameters to be estimated.

The resultant recruitment pattern was normalised to 1.

4.3.4.d Catch per unit effort

Mid-month numbers, $P_{y,m}$, were calculated as:

$$P_{y,m} = \sum_a S_{m,a} N_{y,m,a} - \frac{C_{y,m}}{2} \qquad : 4.15$$

Estimated catch-per-unit effort is calculated as:

$$\left(\frac{\hat{C}}{E}\right)_{y,m} = \ln\left(qNov\_rP_{y,m}\right) \qquad : 4.16$$

where q is the estimated catchability coefficient,
Nov_r is the November (only) adjusted catchability coefficient.

The negative log-likelihood function for the catch and effort data, assuming CPUE is log-normally distributed, therefore becomes:

$$L_c = nLn\left(\sqrt{2\pi}\hat{\sigma}\right) + \frac{n}{2} \qquad : 4.17$$

where n is 12 months*10 years and $\hat{\sigma}$ is calculated as:

$$\hat{\sigma}^2 = \frac{1}{n}\sum_y\sum_m\left[\ln\left(\frac{C}{E}\right)_{y,m} - \ln\left(q\left(\sum_a S_{m,a}N_{y,m,a} - \frac{C_{y,m}}{2}\right)\right)\right]^2 \qquad : 4.18$$

where q is the estimated catchability coefficient.

4.3.4.e Independent survey

An independent survey was undertaken in October 1997, with a resultant absolute index of abundance and confidence intervals. The constant of proportionality of the survey was estimated by Leslie-DeLury trials using similar gear in Western Australia (Joll & Penn, 1990). As a result, the numbers fit was estimated within range of this value by adding to the likelihood function i.e.

$$L_s = \frac{\left(\ln\left(N_{1997,10,5}+N_{1997,10,6}\right)-\ln\left(N^{survey,obs}_{1997,10,juveniles}\right)\right)^2}{2\sigma^2_{survey,juveniles}} + \frac{\left(\ln\left(\sum_{a=7}^{13} N_{1997,10,a}\right)-\ln\left(N^{survey,obs}_{1997,10,adults}\right)\right)^2}{2\sigma^2_{survey,adults}}$$

: 4.19

where $N^{survey,obs}_{1997,10,juveniles}$ are the 'observed' juvenile (0-year olds) numbers from the survey,

$N^{survey,obs}_{1997,10,adults}$ are the 'observed' adult (1+ year olds) numbers, and

$\sigma^2_{survey,adults}$ and $\sigma^2_{survey,juveniles}$ are the survey variance for the adult and juvenile estimate respectively.

4.3.4.f Tag model

Tagged scallops were measured and released during the October 1997 survey and the return data was available for analysis. Tag animals were assigned an ages 1 to 12 months and a 13th plus group (i.e. more than one years old) based on a von Bertalanffy growth curve with parameters L_∞, K and t_0 of 105.5 mm, 0.05 week^{-1} and 0 years respectively (Dredge, 1985b). Numbers were updated per month in a similar manner to the dynamic model i.e.:

$$N^t_{y,m+1,a+1} = \begin{cases} 0 \text{ for a} = 1 \\ N^t_{y,m,a}\left(1-S_{m,a}F_{m,a}\right)e^{-M} \text{ for a}+1=2 \text{ to } 12 \\ N^t_{12}+N^t_{y,m,13}\left(1-S_{m,13}F_{m,13}\right)e^{-M} \text{ for a}=13 \end{cases}$$

: 4.20

Estimated tag returns were calculated by:

$$C^t_{y,m} = \sum_a S_{m,a} N^t_{y,m,a} F_{y,m}$$

: 4.21

where $N^t_{y,m,a}$ and $C^t_{y,m}$ are the predicted numbers of tagged animals and the predicted numbers of tagged animals caught respectively.

The tag likelihood function (L_t) therefore is described below:

$$L_t = \sum_y \sum_m - C^t_{y,m} + C^{t,obs}_{y,m} + C^{t,obs}_{y,m} \ln\left(\frac{C^t_{y,m}}{C^{t,obs}_{y,m}}\right)$$

: 4.22

where $C^{t,obs}_{y,m}$ is the observed tag returns in month, m an year, y.

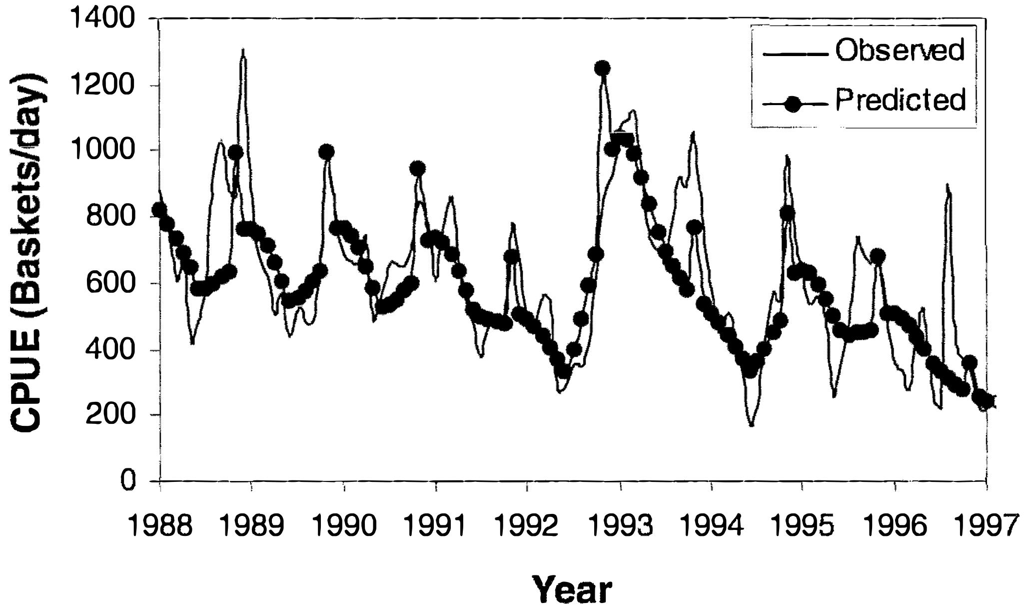

Figure 4.3. *Model fit 'Predicted' to the 'Observed' catch rate data from 1988 to 1997 between latitudes 22.5°S and 25°S from CFISH. Note that the annual peaks observed are generally predicted by the model, with the notable exception of 1997. The 1997 trends are influenced by an independent survey treated as an absolute index of abundance.*

4.3.4.g Results

A fit to the observed catch rate data and tagging data are given in Figure 4.3 and 4.4. Although the work is still at a very early stage, a surprisingly good fit to the data was produced. Estimates of recruitment ± 1 standard deviation are given in Figure 4.5.

These show that the survey data is instrumental in providing estimates of recruitment with narrow confidence intervals, whereas the early years are estimated with less confidence. Narrower estimates will be possible if additional data, such as small-scale surveys completed in 1988–89, are incorporated to this model. The group suggested that a large-scale model be developed that incorporates size information and also is spatially explicit.

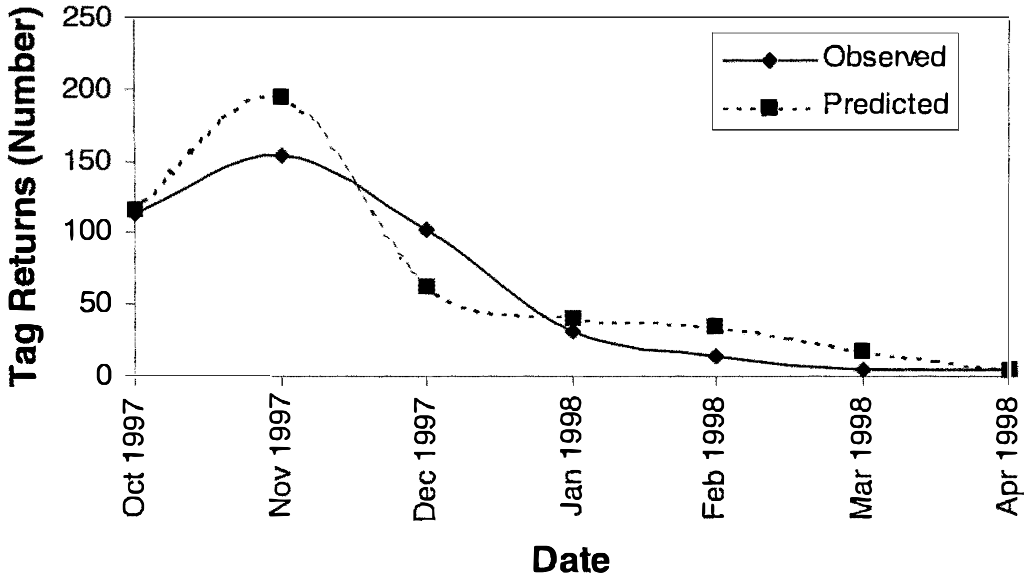

Figure 4.4. *Model fit, 'Predicted' to 'Observed' tag returns data. Tagged animals were released during the October 1997 independent survey over the whole survey area. Tags were returned by the fishing industry. Animals tagged in the preservation zones have not been included in this analysis.*

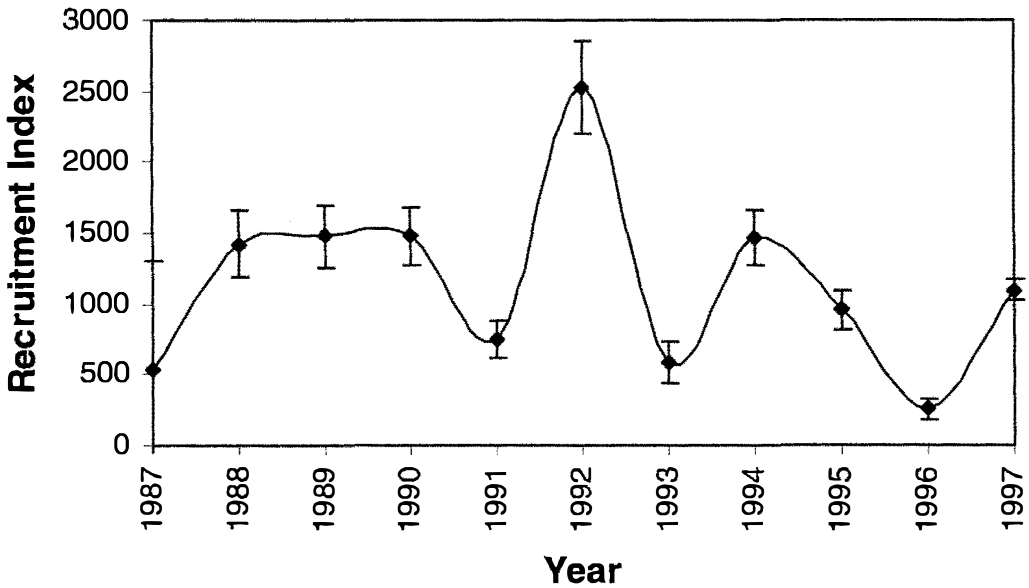

Figure 4.5. *Model estimates of recruitment ±1 standard deviation. As expected, the largest uncertainty in the estimate is the 1987 initial recruitment estimate.*

4.4. CONCLUSIONS

4.4.1. GROUP REPORTS

Preservation zones, that are closed to fishing, have been established in the fishery as a spawning stock refuge. A model was developed to investigate cost implications of these closures. This demonstrated that opening these zones in December to expose animals larger than 90 mm (shell height) to fishing pressure could produce a maximum $2.4 million dollar benefit to the fishery. The cost to the fishery of the preservation zones was interpreted as loss of the legal size standing stock value.

A simulation model was also used to test the benefits and costs of a winter closure from 20 September to 1 November. At present, animals larger than 95 mm shell height can legally be fished during that period. The model considered shell chipping during the catch process, growth rates, meat condition and price per kilogram of meat over time. This preliminary analysis concluded that a late winter/spring closure of the whole fishery would enhance the value of the fishery by approximately $1 million dollars. There are also implicit savings associated with such a closure e.g. in reduced operating costs.

A generalised linear model was applied to standardise the CFISH logbook catch rate data. This group highlighted problems with the catch data being entered in the numbers and basket columns interchangeably. This problem seems to be more chronic in the early years of the database. No vessel characteristic data was available and therefore a unique boat number, "vessel sequence number", was used as a surrogate. A peak in standardised catch rates in 1993 and thereafter a serious decline to historically low levels in 1997 was evident.

A relative age model that utilises unstandardised catch rate, independent survey and tagging data was used to estimate yearly recruitment levels. The survey data was instrumental in providing recent year's estimates of recruitment with narrow confidence intervals. It confirms the high recruitment in 1992 (corresponding to a high catch rate in 1993) and a decline to historically low levels in 1996. The slight recovery of recruitment in 1997 may be debateable, as the standardised catch rate series does not confirm this upward trend in the unstandardised data.

The independent survey was seen as fundamental to the on-going sustainable management of the resource. A clear decline in catch rates and estimated annual recruitment highlights the possibility of unsustainable catch levels. Three preservation zones were instituted in early 1997 to address this situation. The independent surveys have demonstrated that these zones protect a significant proportion of the scallop population. At this stage it is not clear whether or how these areas, in fact, seed the remaining fishing grounds.

4.4.2. PROGRESS TO DATE

A summary of progress to date in terms of data quality and stock assessment knowledge is given in Table 4.3.

Category		Comments
Commercial	Catch	Potentially serious problems with the data as the catch has been entered in the basket or kilogram units columns interchangeable and incorrectly.
	Effort	Fairly good, but unchecked data.
	Catch rate	Historical data from voluntary logbook programs and other studies would extend the data to 1977, but is unavailable for analysis because the database entry is incomplete and unchecked. Data resides with QFMA. There is an urgent need to have the data developed and made available. Catch and effort series for 1977 to 1980 is available.
Recreational	Catch, effort and catch rate	N/.
Independent index of biomass or recruitment		Large-scale independent survey since 1997.
Estimates of natural mortality		Good estimates of maximum natural mortality, but none are recent. Given changes in fishing levels and present changes in benthic community structure, this should be re-estimated.
Estimates of fishing mortality or biomass		Some estimates of F from tagging data. Relative age model developed in workshop, estimates annual recruitment levels.
Input controls		Limited entry, gear restrictions, preservation zones, hull unit controls and size limits.
Output controls		None.
TACC Decision rules		N/A.
Performance indicators		Broad and untested performance indicators in draft Management Plan.

Table 4.2. Summary of progress to date on data quality, stock assessment and management knowledge.

4.4.3. MONITORING, RESEARCH DIRECTION AND PRIORITIES

a. Highest priority was given to the scallop survey. The 1997 survey provided so much valuable data that it ought to be continued, ideally every year. It is, however, a costly project and will require financial support from the industry.

b. Improve our understanding of the relation between fishery performance indicators and CPUE data. In the current management plan it is proposed to put in place performance indicators determined by CPUE, but the usefulness of this approach has yet to be demonstrated — CPUE may not be strongly related to stock abundance. This project should have a high priority

c. Use VMS data capture to provide detailed stock assessment information. With the introduction of VMS to the trawl fleet the potential for its use to gather information on fleet dynamics and the distribution of effort would be of tremendous value in monitoring the status of the stock. This will be difficult to develop but should have a high priority as, if it proves successful, it could in the long run have a high return for a low cost. A detailed study of the fleet dynamics and effort distribution in the scallop fishery and management systems using serially closed areas could be used to optimise the value of the scallop catch.

d. A stock assessment of the scallop resource has been shown to be possible. This work needs to be upgraded to a more complex model that investigates the spatial aspects of this fishery as well as potential future management options. Useful extensions include; an improved analysis of the effects of handling-induced mortality and shrinkage through chipping during the catch process; determination of recruitment levels by studying the preservation zones (given various spawner stock-recruitment relationships); inter-annual variability and the replenishment potential of various 'closure' areas; variation in meat value and meat quality through the months, and; changes in fishing pattern outside closure areas.

e. Characterise the growth of scallops by region (latitude). In the workshop it was shown that by taking advantage of closed areas at the right time of year, millions of dollars could be added to the value of the catch. These analyses are strongly influenced by the growth characteristics in each region (which is known already to vary by latitude). Characterising growth by region should therefore have a high priority. This should be tied in with completing the closure work done by Group 1 and 2 in this workshop and may be captured by the model recommended above.

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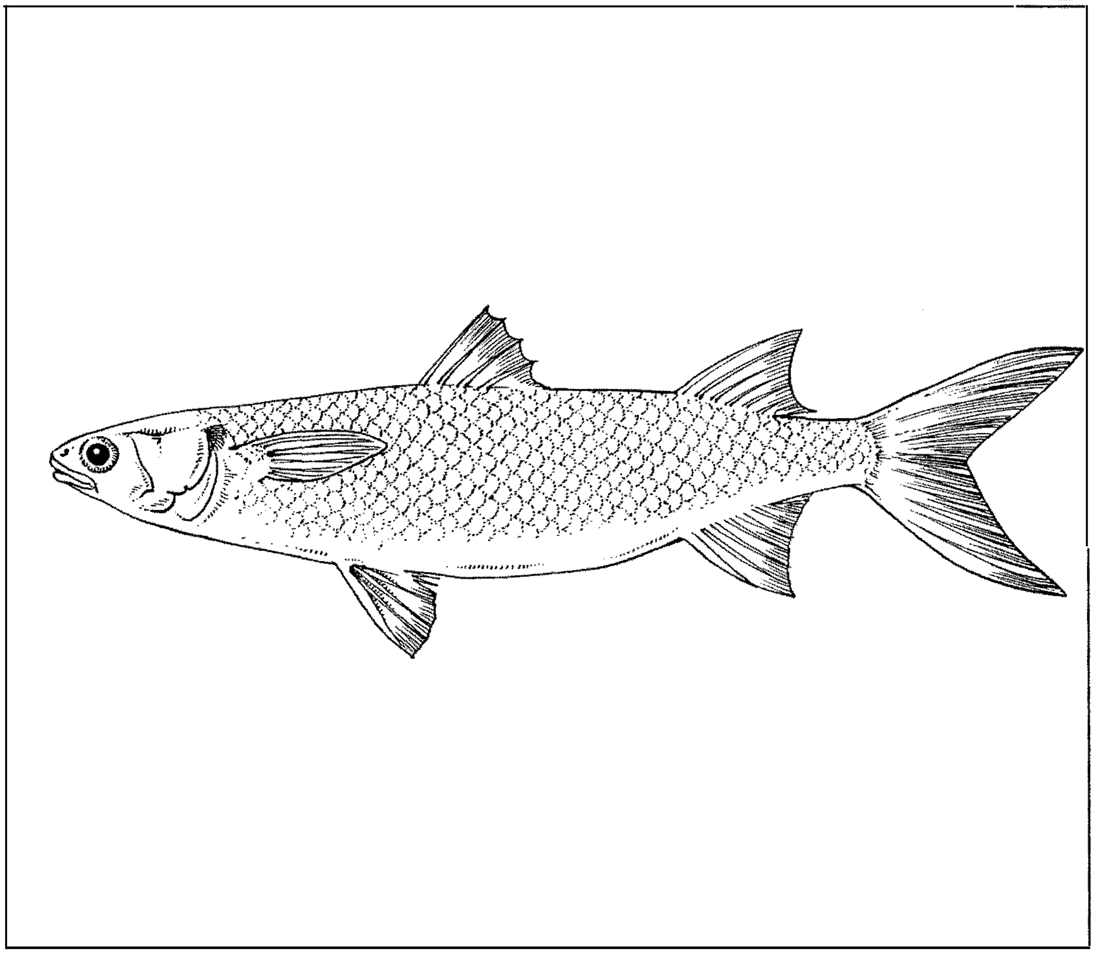
common name

SEA MULLET 5



Mugil cephalus

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5.2. INTRODUCTION: SEA MULLET IN QUEENSLAND AND NEW SOUTH WALES

5.2.1. FISHERY STATISTICS

The sea mullet (*Mugil cephalus*) is an important commercial fisheries resource in Queensland and New South Wales.

In Queensland, sea mullet sustains the largest single finfish fishery and are the mainstay of the fresh fish trade. There are 1 039 licensed net fishers in Queensland with 300 of these targeting sea mullet as one of their principal species. Approximately 60 of these operate in Moreton Bay. The fishery extends from the New South Wales–Queensland border north to Townsville. About 1 800 t is caught annually between the border and the northern tip of Fraser Island with a further 200 t caught between Fraser Island and Townsville. The major sea mullet fishing areas are Fraser Island, the Sunshine Coast beaches, Moreton Island, North Stradbroke Island and Moreton Bay. The latter three account for about half of the total annual catch. Excluding the period from 1970 and 1987, the annual sea mullet catch from 1943 to 1995 has ranged from 1 241 t in 1960 to 2 686 t in 1988, with an average catch of 1 886 t (Figure 5.1).

In New South Wales, catches have increased from about 3 000 to 4 000 t in the last 15 years. While the estuarine component of the catches has remained at about 2 000 t, the ocean beach component has increased from about 500 t per annum to 2 000 t over the last 15 years (Figure 5.2). This component of the fishery is comprised largely of sea mullet migrating to spawn and has increased as a result of a growing market for sea mullet roe.

The key point about the ocean beach component of the sea mullet fishery is that it targets the mature and pre-spawning population. We do not have sufficient information to predict the consequences of the recent increases in the oceanic catch of sea mullet. However, management and industry will become increasingly vulnerable to the problems associated with over-exploitation if this increasing trend in

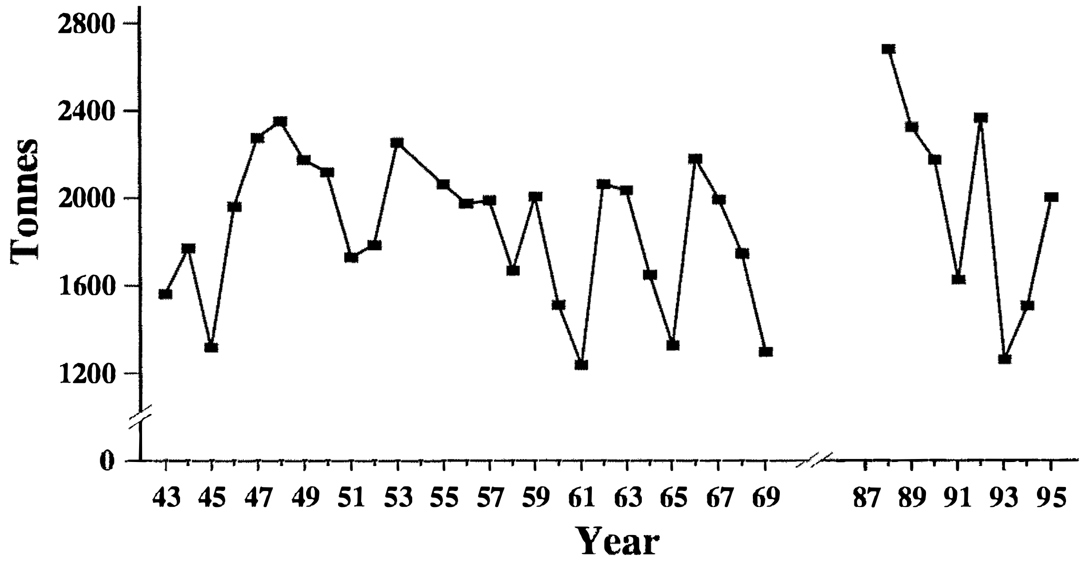

Figure 5.1. *Total commercial catch of sea mullet in Queensland waters. Overall average catch is 1 886 t. Note the breaks in both axes.*

harvest continues without due regard for the conservation of the stock, and the maintenance of recruitment levels.

5.2.2. VALUE OF THE FISHERY

The Queensland fishery is valued at 7 to $8 M per annum. The estuarine catch is valued at ~$2.3 M and the ocean beach catch is valued at ~$5 M. Half of all spawning fish caught for roe are taken by the 70 fishers licensed in the ocean beach fishery with the other half caught by fishers in estuarine areas. While it once made up a substantial part of the fishery, the value of the 'hard-gut' component has decreased to less than $0.2M in the last 15–20 years. ('Hard-gut' is non reproductively active mullet that migrate during summer [Dec–Feb])

The New South Wales fishery is valued at approximately $11.4 million per annum to the fishers, with approximately 870 fishers and about 380 taking 90% of the catch. The estuarine sector of the fishery is valued at about $4.1 million and involves some 770 fishers. The ocean beach sector is valued at approximately 1.8 times ($7.3 million) that of the estuary sector and involves only half (380) the number of fishers. Almost half ($5.2 million) of the value of the total fishery in New South Wales is from spawning run catches on ocean beaches in the central and mid north coast during April and May.

5.2.3. COMPONENTS OF THE QUEENSLAND FISHERY

The Ocean Beach Fishery is a specifically designated fishery, under different management from the remainder of the east coast net fisheries in Queensland. It is a limited entry fishery with 70 licences endorsed to fish on the ocean beaches between the Queensland – New South Wales border and the northern tip of Fraser Island from the 1st April – 30th August each year. This fishery primarily targets the spawning run of sea mullet. 70–80% of the total sea mullet catch for Queensland is taken during the ocean beach season from April to August (Figure 5.3) with 33% of the total catch taken during June. About half the catch

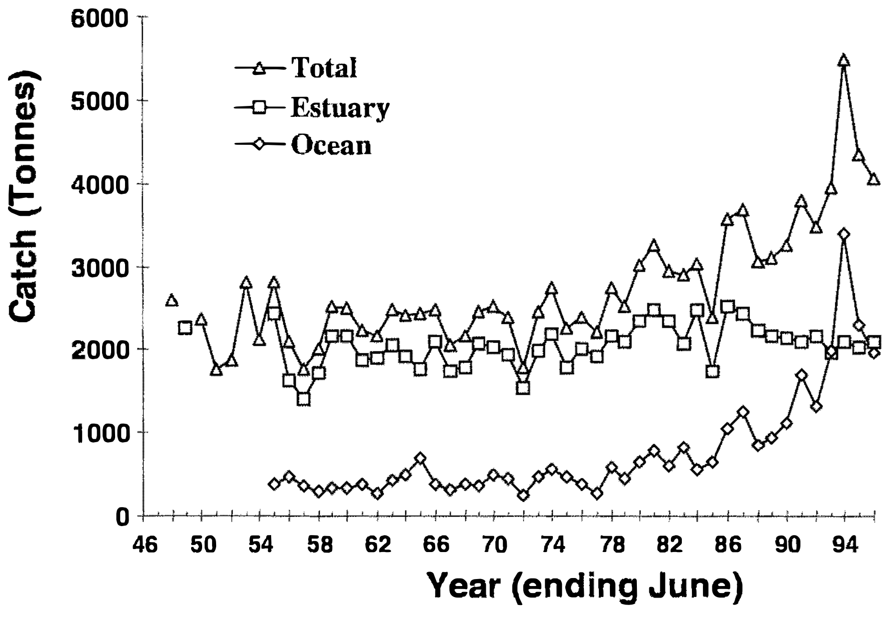

Figure 5.2. *Commercial catches of sea mullet from New South Wales showing the ocean beach and estuary catches from 1955–56 to 1995–96 and total catch from 1947–48 to 1995–96.*

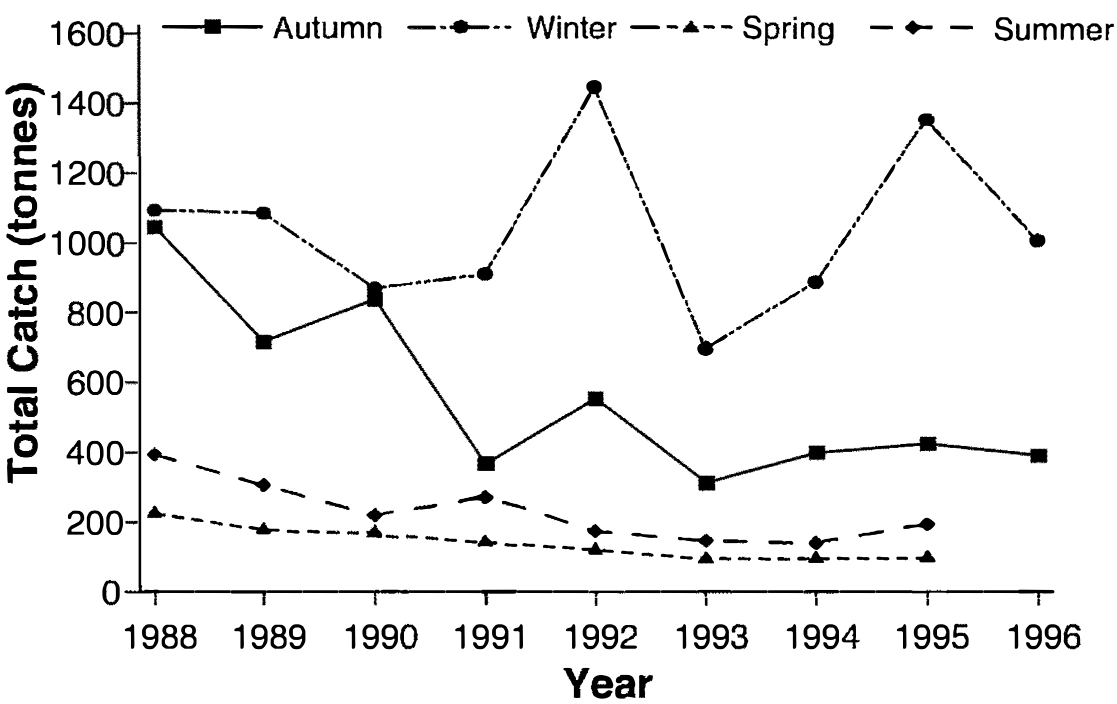

Figure 5.3. *Seasonal changes of commercial sea mullet catches in Queensland. The dominance of winter and autumn is clear. Autumn is defined as March through May, Winter is June through August, Spring is September through November and Summer is December through February.*

during the ocean beach season is taken in estuaries, rivers and areas outside the designated ocean beach fishery. Most of the latter is in spawning condition, and is sold for roe at prices similar to those received by the ocean beach fishers.

The estuarine fishery for sea mullet catches about 25% of the total sea mullet in landed in Queensland. Fishers in this fishery often operate as individuals or in pairs to take mullet in gill and tunnel nets. They provide about 80 t of meat to local markets throughout Queensland in all months other than in the spawning season. Catches from estuaries are usually lowest in spring, immediately after the winter spawning run, with increasing catches throughout summer and into autumn (Figure 5.3).

5.2.4. AGEING

Ageing studies indicate that the opaque rings observed in thin sections of the otoliths (ear bones) in sea mullet are formed annually. The ages of sea mullet in commercial catches range from 2 to 12 years and are dominated by ages 2 to 6 years in Queensland and 3 to 7 in New South Wales. Estuary catches have higher proportions of younger fish and lower proportions of older fish than spawning run catches. On average the females were larger than males in the catches. This difference in size is attributed more to faster growth in females than a difference in the age structure of catches between the sexes.

5.2.5. SIZE AND AGE STRUCTURE

5.2.5.a. Catch structure – estuary and ocean beach

In total 10 432 sea mullet were measured from the 6 sites in Queensland. Of these, 2 286 were returned to the laboratory for further

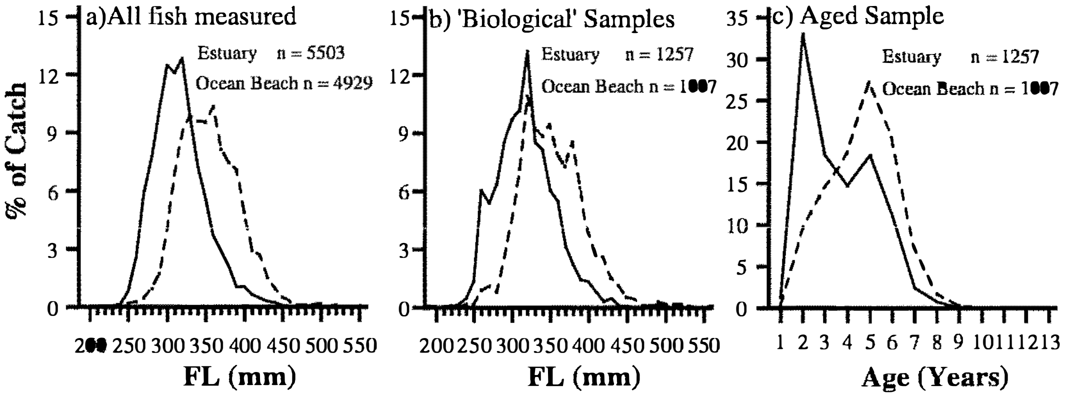

Figure 5.4. *Size and age distribution of sea mullet from Queensland estuary and ocean beach catches. Data was derived from **a)** all field length measurements, **b)** lengths of fish from samples obtained from 6 sites in Queensland and kept for biological analysis in the laboratory ('biological samples') and **c)** ages of these biological samples. Solid lines represent Estuarine fisheries whicle dashed lines represent Ocean Beach fisheries.*

biological examination and 2 264 were successfully aged.

Sea mullet taken in estuarine catches were generally smaller than those taken in ocean beach catches (Figure 5.4a). The average size for estuarine caught mullet was 315 mm FL and for ocean beach mullet 353 mm FL. The proportion of the catch over 370 mm FL in the estuarine catch was 9% whereas in the ocean beach catches it was 37%. Estuarine caught sea mullet ranged in size from 190 to 490 mm FL. Ocean beach caught sea mullet ranged in size from 210 mm FL to 560 mm FL. Associated with the differences in size structure of the catch was a noticeable difference in the age structure. Fifty three percent of the estuarine catch was less than 4 years old while 25% of the ocean beach catch was less than 4 years old (Figure 5.4c).

5.2.5.b. Estuary catches

The average size of fish caught in estuaries was 313 mm FL in 1995 and 316 in 1996 mm FL (Figure 5.5a). Females were larger than males with

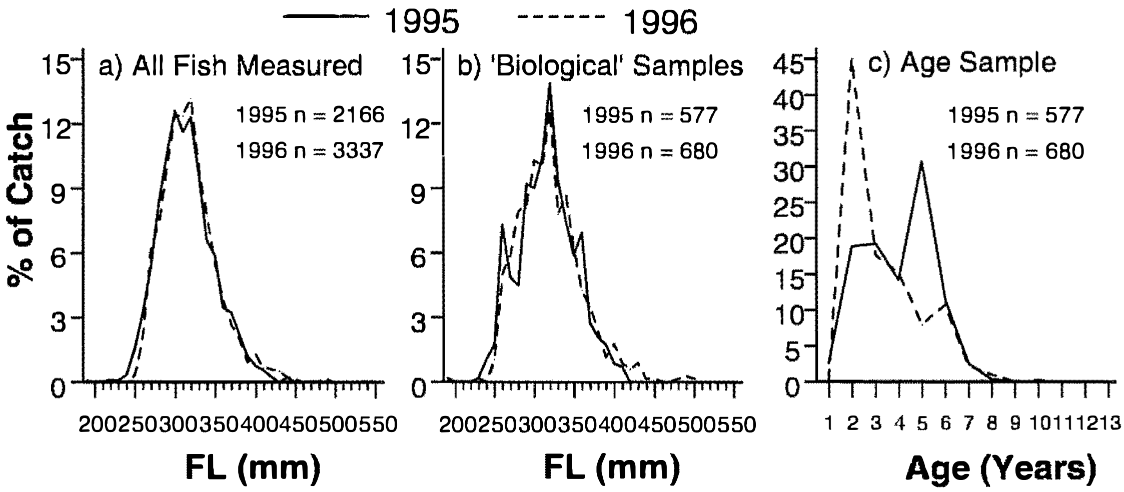

Figure 5.5. *Size and age distribution of sea mullet caught in the Queensland estuary fishery in two separate years. Data was derived from: **a)** all length measurements; **b)** lengths of biological samples; **c)** ages of biological samples.*

average sizes of 325 and 313 mm FL respectively. Juvenile fish contributed about 10% of the catch for both years and were smaller than males and females with an average size of 279 mm FL. Many of the juvenile mullet caught had reached the legal size and had entered the fishery, however many were still sexually immature.

The age structure of the estuarine caught fish was dominated by 2–7 year old fish, with females dominating the older age classes. There were also large differences in age structure between years. In 1995 catches were mainly comprised of fish between 2 and 6 years old with 5 year olds dominating the male catch and 2 and 5 year olds dominating the female catch. The 1996 catch was dominated by 2 year old fish, newly recruited to the fishery in that year (Figure 5.5c). An interesting and important feature to note about this difference in age structure between years is that the differences are not reflected (Figure 5.5a) by the size distribution of the catch.

Estuarine catches of fishers working in the Moreton Bay and Maroochy River fisheries catch similar sized fish taken while the fish at the Tin Can Bay site were smaller. Average sizes for fish from each of the sites was 323 mm FL in Moreton Bay, 326 mm FL in the Maroochy River and 301 mm FL in Tin Can Bay. At the Moreton Bay and Maroochy River sites male and female fish were common between the ages of 2 and 6 years with juveniles less than 5 years old making up about 7% of the total catch. The smaller size of the sea mullet caught at Tin Can Bay is reflected in the age composition with the majority of the catch being less than 4 years old.

5.2.5.c. Ocean beach catch

The average size of female fish was between 45 and 50 mm larger than the males at all sites with females averaging 375 mm FL and males 327 mm FL.

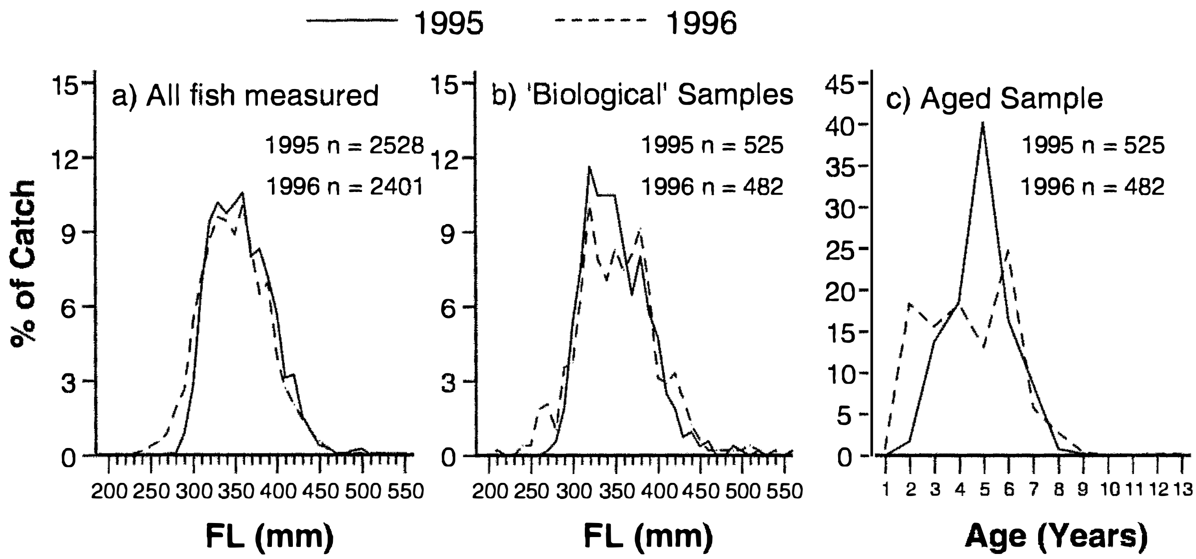

Figure 5.6. *Size and age distribution of sea mullet caught in the Queensland ocean beach fishery in two separate years. Data was derived from:* ***a)*** *all length measurements;* ***b)*** *lengths of biological samples;* ***c)*** *ages of biological samples.*

The age structure of the ocean beach catch shows that fish from 2 to 8 years old are commonly caught in the fishery. Fish over 6 years old were usually large females. The 1995 ocean beach season was dominated by 5 year old fish. The 1996 season was not dominated by any particular age class, however, it is interesting to note that about 17% of the catch in this year was of 2 year old fish, reflecting the pattern observed in the estuarine fishery (Figure 5.6c). The 2 year olds caught in the ocean beach fishery would have been newly recruited fish that had matured early, resulting in their participation in the spawning run. Fish caught at Fraser Island showed a greater proportion of 2 and 3 year olds while 4, 5 and 6 year olds were dominant at the Sunshine Coast and Stradbroke Island. Both male and female sea mullet caught in the ocean beach were represented in older age classes than those caught in the estuarine fishery.

5.2.6. REPRODUCTION

The proportion of sea mullet involved in spawning runs increases from age classes 3 to 6. It is likely that spawning occurs in oceanic waters over a range of latitudes along the East Coast of Australia. Advanced stages of reproductive development in females and males were found at all sites in Queensland and New South Wales, but no running ripe females were found in commercial catches. Therefore there is still no definite answer for the question 'Where do mullet spawn?'

Gonad development of Queensland sea mullet begins in autumn with increases evident in both male and female GSI by April. Maximum GSI (i.e. the proportion of body weight that is gonad) was attained in both sexes between June and August with a return to low values by October. Male GSI during the peak spawning period averaged 6.7% with a maximum of 13.9% and females during the same period averaged 17.0% with a maximum value of 24.6%.

5.2.7. MOVEMENT

A total of 2425 sea mullet were tagged and released in New South Wales waters during 1995 and 1996 (Figure 5.7). To the end of August 1997, 108 (5.8%) recaptures had been reported out of 1877 tagged and released in 1995 and 59 (10.8%) out of 548 tagged and released in 1996 (Table 5.1).

Location	Number tagged in 1995	Number recaptures reported by August 1997	Number tagged in 1996	Number recaptures reported by August 1997
Tweed Heads (Hard-gut)	355	17	-	-
Tweed Heads (Spawning run)	653	22	277	25
Port Stephens (Spawning run)	287	23	162	8
Clarence River	495	39	72	25
Shoalhaven River	87	7	37	1
Total	1877	108	548	59

Table 5.1. Numbers of sea mullet tagged at various locations on the east coast of Australia between 1 January and 31 June 1995 and the numbers of reported recaptures up to August 1997.

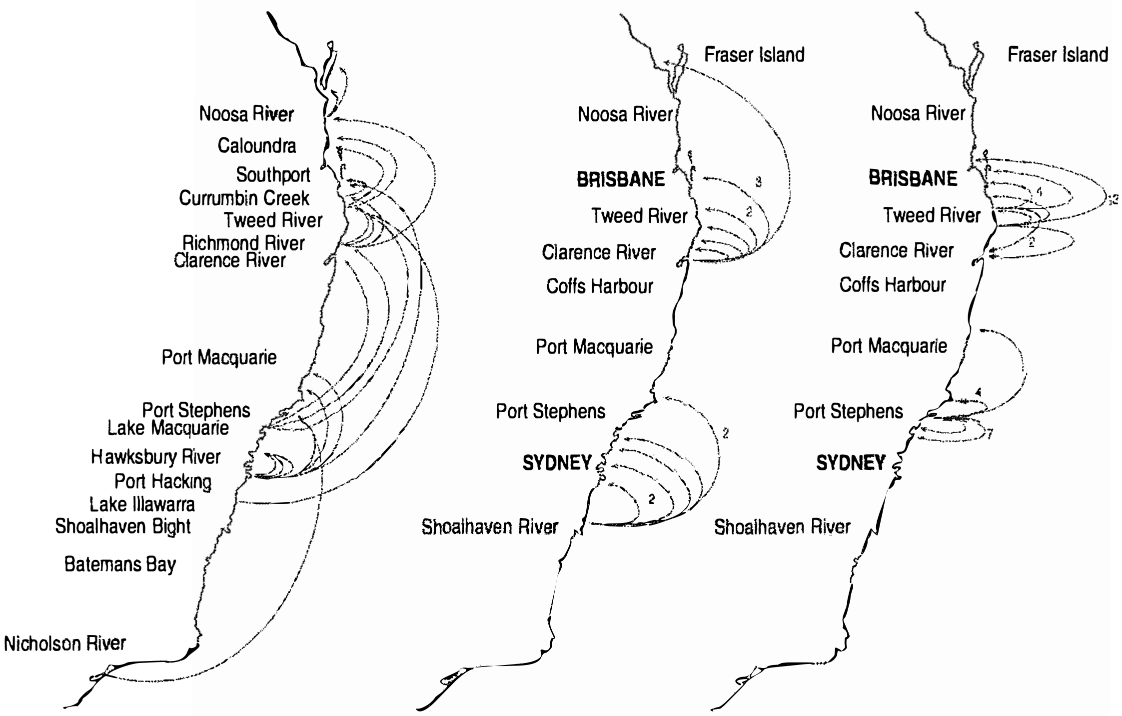

Figure 5.7. *Map showing the movements of recaptured sea mullet in:* ***a)*** *a previous study (Kesteven 1953);* ***b)*** *estuary releases;* ***c)*** *ocean beach releases in this study.*

Tagging of sea mullet in New South Wales during 1995 and 96 showed both northerly and southerly coastal movements. Sea mullet tagged in estuaries were recaptured in or north, but not south, of the estuary of release (Figure 5.7b). This is a similar result to that in a previous sea mullet tagging study (Kesteven 1953) on the coast of New South Wales. In this previous study, the recorded coastal movements of sea mullet which were tagged mostly in estuaries, were predominantly northward (Figure 5.7a).

Sea mullet tagged during spawning runs on ocean beaches have been caught north and south of the release site during or after spawning migrations (Figure 5.7c). There were many examples of sea mullet tagged during spawning runs and recaptured in the same or following spawning seasons. Several sea mullet tagged on Stockton Bight in the 1995 and 1996 spawning seasons were recaptured at the same stretch of beach in the following season.

5.2.8. ASSESSMENT OF THE LEGAL SIZE.

Male sea mullet mature at about 270 mm fork length or a total length of 304 mm. Female sea mullet mature at about 300 mm FL or a total length of 338 mm. The difference in size at first maturity is most likely due to differences in growth rates between male and female mullet.

Of the 10 432 sea mullet examined from commercial fishing operations in Queensland 225 (2.2%) were below the legal size limit of 30 cm TL. Estuarine fishing operations accounted for 197 (1.9%) of these with ocean beach operations taking 28 (0.3%). In the estuarine operations 74% of the undersize mullet were taken during the summer period from November to February.

Length measurements showed that 1 691 (16%) fish were below the size at first maturity for females. Estuarine catches contained 1 508 (89%) of these while ocean beach catches contained 183 (11%). Assuming that 75% of the total catch is taken during the ocean beach season and 25% in the estuarine fishery, with a 1:1 sex ratio, 1.4% of total ocean beach catch and 3.4% of the total estuarine catches would be of immature females.

Under the current management arrangements used in the Queensland commercial mullet fisheries, the legal size limit and net restrictions are allowing the vast majority of male and female mullet to mature before entering the fishery.

5.3. MULLET TASK GROUPS

Due to limited available time, only three tasks were identified with rather broad portfolios:

1. Discussion on effort in terms of:
    - Technological creep;
    - Integration with New South Wales;
    - Definition of the two main fisheries;
    - Seasonality of effort;
    - Investigation into zero effort records especially search time;
    - Location of effort.
2. Examination of catch records:
    - Spatial distribution of catch;
    - Fishery identification;
    - Integration with New South Wales;
    - Catch rates versus year class strength.
3. Investigation of growth and ageing information:
    - Compare growth data from New South Wales, Queensland and historical sources;
    - Produce a catch curve;
    - Stock structure.

5.3.1. DISCUSSION OF EFFORT IN QUEENSLAND

This group mainly discussed the effects of fish behaviour and logbook data quality on effort in Queensland. There are two main fisheries: an ocean beach and an estuarine fishery. They therefore also investigated a method by which the effort of the different sectors of the commercial fishery can be separated, as gear type is not explicitly recorded in CFISH. This algorithm is required, because the catch and effort of these sectors represent different fishing practices.

5.3.1.a. Some factors affecting effort

Mullet are highly migratory, aggregate and have a patchy distribution. This means that effort is highly seasonal and that catch rates may not be indicative of biomass. Furthermore, the use of the logbook data for management as well as stock assessment purposes, may mean that fishers will misreport their effort and catch to protect their income options. Since search effort is not entered into the logbook, particularly with respect to the ocean beach fishery, effort would remain underestimated.

There was a suggestion that the market price of roe, rather than the availability of fish, drives effort. Fishers are able to know the price before going fishing and can avoid catching mullet if the price is too low. However, ocean beach fishers tend to fish irrespective of price during the open season.

It should also be born in mind, that mullet can form part of a multi-species fishery. Certainly, the ocean beach fishery is generally looking for any fish aggregations and not exclusively for mullet.

In terms of effort creep, no detailed vessel information was available. On discussion of the ocean beach fishery, most of the technology and gear changes that have occurred over the history of the fishery took place prior to the available effort data (since 1988 from CFISH). Until 1986, there were no limits on the number of operators and only minor limits on equipment. After 1986, restrictions on length and depth of nets were introduced. A limit on the type of net material has not been introduced and lighter synthetic gear has been in use before 1986. In the 1960s, motorised tunnel net surfboats were introduced. At the same time, tractors and trucks were used to haul nets onto the beach. In approximately 1986, jet boats were introduced, which would have increased effort efficiency by about 20%. The introduction of good communication devices such as CB radios and cellular telephones occurred prior to 1986, but the technology has improved over time. This improvement in communication was believed to have increased efficiency by 4%.

In the estuarine fishery, three main changes were discussed. Synthetic nets were introduced prior to 1986, GPS have been used for tunnel netting in the 1990s and bycatch reduction devices after 1996. None of these changes were deemed to have had a major effect on effort.

5.3.1.b. Algorithm to separate fishery

The estuarine fishery can be subdivided into a gill net and tunnel net fishery. The gear used by these three fisheries (ocean beach, estuarine gill net and estuarine tunnel net fishery) is completely different and their effort should therefore be separated. The group had limited time to investigate outliers in the CFISH database, but as there were several such outliers encountered, they recommended these should be removed or investigated at a future date.

The following spatial algorithm was designed to identify the fishery and gear used:

Step 1.

- Link the sea mullet effort to fisher records with a 'K' license (QFMA Ocean Beach Licence) between the open ocean beach season of 1 April to 31 August. This effort will be classified as ocean beach effort.
- All other records will be allocated to the estuarine fishery.

Step 2.

- Since a tunnel net is legal only in Moreton Bay and Sandy Straits, a search restricted to these two areas, with the following rules, will separate the tunnel and gill net fishery. Net lengths of more than 800 and less than 2000 m will be defined as effort using a tunnel net.
- Net lengths less than or equal to 800 m, will be declared as gill net effort.

Step 3.

- All remaining effort (i.e. in all other areas and net lengths less than 800 m), are to be declared 'other nets'

5.3.1.c. Recommendations

This group produced an extensive list of recommendations, which have been added to the final mullet recommend-ation list (numbers 4 to 11).

5.3.2. EXAMINATION OF CATCH RECORDS

This group investigated the spatial distribution of the catch and the effectiveness of the fishery identi-fication algorithms developed by the previous group.

This group attempted to identify the different fishery sectors using the catch data. They concluded that this separation is not possible using the catch data alone and that the method developed by the previous group was

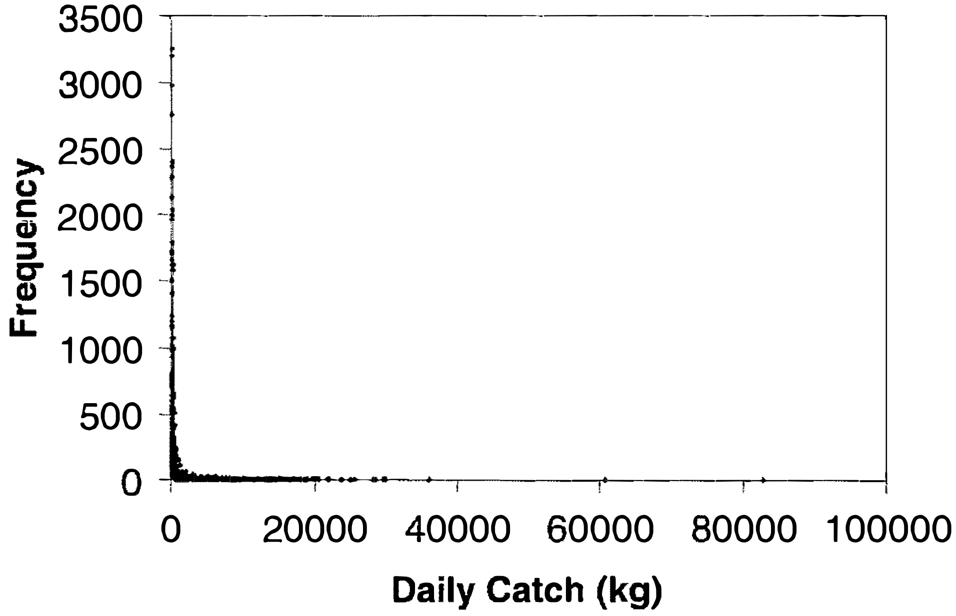

Figure 5.8. *Frequency of mullet (unspecified) and sea mullet catch weight per day from 1988 to 1997.*

the best method. However, they modified the previous groups algorithms into the following rules:

Rule 1: Delete all records where no net length is recorded (about 9000 records which is 10% of the total number of records),

Rule 2: Delete all records where the net length recorded is greater than 2000m,

Rule 3: If (net length ≤ 2000 m) and (not Ocean Beach 'K' licensed fishers), then declare catch as from non-ocean beach fishers using *gill* nets.

Rule 4: If (net length ≤ 2000 m) and (Ocean Beach 'K' licensed fishers out of ocean beach legal season) then declare catch from Ocean Beach fishers using *gill* nets.

Rule 5: If (net length ≤ 2000 m) and (ocean beach 'K' licence fishers during ocean beach legal season) then declare catch from Ocean beach fishers using *haul* nets, and

Rule 6: If catches are in Moreton Bay or Great Sandy Straits (CFISH grid numbers 'V34', 'W34' and 'W37') and (net length is longer than 800 m and less than or equal to 2000 m) then a *tunnel* net was used.

Investigation of the catch rate frequency showed an extremely skewed distribution (Figure 5.8), with most of the catches being less than 20 $kg.day^{-1}$. The unstandardised catch rate corrected for gear type is shown in Figure 5.9. It is clear that the beach seine fishery's catch rate is much higher than that of the other two fisheries. The gill and tunnel net catch rates have remained fairly constant, whereas the ocean beach haul net catch rates varied between 400 and 1 400 $kg.day^{-1}$. Investigation of the catch rates by month clearly show that the tunnel net fishery catch rates peak prior to that of the haul net fishery.

5.3.2.a. Recommendations

- It was the opinion of this group that the algorithm developed worked

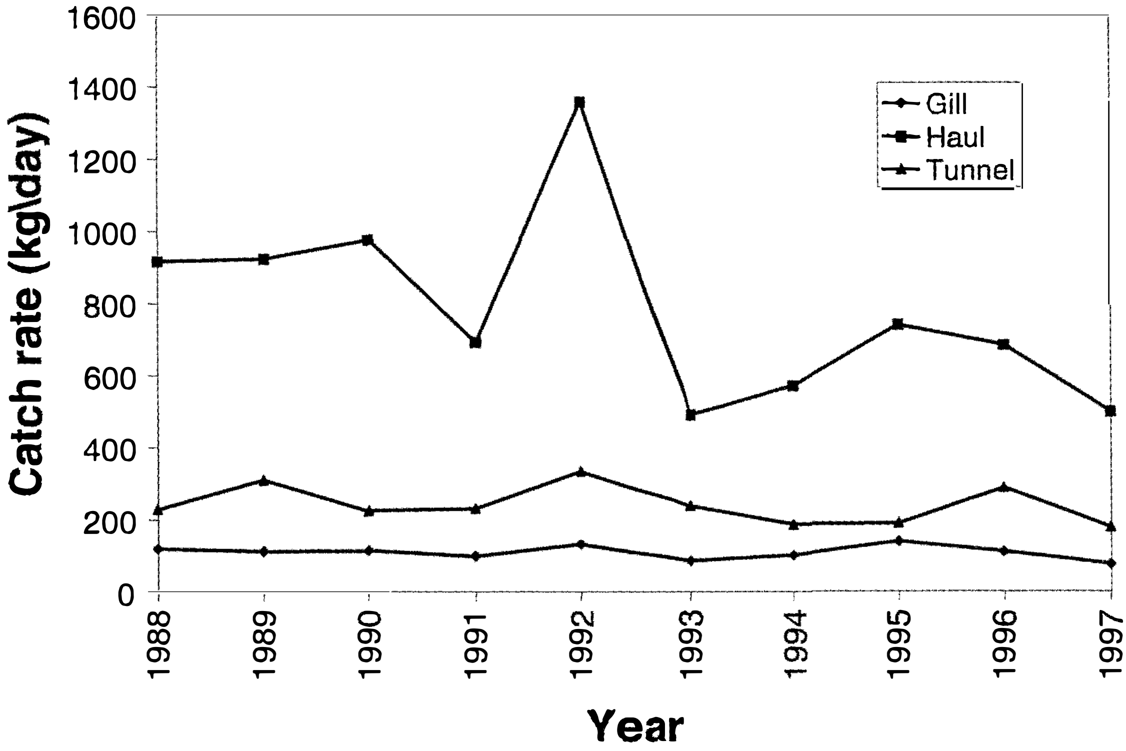

Figure 5.9. *Annual unstandardised catch rates separated by gear type. The separation was made using the decision rules described above.*

well, but that the logbook system be so changed to rule out the need for algorithms in the future. Communication with fishers to explain the importance of this filled in the logbook should also be considered. About 10% of the records had no net length information and these catches were omitted from the analysis.

- This group could not explain the high ocean beach haul net catch rates observed in 1992 and they recommended that the data should be investigated further. Whether the 1992 catch rate high is real or a data entry error could be determined by communicating with the three or four marketers for this product. Furthermore, an investigation of apparent outliers may be directly resolved with the fisher concerned.

5.3.3. INVESTIGATION OF GROWTH AND AGEING INFORMATION

During the introduction, it became clear that mullet are reasonably easy to age using otoliths. It was therefore the group's task to define the utility of this ageing data for stock assessment purposes and to consider whether the data would be of value for long term monitoring. This group therefore investigated the age information in order to classify the age structure of the resource, model a growth function and estimate total mortality.

5.3.3.a. Age structure

Three gender categories were defined in the 1995/6-age database. These are males, females and unidentified (usually juveniles). Males and females generally follow the same trends in relative abundance between age classes and year. The age data were also separated into fish caught by the ocean beach and estuarine fisheries. In total 1 257 and 1 007 otoliths were aged for the beach and estuarine fishery respectively.

It is clear that the fisheries catch a broad range of age classes, from a few 1+ year olds to 7+ and 8+ ages. In 1995, a large 5+ year class can be observed in both fisheries (Figure 5.10). This age class is still clearly visible, especially in the ocean beach fishery, as a 6+ group in 1996 (Figure 5.11).

Figures 5.10 and 5.11 highlight that the catch-at-age over the long term may show strong cohorts, which can be followed from one year to the next. The ocean beach fishery catch-at-age structure is clearer and covers a wider range of size classes. Furthermore, mullet are generally easy to age accurately and precisely. It would be therefore possible to model this structure in order to estimate total mortality, to follow resource age structure and, with a longer dataset, be used in conjunction with catch rates for Virtual Population Analysis.

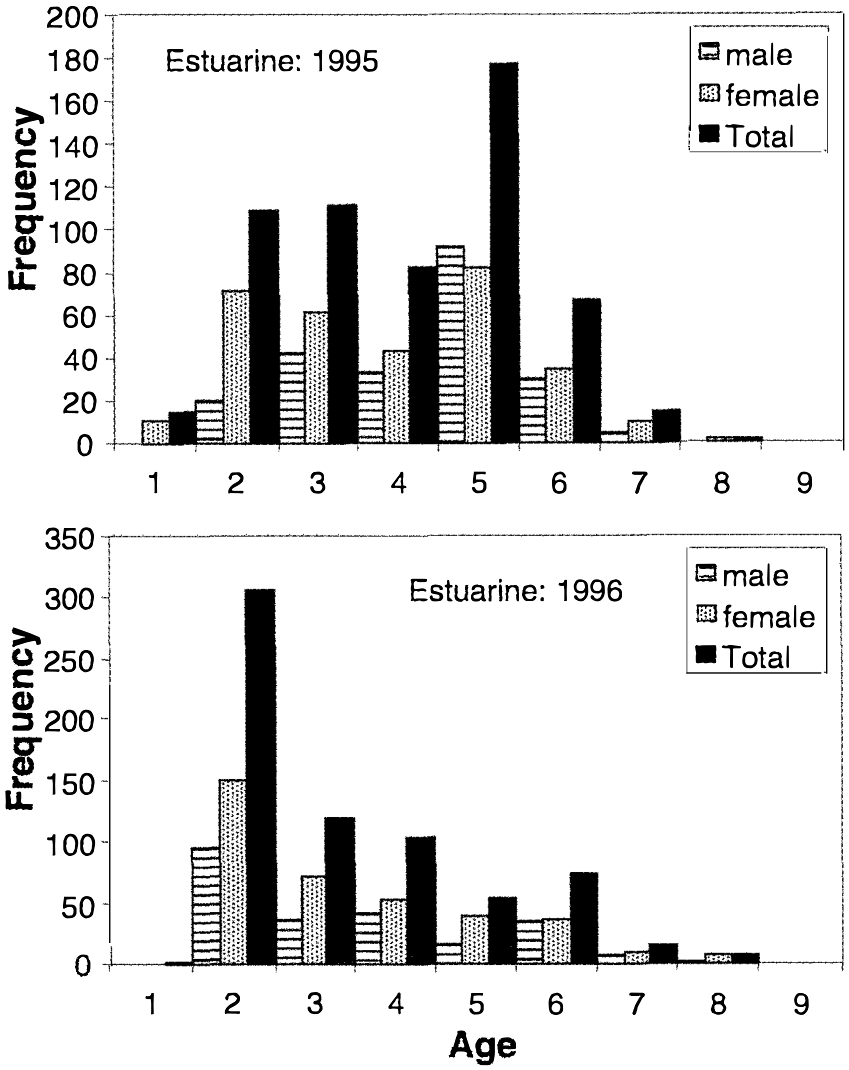

Figure 5.10. *Proportional age structure from the commercial estuarine fishery for the mullet (Mugil cephalus). The top panel is for 1995 and the bottom for 1996. Note the strong year class seen as 5+ in 1995 and 6+ in 1996.*

5.3.3.b. Growth rates and estimates of natural mortality

All the available fork length versus age data were used to estimate a von Bertalanffy growth function parameters as well as obtain preliminary estimates of natural mortality (M $year^{-1}$) (Figure 5.12). These are data from commercial estuarine catches sampled in 1995 for males, females and unsexed, and juvenile data collected in 1995 at Tin Can Bay and Maroochy. A least squares minimisation procedure of residuals were utilised and the resultant estimates of the von Bertalanffy growth parameters are in Table 5.2.

Parameter	1995	1996
Linf	359.2	369.3
K	0.458	0.504
Tzero	-0.603	-0.369
max Age	13	13

Table 5.2 This group investigated the age information so as to classify the age structure of the resource, model a growth function and estimate total mortality.

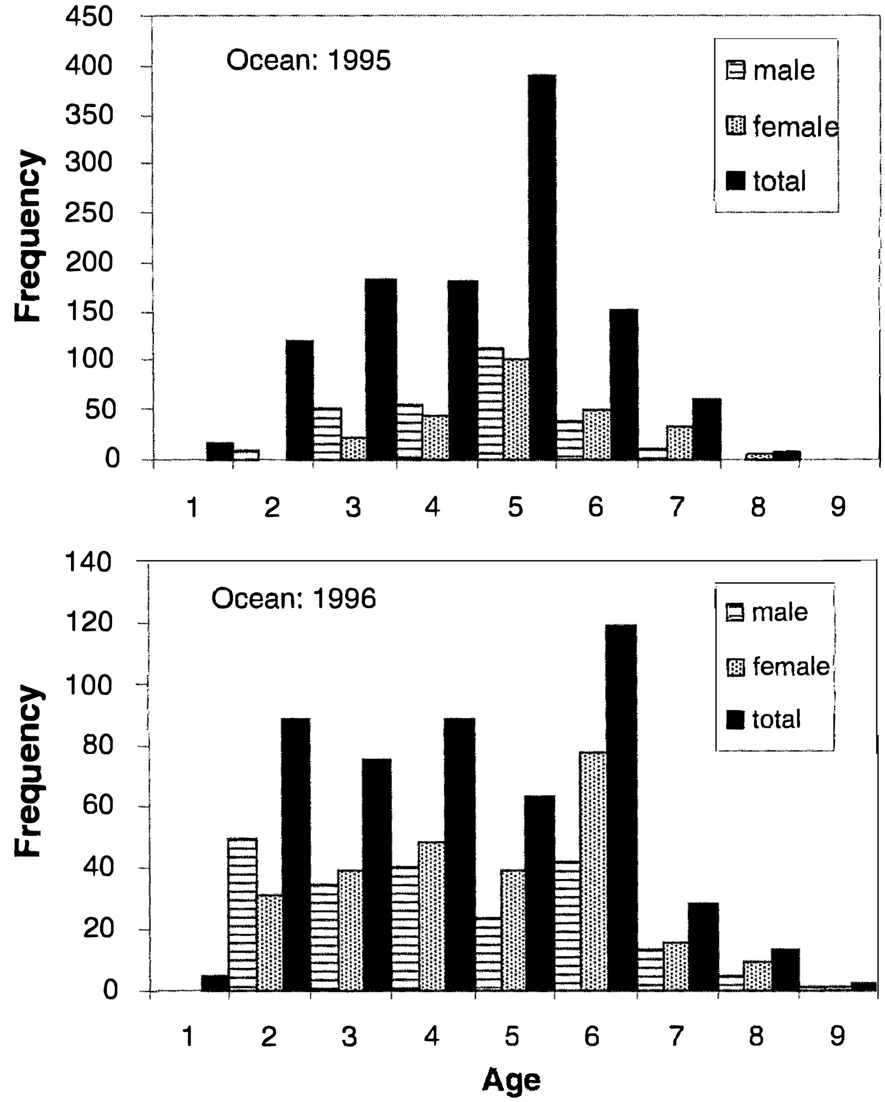

Figure 5.11. *Proportional age structure from the commercial Ocean Beach fishery for the mullet (Mugil cephalus). The top panel is for 1995 and the bottom for 1996. Note the strong year class seen as 5+ in 1995 and 6+ in 1996.*

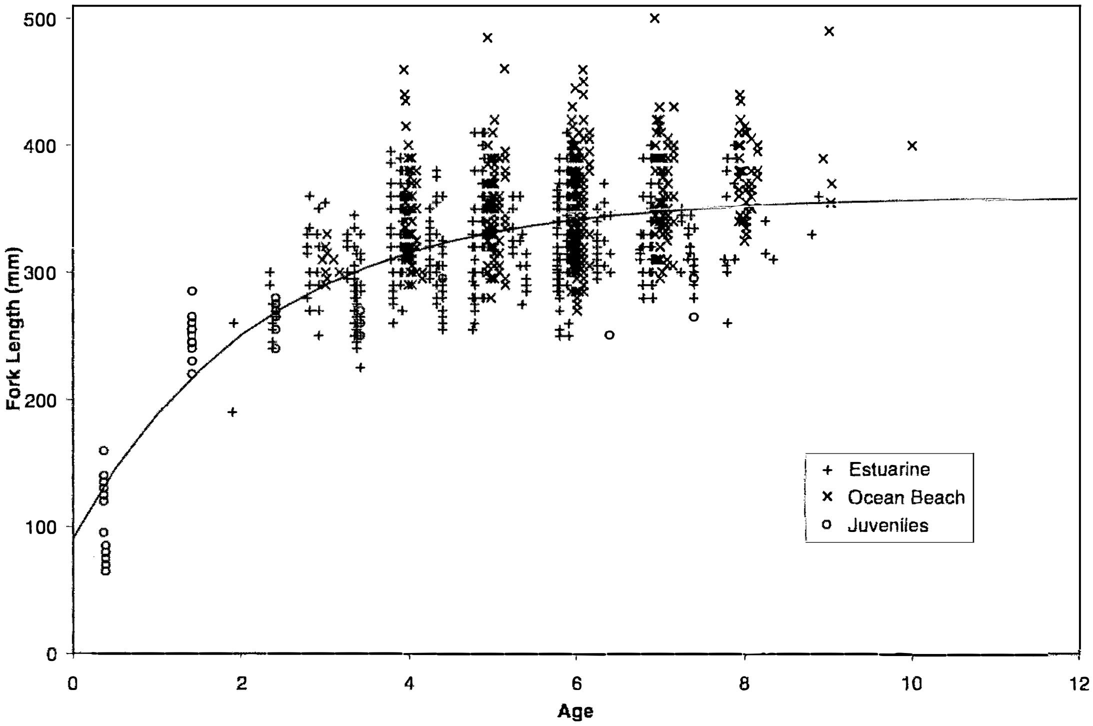

Figure 5.12. *Von Bertalanffy growth model fitted to several data sources using a least squares approach. Data from juvenile and adult, males, females and unsexed fish were pooled. Note that commercial fishers measure total length whereas fork length is used here.*

Fork length varies enormously within a single age class, especially in the older age classes. Furthermore, the female length distributions are much more varied than that of males. It would therefore not be possible to use length as a surrogate of age.

The von Bertalanffy growth estimates of L_∞, K and t_0 ranged from 340 to 380 mm, 0.49 to 0.66 $year^{-1}$ and –0.6 to –0.2 years respectively, depending on the combination of data included in the analysis. The commercial catch data may have been biased by gear selectivity, which was not considered.

Preliminary natural mortality values of 0.34, 0.51 and 0.47 $year^{-1}$ were derived using the Hoenig et al. (1983) estimator and Pauly's estimator (Pauly 1984) on 1995 and 1996 data respectively. The natural mortality estimates were based upon the growth parameter values from the 1995 and 1996 data analysis, in which all the data collected in the relevant year was pooled. They included all juvenile data. These values are obviously very tenuous and no confidence intervals were calculated on any parameter estimates.

A simple model for estimating Z by following the 5+ to 6+ year class from 1995 to 1996 was developed. Obviously, the dataset is too short for a robust measure. Also, emigration and immigration was not considered. The results are given below (Table 5.3).

	Estuarine				Ocean Beach			All
Year-age	m	f	Juv.	Total	m	f	Total	Total
1995 - 5yr	92	82	3	177	111	100	211	388
1996-6yr	36.4	42.8	2.1	86.0	31.8	79.4	109.3	202.5
Z	0.93	0.65	0.34	0.72	1.25	0.23	0.66	0.65

Table 5.3. Numbers of aged mullet in each age classes 5+ and 6+ collected in 1995 and 1996, separated by sex and fishery. Pooled frequencies are also included for the estuarine fishery, the Ocean Beach fishery and all data. The resultant total mortality (Z $year^{-1}$) estimate for each category is given. m are males, f are females and juv. are juveniles.

Total mortality (Z) was calculated as:

$$Z = \ln N_{5,1995} - \ln N_{6,1996}$$

where $N_{5,1995}$ is the number of 5+ year olds in the sample.

The analysis of growth, natural mortality and total mortality is obviously extremely preliminary. However, this group's work clearly shows the value of the age data. With only two years of data, several methods of analysis were achievable. Even though mullet grow to several years of age, a long-term catch curve series was seen as being desirable in order to establish a good stock assessment model of the resource biomass. The animal is relatively easy to age and data is easily obtained. More information on juveniles would be needed than was previously collected. The Ocean Beach data was seen as the most valuable since it was less variable, gave greater age resolution between ages and had a larger distribution of ages. However, if a model of mullet is to be seen as capturing all aspects of the resource, it should include both New South Wales and Queensland data. Collaboration between these states on this straddling stock is therefore essential.

5.4. CONCLUSIONS

5.4.1. GROUP REPORTS

Catch and effort data is not recorded by gear type other than by mesh net. The mesh fishery can apply three main gear types, being ocean beach seine, gill and tunnel nets. The catchability of sea mullet for these gear types would be different. Algorithms based on region, month and licence package were developed to define catch and catch rate records by gear type. In this analysis, several outliers were discovered. The catch rate frequency distribution was extremely skewed with most of the catches being less than 20 $kg.day^{-1}$. The catch rates for the ocean beach seine fishery was much higher than the other two fisheries. The unstandardised gill and tunnel net catch rates remained fairly constant over the period 1988 to 1997. Beach seine catch rates showed a large peak in 1992, however, the reality of this peak was disputed by some of the fishers present at the workshop.

Age information was extremely useful even though the dataset was short. The fishery catches a broad range of age classes, from 1+ to 8+ year olds and therefore several years of data would be required. The catch-at-age curve showed a strong cohort that could be followed over the two years sampled.

Total mortality values were estimated by following the fate of the strong cohort. The analyses of this group was extremely promising, but could only be treated as preliminary given the short dataset.

All available fork length versus age information was combined to estimate von Bertalanffy parameters. Fork length varies enormously within a single age class and could not be used as a surrogate for age. Based on the growth estimates, preliminary natural mortality values were estimated.

5.4.2. PROGRESS TO DATE

A summary of progress to date with respect to data, stock assessment and management are given in Table 5.5.

5.4.3. MONITORING, RESEARCH DIRECTION AND PRIORITIES

1. Age composition of the commercial catch should continue. This appeared to produce the best index of the resource status. Due to the many age classes, this will be a long-term venture in terms of running Virtual Population Analyses, but the consensus was that the investment would be highly cost-effective and beneficial. A non-equilibrium yield-per-recruit

Category		Comments
Commercial	Catch	Spatial resolution not at Management Plan scale. Gear type below mesh net is not specified.
	Effort	As above. Search time not recorded. Combine crews from different endorsements either log catch per endorsement (resulting in 2 days of effort being calculated) or as a single log (resulting in 1 day of effort being calculated). Definition of effort is unclear in multi-species and multi-endorsed fishery.
	Catch rate	As above.
Recreational	Catch, effort and catch rate	Unknown, probably insignificant in relation to commercial catch.
Independent index of biomass or recruitment		None.
Estimates of natural mortality		Preliminary estimates in workshop without variance estimation based on small dataset.
Estimates of fishing mortality or biomass		As above.
Input controls		Minimum legal size, spatial and seasonal closures on some sectors. Gear restrictions.
Output controls		None.
TACC Decision rules		N/A.
Performance indicators		None.

Table 5.4. A summary of progress to date in terms of data quality, stock assessment and management.

model could be attempted in the short term.

2. Detailed ageing and growth studies of 0+ and 1+ animals are required to corroborate expectations concerning mullet stock productivity. Initially, available data should be investigated in collaboration with New South Wales.

3. Simulations are needed to investigate the Draft Management Plan's management rules in terms of reference point trigger frequency

4. Greater spatial resolution is required to fully analyse the ocean beach effort data. The standard 30 by 30-minute grid records are too coarse. The ocean beach fishery should be required to log their data at a 6 by 6 minute (at least) scale. This will allow greater spatial identification in terms of the legislated ocean beach zones in the new Management Plan.

5. A primary fisher for multiple crews in the beach seine fishery should be nominated. At present, the catch and effort of these logbook records would either be split between the licence holders or lumped into a single catch record. This has a huge effect on recorded effort, but without a consistent direction of bias. Any changes to the logbook should take into consideration potential resource allocation problems.

6. Due to the multi-species nature of the estuarine fishery, a target species recorded at start of fishing day should be required. Gill nets are more specific in terms of targeting the catch than tunnel nets, since the mesh size allows for some species selection.

7. The catch by haul net should be recorded i.e. greater differentiation of gear used should be required. A major deficiency is that until recently net type was not recorded, so that mullet taken by ocean beach haul net could not be separated from those taken in estuarine mesh and tunnel nets.

8. If possible, the catch and effort of the estuarine fishery should also be recorded at 6 by 6' grid.

9. In addition to sea mullet (*Mugil cephalus*), several other mugilid species – including tiger mullet (*Liza argentea*), mud or flat-tail mullet (*L. subviridis*), fantail mullet or flicker (*Mugil georgii*), and sand or blue-tailed mullet (*Valamugil buchaneni* or *V. seheli*) - are taken commercially along the Queensland coast. These species represent less than 1% of the annual mullet catch, and the great majority is probably taken in estuarine and tidal riverine systems rather than on ocean beaches. However, there remains the possibility that some catches may have been mis-identified, or that some records of (unspecified) mullet represent catches of species other than sea mullet.

10. Investigate the possibility of tracking the catch rates of a few good fishers that present good data, as an alternative or supplement to using all the fishers' data.

11. Greater collaboration with New South Wales is needed, as this is a straddling stock. The New South Wales catch seems to be higher than that in Queensland. New South Wales have recently attempted to improve logbook information. They record their catch and effort monthly, with details such as the number of days fished including search time, number of shots and catch by method.

5.5. REFERENCES

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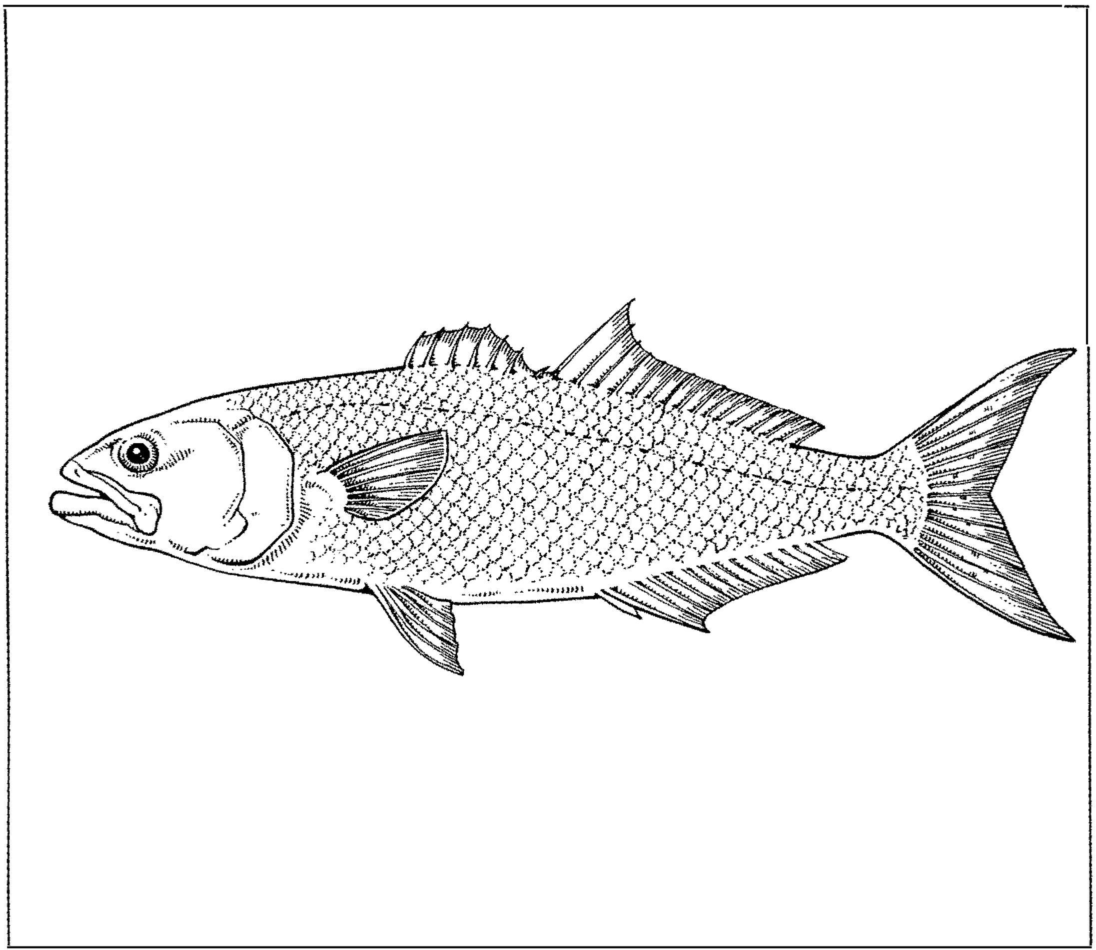
common name 6

TAILOR



Pomatomus saltatrix

6.1. PARTICIPANTS

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6.2. INTRODUCTION

Tailor (*Pomatomus saltatrix*) are distributed worldwide, occurring in the subtropical and temperate waters of Australia, Africa, the Mediterranean and Black Seas, and the east coast of North and South America. In Australia, they occur between Fraser Island in Queensland and Onslow in Western Australia. The east and west coast stocks are genetically distinct. Although they occur in southern waters, catches of tailor are rare in the Great Australian Bight, western Victoria and Tasmania.

The fish move northward to aggregate on ocean beaches in large schools during late winter and spring. The largest known spawning aggregation occurs at Fraser Island. Tailor are serial spawners, and release eggs and milt over extended periods of time. The eggs are pelagic and each female can produce up to one million eggs in a spawning season. Larvae hatch from eggs after about two days and remain in the plankton until they reach between 35 and 45 mm. They then move into estuaries.

Tailor are highly fecund, serial spawners with an extended spawning period that may stretch out over many months. Monthly mean gonosomatic indices indicate a peak of spawning activity in southern Queensland between September and October, with some spawning during the rest of the year (Zeller et al. 1996). This is supported by monthly egg survey data from the Bribie Island area (J. Staunton-Smith personal communication) and data from Miskiewicz et al. (1996). Eggs are usually 0.9 – 1.2 mm in diameter.

Juveniles feed on small crustaceans, cephalopods and fish. Adults prey mainly on small schooling fish such as pilchards, garfish and sea mullet. They are cannibalistic and large individuals can be caught using tailor flesh baits. Because of this behaviour tailor schools tend to be of similar sized fish.

Juvenile tailor enter estuaries at 35 to 45 mm total length. At about 200mm FL juveniles move into open bay areas forming large schools. On reaching maturity, tailor move from the estuaries onto the open surf beaches. Adult tailor may return to estuarine and brackish waters throughout the year.

6.2.1. GROWTH

Bade (1977) gives two alternative sets of von Bertalanffy growth parameters (Table 6.1). He gave two options because he was uncertain how many growth annuli were laid down each year on the scales he used for ageing.

The FRDC Integrated Stock Assessment and Monitoring (FRDC T94/161) project's preliminary estimates of growth parameters are based on otoliths from tailor frames

Source	L_∞	K	t_0
Bade 1977	72.6	0.3267	0.296
Bade 1977	72.7	0.163	0.409
van der Elst 1976	75.1(FL)	0.197	0.0322
Barger 1990	101.9	0.096	-2.493
Barger 1990	94.4	0.180	-1.033
Terceiro and Ross 1993	94.6	0.242	-0.128

Table 6.1. A comparison of von Bertalanffy growth parameters from several publications.

collected from recreational fishers at Fraser Island during August 1995. Otoliths were aged whole under a light microscope. These data come from one reader, and their precision and reliability have not been estimated.

The software package PCYield II (Punt 1992) was used to estimate parameters of the von Bertalanffy growth curve, and to generate standard errors, given below. These results were L_∞=40.0 ±2.28 cm, K=1.74 ±0.57 yr^{-1}, and t_0=0.86 ±0.69 yr, based on a sample size of 152. These results are unusual with a very low value of L_∞ and very high k and t_0 values relative to values from both the previous estimate from the same population, and estimates from other populations of the same species. The difference may have been caused by the lack of fish older than 4 years in the 1995 sample, and problems with obtaining samples from enough schools of tailor.

Given these factors, it was decided to use one of Bade's estimates in the interim until further data have been collected and our results validated. Of Bade's two parameter sets, we chose the one that gave the better least-squares fit to our sampled data. This parameter set was L_∞=72.6 cm, K=0.3267 yr^{-1}, and t_0=0.296 yr.

6.2.2. MORTALITY

Mortality was estimated in several ways under different assumption sets. Estimates at this stage suffer from the short time series of available data. They will improve as more years of data are collected. Methods for estimation of total mortality (Z = fishing mortality (F) + natural mortality (M)) are given below.

All of these methods assume that catch samples are unbiased with respect to size and age. However the catch samples come from only onshore stocks, and there may be offshore stocks where larger fish predominate, as occurs in Western Australia (Lenanton et al. 1996). If this is the case these mortality rates have been overestimated.

6.2.2.a. Total Mortality (Table 6.2)

1) Slope of Log(catch at age) against age (Butterworth et al. 1989).

2) Z was estimated from the formula $\hat{Z} = \ln\left(1+\frac{1}{\bar{a}-a_f}\right)$, with standard error $\frac{1}{\sqrt{N}}$ (Chapman and Hobson 1960, Butterworth et al.. 1989). Age at full recruitment (a_f) was calculated from the age of the youngest fully recruited age class in the sample. Average age ($\bar{a}$) included only fish older than a_f.

   The estimates of standard error given by this method are unrealistically small, given annual variations in recruitment, fishing mortality and natural mortality. Data came from samples obtained on Fraser Island during August 1995. As with the above estimator, the fact that only two fully recruited age classes were observed makes this estimate unreliable.

3) and 4) Length-based methods were used to estimate Z. Log(Number at length) was regressed against log (1 - length/ L_∞), the slope giving Z/K (Galluci et al. 1995). Only lengths from fully recruited size classes were used. Length at full recruitment was estimated from the mode of the length frequency distribution. It is ostensibly 27cm fork length (minimum legal size), but was observed to be 32 cm fork length from the length data.

Method for estimating Z	Estimate ± s.e.
1) Log catch at age against age	2.17
2) log(1 + 1/(mean age - age at full recruitment))	2.3 ± 0.26
3) Log(N at length) vs. log(1-L/L_∞) - recreational data	2.19 ± 0.13
4) Log(N at length) vs. log(1-L/L_∞) - commercial data	2.14 ± 0.37
5) Z=K((L_∞ - mean length)/(mean length - L_{crit}) - recreational data	2.7
6) Z=K((L_∞ - mean length)/(mean length - L_{crit}) - commercial data	3.35
6) Mean of above estimates	2.48

Table 6.2. Total mortality (Z) estimated using four different methods, and the average value given by the methods.

The L_∞ and K estimated by Bade (1977) were used, together with the length distributions from both commercial and recreational data. The recreational data was obtained in both 1995 and 1996, and the commercial data came from 1996 only. Error in the slope estimate was used to give a probability distribution for Z.

5) and 6) Z was estimated from the formula $\hat{Z} = K\left(\frac{L_\infty - \bar{L}}{\bar{L} - L_{crit}}\right)$ (Beverton and Holt 1956), where L_{crit} is the length at full recruitment, and $\bar{L}$ is mean length for fish greater than L_{crit}. Bade's (1977) von Bertalanffy parameters were used, together with length data from the August 1995 sampling program.

6.2.2.b. Natural Mortality (Table 6.3)

Natural mortality estimates were similarly obtained in a number of ways.

1) Pauly's (1980) equation was used to estimate natural mortality based on von Bertalanffy growth parameters and mean seawater temperature, according to the formula:

$$M = e^{-0.0066 - 0.28\log(L_\infty) + 0.65\log(K) + 0.46\log(Temp)}$$

Von Bertalanffy growth parameters were obtained from Bade (1977).

2) Hoenig (1983) equation was used to estimate natural mortality from the age of the oldest fish ever found, by the equation

$$M = e^{1.44 - 0.982\log(MaxAge)}.$$

Max age was obtained from the oldest fish found by Wilk (1977), in a North American population of *P. saltatrix*. The maximum age from Bade's (1977) study could not be used because he aged relatively few fish, and the population was heavily exploited.

3) The assumption made by Butterworth *et al.* (1989) for South African *P. saltatrix* was used.

4) Rikhter and Efanov's (1977) equation:

$$M = \frac{1.521}{0.7t_m} - 0.155,$$

where t_m is the age in years at which 50% of the stock is sexually mature. Bade (1977) estimated that 'the majority' of males were mature at 26 cm and females at 28 cm. An intermediate figure of 50% mature at 26 cm was arbitrarily chosen. This corresponds to an age of 1.65.

5) The average of the above estimates.

Method for estimating M	Estimate
1) Pauly	0.59
2) Hoenig et al.	0.49
3) van der Elst	0.40
4) Rikhter and Efanov	1.16
5) M - average of above estimates	0.66

Table 6.3. Natural mortality (M) estimated using three different methods, and the average value given by the methods.

Fishing mortality was estimated by subtracting the average of the natural mortality estimates from the average of the total mortality estimates, giving F=1.8.

It should be emphasised that estimates of total mortality (Z) also include emigration from the fishery. If older age classes of tailor are less available to, or less targeted by, the recreational and commercial fisheries than the younger age classes, then Z over-estimates total mortality rate. This issue still needs to be investigated.

Tailor migrate northward during late winter and spring. This movement is associated with the spawning run for these fish and often extends for hundreds of kilometres. The northern tip of Fraser Island has been identified as a major spawning site for tailor with large aggregations of ripe fish appearing between August and October each year. The spawning closure during September between Indian Head and Waddy Point was introduced as a precautionary measure but because of a number of uncertainties surrounding the life history of the species, it has not been possible to evaluate the effectiveness of the closure. However, tailor egg distributions from recent icthyoplankton surveys suggest widespread spawning activity along the southern coastline. Once spawning has occurred adult fish move southward again.

6.2.3. FISHERY

Commercial fishers use beach seine or haul nets to catch tailor. This southern Queensland ocean beach fishery extends from Fraser Island to the New South Wales border and focuses on sandy beaches exposed to oceanic conditions, particularly on the eastern shores of Stradbroke, Moreton, Bribie and Fraser Islands. However, this fishery primarily targets the roe fishery for migrating sea mullet (*Mugil cephalus*) on their seasonal pre-spawning run up the coast from estuaries in New South Wales and southern Queensland. Tailor are caught in beach haul nets and may be taken as bycatch in mullet shots. However fishers try to avoid such bycatch in mullet nets because of the damage tailor can do to the net by cutting the mesh with their teeth. To minimise this damage, tailor schools tend to be fished with heavier ply nets. An essentially small and incidental catch in the estuarine fishery is also observed. Tailor are sometimes targeted with gill nets in estuaries, but this is not a common practice. Recreational fishers also catch migrating tailor. Both recreational and commercial sectors are major stakeholders in this fishery. The recreational catch of tailor in the southern region was believed to be at least as large as the commercial catch (Pollock 1980), catches from Fraser Island alone in 1979 amounting to 180 tonnes.

Both commercial and recreational fisheries operate in a very narrow coastal band. Tailor only a few hundred meters off the coast are therefore out of reach to both sectors. Tailor in Western Australia are known to be distributed both inshore and offshore as far as the outer shelf (Lenanton et al. 1996).

The commercial tailor fishery on the Queensland east coast reached a peak reported production of around 400 tonnes during the 1960s, which lasted through to the mid 1970s. Since then production has fallen to about 200 tonnes per annum, but apparently for reasons other than overfishing. The market demand for tailor fell at about this time and has not returned to its earlier level. At the same time the level of recreational fishing activity increased considerably, to the extent that now the recreational catch is estimated to be as much as three to four times the size of the commercial catch. Pollock (1979) estimated the recreational catch of tailor from Fraser Island to be 180 tonnes, while the commercial fishery in that area caught about 25 tonnes. In 1995 there was a marked increase in the recreational catch, attributed to a natural increase in the abundance of tailor in inshore waters of northern NSW and southern Queensland.

In the commercial ocean beach fishery, tailor are taken exclusively by haul or seine net. Occasionally haul nets are used in the estuarine fishery where the structure of the shoreline permits (e.g. around the Redcliffe Peninsula), but gill (mesh) and tunnel nets are the usual methods used in protected waters.

Gill nets capture fish by entanglement, usually by the gill covers or spines. Mesh sizes of gill nets used for taking mullet range from 3 to 3¾" depending on the time of the year. The 3" mesh effectively selects for legal sized fish.

Tunnel nets are used to fence an intertidal area that is then allowed to drain off with the ebbing tide. Mesh size of the wings is usually 2¼" which is too small to gill most fish. The fish are collected in a race staked below the low tide mark, from which they are sorted, with undersized fish being immediately returned to the water.

The commercial ocean beach fishery is restricted to 70 licence-holders in Queensland and to a season extending from 1 April to 30 August. Licence holders may fish individually with a crew of 3 or 4 assistants. Operators may also form groups in which the catch is divided between several co-operating licence holders and their fishery assistants. The amalgamation of individual teams into groups (which can comprise as many as 12–15 people) results in a reduced level of competition and conflict on the beaches, and gives all fishers concerned a fair share of the total catch.

The commercial tailor fishery is driven by a variable and generally decreasing market demand, but recreational pressure on the stock continues to increase with the greater accessibility of remote beach areas resulting from the popularity of four-wheel-drive vehicles. Of all of the State's marine finfish stocks, the tailor stock gives the greatest concern at present with respect to potential overfishing.

The commercial catch of tailor is principally for a relatively small fresh-chilled market. No reliable figures are available for the amenity value of the recreational tailor beach angling fishery, but the associated flow-on to infrastructure industries (beach vehicles, fishing gear, fuel etc.) would be substantial.

Commercial statistics relating to the tailor fishery is available for most of the period from 1944 to the present, but the reliability of the figures is highly variable. During the post-war period until 1981 the Queensland Fish Board (QFB) was the primary marketing agency for seafood products. The Board maintained records of daily landings (by species), but not fishing effort. Illegal marketing (outside the QFB system) is known to have

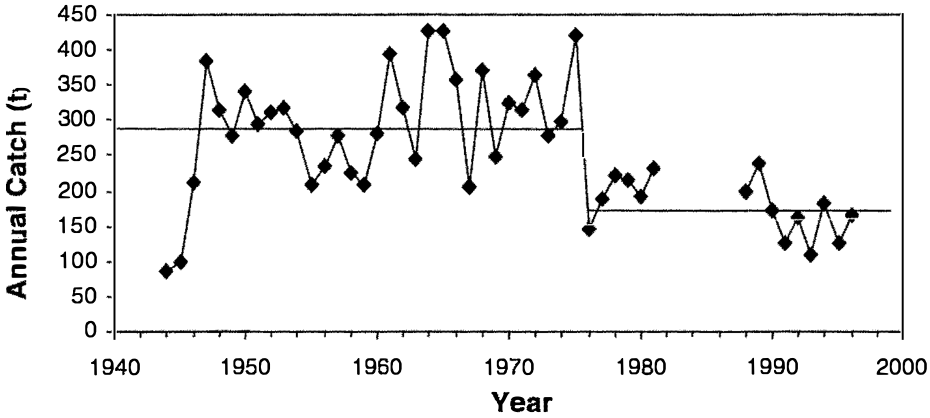

Figure 6.1. *Commercial catch of tailor (Pomatomus saltatrix) in Queensland waters.*

occurred, but it is impossible to gauge the extent of this with any confidence. The landings figures therefore under estimate the actual landings by an unknown and probably variable factor. Between 1944 and 1969, landings were recorded in pounds (lb.) whole weight. From 1970 onward separate records were kept for whole fish (presumably gilled and gutted) and fillets. Between 1970 and 1973 all records were expressed as pounds, thereafter (from 1974 onward) they were recorded as kilograms. For the purpose of our analysis, all figures have been converted to whole weight (kg.) equivalent on the basis that 1 lb. = 2.2 kg, and whole (gilled and gutted) weight = 2 x fillet wt.

In 1988 DPI introduced a fishery-wide compulsory commercial logbook program (CFISH). CFISH required licence-holders to submit monthly catch returns detailing daily catch, effort, and location. The logbook system was subsequently taken over by the new QFMA and became known as the Queensland Fisheries Information System (QFISH). Unfortunately, for about seven years between the privatisation of the QFB and the establishment of CFISH, no fishery statistics were collected routinely (i.e. apart from short-term voluntary research logs) in Queensland.

The CFISH database does have shortcomings. A major deficiency is that until recently net type was not recorded, so that tailor taken by ocean beach haul net cannot be separated from those taken in estuarine mesh and tunnel nets. The way the ocean beach fishery functions also creates difficulties with the available indices of fishing effort. A large part of the effort in a haul net fishery for migratory schooling species consists of searching or spotting, which is not incorporated in the compulsory logbooks. Another complication is the ability of beach crews to join forces on an *ad hoc* basis, which clearly influences effective effort. However, there is no way to determine the size or number of crews involved in any fishing operation from the existing dataset.

The history of commercial tailor catches in Queensland appears to comprise two phases (Figure 6.1). The first phase, prior to 1975, is characterised by a mean annual catch of 290 t, while from 1976 onward annual catches have been consistently and substantially lower, at around 170 t. It is important to note that the sudden decrease did not occur in the period of change from one reporting system to the other, but while the QFB was in operation. The sudden fall-off in annual catches of tailor may have been related to market demand, which is known to have slumped in the mid-1970s when the QFB lost its regular contract with the Queensland Government for the supply of fish products to the State's public hospitals and institutions.

The horizontal lines in Figure 6.1 are included to indicate the location of the two long-term averages rather than to suggest a lack of trend in the data time-series. After 1976, in fact, there appears to have been a slight drop in the size of the annual commercial tailor catch. To determine whether this reflects a similar trend in stock size would require a far more sensitive measure of population abundance than raw annual reported catches.

6.2.4. YIELD-PER-RECRUIT

YPR was modelled using the von Bertalanffy growth curve from Bade (1977) and the estimates of Z and M described above. An iterative YPR model was used (Hoyle and Sumpton in prep.) in order to estimate risk associated with the predictions, and to allow for error in the input parameters. The minimum legal size (with standard error) that would maximise the average yield for F between 0.6 and 1.0 is 37.8 ± 2.3 cm FL, or 42.3 cm total length. The current minimum legal size is 30 cm total length.

However, it is apparent from the length data that have been collected that most fish do not become available to the Queensland tailor fishery until they reach approximately 32 cm fork length, or 36 cm TL. This gives an average yield per recruit of 0.201 kg. The optimum length of first capture is 42 cm TL, which would result in an average yield of 0.225 kg per recruit (an increase of 12%).

However, achieving this length at first capture is not straightforward. According to the von Bertalanffy growth curve, the growth in a year from an average length of 32 cm FL will be result in average length of 43.3 cm FL, or 48.5 cm TL. YPR at this length is 0.207 kg, an increase of only 3%.

Average length at recruitment to the fishery (TL in cm)	Yield per recruit (kg) ± standard error	Change from current yield
30	0.212 ± 0.002	5.5%
35.8	0.201 ± 0.002	0.0%
40	0.223 ± 0.003	11.0%
42.0 (optimum)	0.225 ± 0.004	11.8%
48.5	0.207 ± 0.004	2.9%

Table 6.4. Yield per recruit at various average lengths (TL) at recruitment to the fishery. The yield is the average yield per recruit when F is 1.8. Natural mortality was set to 0.66 with standard deviation of 0.07. The selectivity ogive was based on a CV of 0.15 with standard deviation of 0.03.

If the minimum legal size were raised, yield would not increase immediately. There would be an initial decrease in yield because of a relative lack of fish in the older age classes. However, in the long term (assuming that the increased spawning biomass did not adversely affect the number of recruits to the fishery) the average size of fish taken would increase, with the total number taken remaining below today's levels. Other factors to be taken into account are:

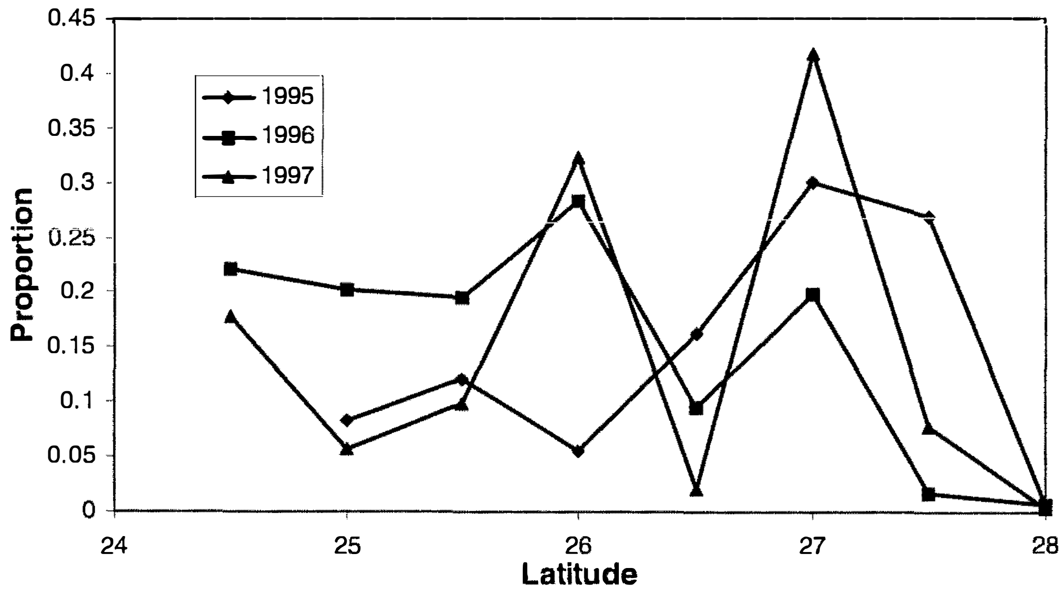

Figure 6.2. *Commercial tailor catch for years 1995, 1996 and 1997 by Latitude.*

- the catch taken in New South Wales,
- the possibility that older fish may differ in their availability to the fishery,
- the possibility that the different sectors involved in the fishery may have differing fishing objectives,
- and that increases in biomass of older (larger) fish may have a density-dependent effect on the mortality of younger age-classes.

6.3. TAILOR TASK GROUPS

1. Size structure and distribution.
2. Estimating relative commercial and recreational harvest.
3. Analysis of recreational and commercial catch rates.
4. Investigation of ageing and growth estimates.

6.3.1. SIZE STRUCTURE AND DISTRIBUTION

At present, all size structure analysis has been using samples unweighted by catch size. Samples have been collected over a wide range of latitudes. Workshop participants highlighted that unweighted length-frequency distributions may be biased towards large catches from a specific latitude.

Commercial size frequency data was available for 1996 and 1997 from the 'Integrated Stock Assessment and Monitoring Program' (FRDC T94/161), with the latter year having the most comprehensive dataset. The relevant year's commercial catches by latitude for the months April to August were used to weight the size frequency (Figure 6.2). Large relative catch changes by year and by latitude can be observed. In 1995 and 1997, most of the catch was taken from latitude 27°S (27° – 27.99°S), which corresponds to Moreton Bay and the offshore islands.

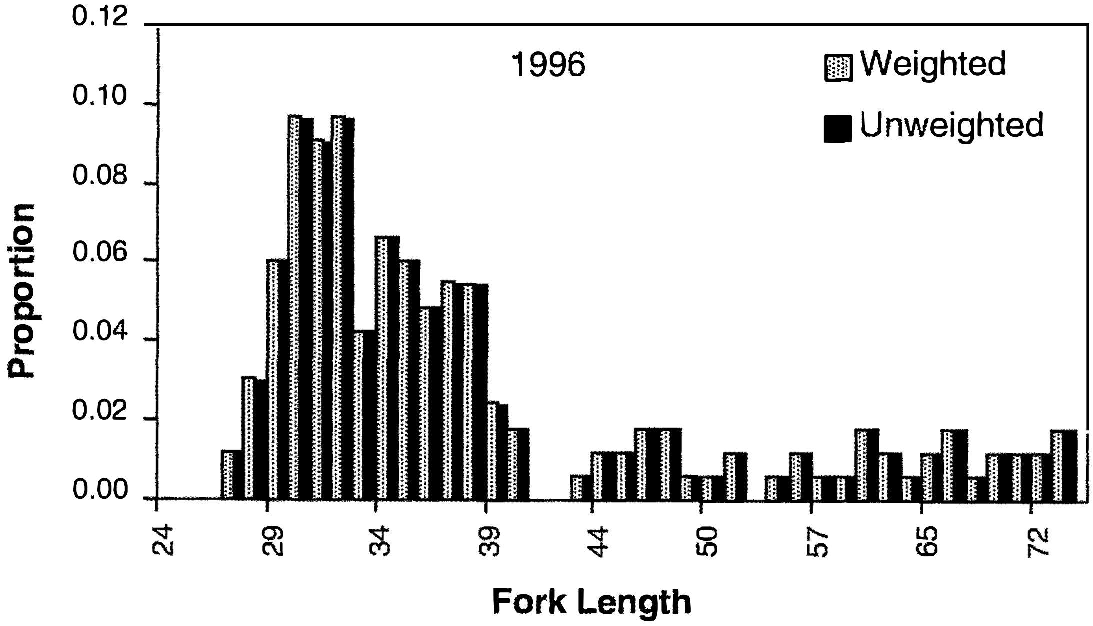

Figure 6.3. *Weighted and unweighted commercial tailor size-frequency distributions for 1996. Very little difference can be observed between the different size-frequencies.*

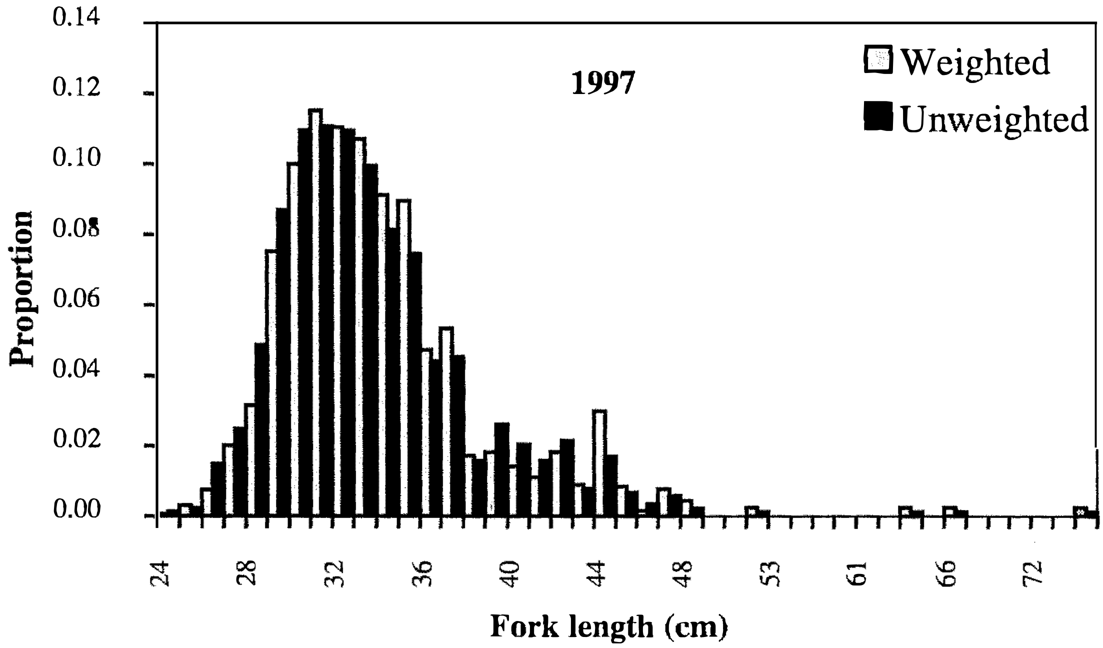

Figure 6.4. *Weighted and unweighted tailor commercial size-frequency distributions. Only a slight change in distributions can be observed.*

Weighted and un-weighted commercial size frequency distributions are given for 1996 and 1997 (Figure 6.3 and 6.4). Although there is a slight shift to larger length frequencies for the 1997 data, no effect of weighting was observed in the 1996 data. The lack of change in 1996 was due to each of the three latitudinal ranges, which reported catches, effectively having identical catches. This was not the case in 1997 and so the weighting had a discernible effect. The 1996 data includes a sample in which large tailor were targeted. The group recommended that this sample should be removed.

Although the effect of weighting was not large, the group recommended that this procedure should be continued in further analysis. Any major latitudinal shift in catch would therefore be taken into consideration. This work will be reported in the FRDC T94/161 'Integrated Stock Assessment and Monitoring Program'.

6.3.2. ESTIMATING RELATIVE COMMERCIAL AND RECREATIONAL HARVEST

Total recreational and commercial catch is not a good estimator of tailor stock health, but does give an index of the relative resource share between the two major fishing sectors. Unfortunately, in the past, there has been no data available as to the recreational catch. Only the commercial catch is monitored in the QFMA logbook program. There has, however, been much debate as to the recreational catch and its size relative to the commercial catch because the resource is perceived to be under heavy fishing pressure. QFMA has recently undertaken an extensive recreational telephone and logbook survey (RFISH). They have kindly made their preliminary data available for analysis. This was the first time that size of the recreational catch of tailor could be estimated.

In the workshop, a first attempt at a very rough mean and upper limit of the recreational catch was estimated on the basis of the following assumptions:

- a logbook participation loss of 10% in the second quarter of the survey, followed by 17% in the third and 33% in the fourth quarter.
- The survey covered 0.75% of the total recreational fishing community (i.e. 5 000 out of a possible 667 600 people). The maximum catch figure assumes that 0.5% of the total recreational fishers participated in the survey (i.e. 1 in 200 of the 667 600 fishers).
- The average weight of a tailor was estimated as 0.4 kg from recreational size frequency data.

A first estimate of recreational tailor catch (tonnes) resulted in an average of 292t and a maximum of 437t. The commercial harvest based on CFISH is between 100t to 200t per annum. Obviously, this work is extremely preliminary, but does show that the recreational catch is of the same magnitude or greater than the commercial catch. The RFISH program data will be analysed formally by the Australian Bureau of Statistics and reported on by QFMA.

6.3.3. ANALYSIS OF RECREATIONAL AND COMMERCIAL CATCH RATES

A comparison of commercial and recreational catch rates has never previously been completed using standardisation methods, although these datasets can not be combined as they cover different time periods etc. The group's objective was to standardise the two datasets by year, month and other factors, if necessary, and then to compare the relative trends.

Location Number	Location
30	Caloundra
40	Double Island Point
41	Double Island Point Surf
62	Jumpinpin
63	Jumpinpin Surf Bar
80	Moreton Island
81	Combi Point
84	Reeders Point, Moreton Island
86	South Moreton Island
87	Moreton Island Surf
93	North Stradbroke Island
114	South Stradbroke Island
115	South Stradbroke Island Surf
182	Surf Undefined

Table 6.5. Locations and their code within the recreational club dataset used in the analysis of effort standardisation.

6.3.3.a. Recreational club data

Recreational club data was kindly made available to the workshop by QFMA. The group selected recreational club data from ocean beach areas only (Table 6.5) so as to be able to compare with commercial ocean beach catch rates. The analysis discounted small clubs that contributed only a small amount of data. The remaining 400 records were used.

An analysis prior to the workshop indicated that the average weight of tailor.fisher^{-1}.trip^{-1} had not changed significantly between 1973 and 1991. This work will be reported on in the 'Integrated Stock Assessment and Monitoring Program: report (FRDC T94/161). A General Linear Model of the ocean beach recreational club catch rate data as the natural logarithm of number of fish caught.fisher^{-1}.trip^{-1}+1 was modelled, with year, month, club and location as factors. The location and year factors were significant. The resultant standardised graph shows a major increase in relative catch rate during the late 1960's and early 1970's, whereas, following a decline to 1960s levels, the catch rates have remained relatively stable in the last decade (Figure 6.5). The standardisation had its largest effect on years where little data was available, tending to bring these years to a similar relative catch rate as adjacent years.

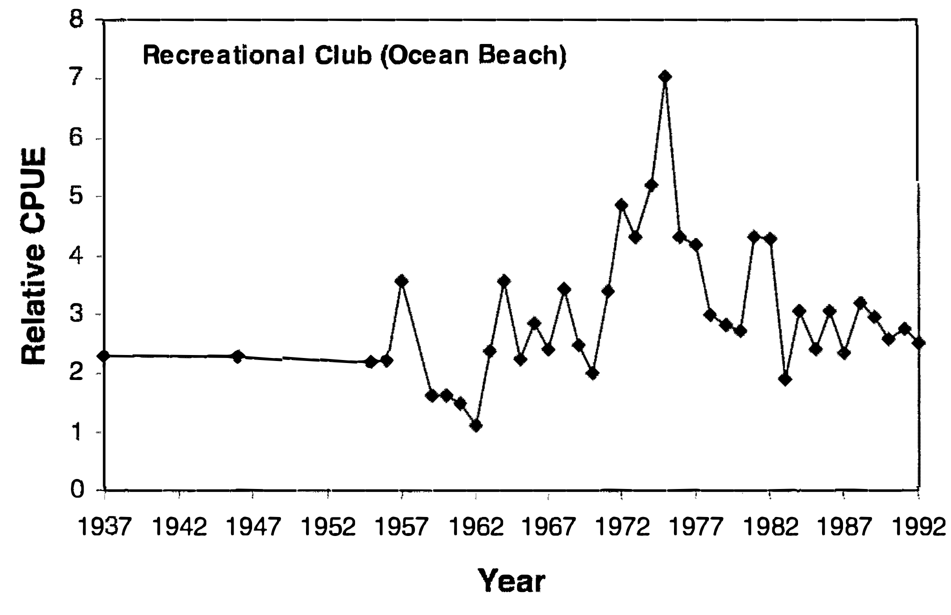

Figure 6.5. *Standardised recreational club catch rate (number fish caught. fisher^{-1}.trip^{-1}) data from ocean beach areas*

6.3.3.b. Commercial catch rate data

The tailor catch and effort data was allocated to the two fisheries categories; the ocean beach and an 'incidental' fishery (which would be mostly estuarine caught fish). The algorithm used to divide the catch and effort data was to define the Ocean Beach catch as tailor caught between April and August by a 'K' QFMA licensed (Ocean Beach licence) fisher and the remaining records as 'incidental'. The 'incidental' fishery was not separated further.

To remove outliers and possible incorrect allocation to fishery, records with catches less than 100kg for the ocean beach fishery and catches greater than 100kg for the 'estuarine' fishery were eliminated from consideration. A weighted (by number) GLM of the natural logarithm of the two catch rates (plus one to avoid taking the log. of zero) with year, month and 'vessel sequence number' as a factor was undertaken. 'Vessel sequence number' is unique to a vessel or seining operation with a specific set of characteristics. If any major change to the vessel or operation occurs, then a new unique number is given.

A non-significant linear trend (p=0.068) in the ocean beach fishery catch rates was observed (Figure 6.6). A similar trend was observed with the standardised 'estuarine' catch rate weighted GLM (Figure 6.7). There is very little difference between standardised and unstandardised trends. Standardisation of the 'incidental' fishery seems to have had a very small effect on the trend. It was suggested that the most important information for commercial effort standardisation is market price, since the behaviour of the fisher is affected by this factor. This information was not available at the workshop and it was recommended that a more in-depth analysis of this data with price be undertaken.

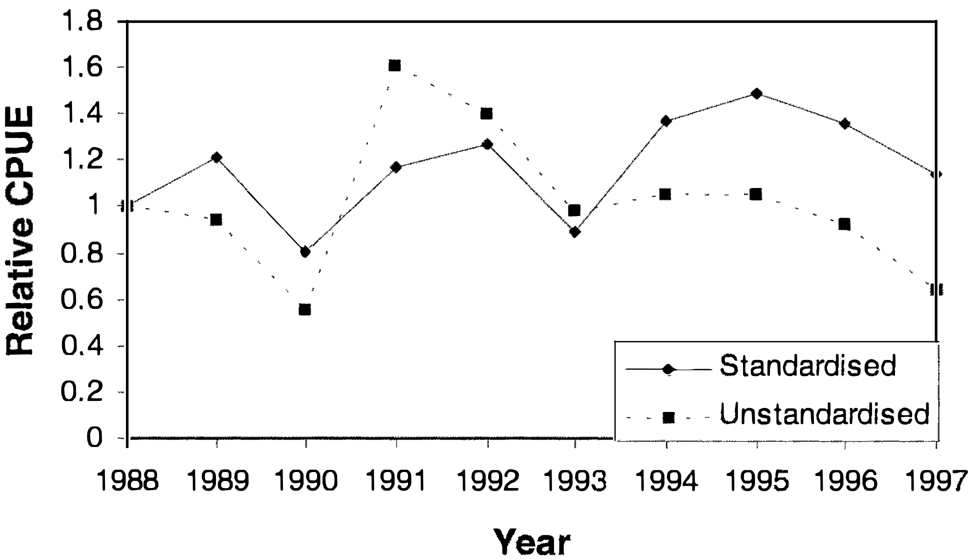

Figure 6.6. *The commercial ocean beach standardised relative catch rate from a weighted (by number) General Linear Model (GLM). A non-significant (p=0.068) trend was observed*

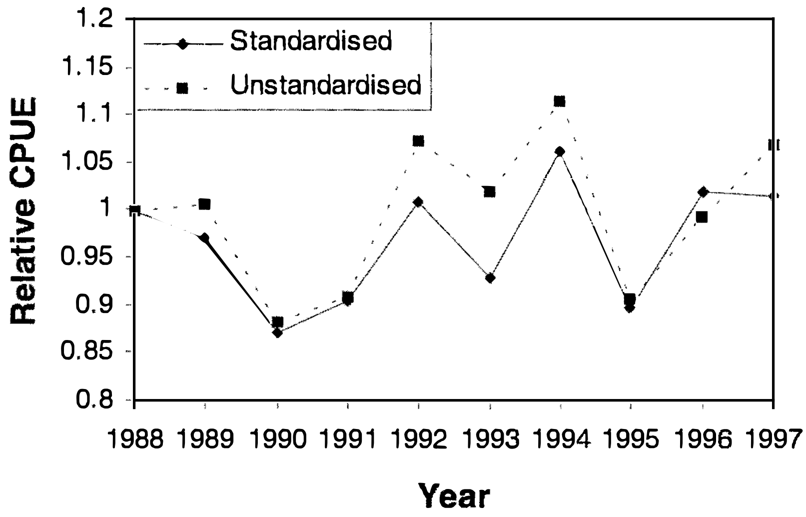

Figure 6.7. *The commercial 'incidental' standardised relative catch rate from a weighted (by number) General Linear Model (GLM). A significant decline over years (p=0.007) can be observed.*

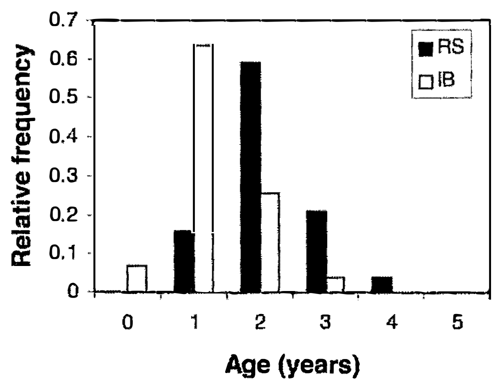

Figure 6.8. *Comparison of ageing frequencies by two readers, Ian Brown ('IB') from DPI, Deception Bay and Richard Steckis ('RS') from WA Fisheries, Perth. Note that RS tends to age the same ototliths as being older than IB's ageing.*

6.3.4. INVESTIGATION OF AGEING AND GROWTH ESTIMATES

There was great concern at the very low proportion of older fish in the commercial catch samples. If this factor is a reflection of reality, then this resource is being subjected to enormous fishing mortality. This group, therefore, had to address the question of whether the ageing technique used by the FRDC T94/161 Integrated Stock Assessment and Monitoring Project (ISAMP) team is subject to:

- bias i.e. assigning ages that are younger or older; or
- precision error i.e. high variation that has lead to an overestimate of total mortality.

6.3.4.a. Bias

In terms of bias, a scientist from Western Australia working on tailor, Richard Steckis, was asked to age sectioned otoliths. Richard tended to age these otoliths older than those within the Centre (Figure 6.8). As a result, his estimates produced a lower total mortality estimate of 0.81 $year^{-1}$ as opposed to the 2.0 $year^{-1}$. However, the project had favoured whole otolith readings and did not use sectioned otoliths for most of their study. Wayne Sumpton from DPI who was originally involved in this project was therefore asked to age a few of the whole otoliths. His results tended to agree with the estimates from the ISAMP project. This highlighted that there is much disagreement with the ageing between States and that validation is required.

6.3.4.b. Precision

The ISAMP ageing experiment's results were used to adjust for the degree of variance in ageing of a single otolith.

In this experiment different readers within the Centre read whole and sectioned otoliths twice. In Table 6.6 an example of averaged double ageing of whole sectioned otoliths for readers Ian Brown and Michelle Sellin demonstrates that the level of disagreement between two independent readings by a single reader of 328 otoliths are high for tailor and that reader bias changes with age of fish.

Since this table can be interpreted both along the row and down a column, the average of these two approaches resulted in the following normalised transition matrix (Table 6.7). For ages 4 and 6, no data was available and therefore no variance or bias was assumed.

Age	0	1	2	3	4	5	6
0	**1**	0	0	0	0	0	0
1	1	**190**	12	0	0	0	0
2	0	17	**96**	4	0	0	0
3	0	1	5	**0**	0	1	0
4	0	0	0	0	**0**	0	0
5	0	0	0	0	0	**0**	0
6	0	0	0	0	0	0	0

Table 6.6. Comparison of average paired otolith readings of the same set of otoliths by two readers combined. Highlighted numbers show number of otoliths pairs which were aged the same. As fish age increases the bias changes.

Age	0	1	2	3	4	5	6
0	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1	0.25	0.92	0.13	0.07	0.00	0.00	0.00
2	0.00	0.07	0.84	0.86	0.00	0.00	0.00
3	0.00	0.00	0.04	0.00	0.00	1.00	0.00
4	0.00	0.00	0.00	0.00	1.00	0.00	0.00
5	0.00	0.00	0.00	0.07	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 6.7. Normalised transition matrix demonstrating bias and variance of paired otolith readings. For ages 4 and 6 no data were available.

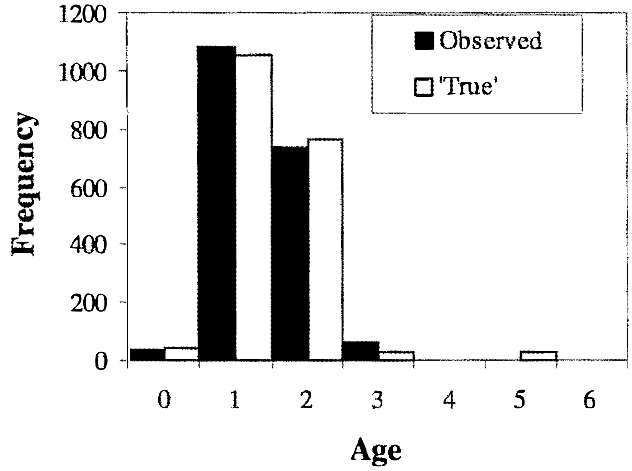

Figure 6.9. *Difference between 'True' and the observed age struture. The 'true' age structure attempts to take into consideration the bias and variance of paired otolith readings.*

Using all the 1997 age data, it is possible to calculate the true age structure ($N_{true,a}$) by multiplying the inverse of the transition matrix ($T_{age,age'}$) with the observed age structure ($N_{observed,age}$) i.e.:

$$N_{observed,age} = T_{age,age'} N_{true,age} : \qquad 6.1$$

The difference between these age structures (Figure 6.9) are not as marked as those between otoliths aged by scientists from the two different Centres.

The resultant total mortality (year^{-1}) from a catch curve analysis changes from 1.9 to 1.3 for the observed and 'true' respectively. Given this high total mortality, the resource would still be interpreted as being overexploited. It would therefore be fundamental to the management of this fishery to validate the ageing of tailor or to clearly demonstrate that these animals cannot be aged with high confidence.

6.4. CONCLUSIONS

6.4.1. GROUP REPORTS

There was great concern expressed at the very low proportion of older fish in the commercial catch samples. If this factor reflects the true situation, this resource is being subjected to enormous fishing mortality that could not be sustainable. Two possible error sources could bias the catch-at-age curve. Otoliths may be incorrectly interpreted as being younger than they really are or large and older animals tend to remain offshore and are therefore not vulnerable to the commercial and recreational fishery. This situation has been observed in Western Australia, but was thought to be unlikely in Queensland waters. A scientist from Western Australia, invited to participate in the workshop, read and interpreted the otoliths of Queensland animals previously aged by Queensland research staff. The bias and variance between the readers from the centre and Western Australia, within the centre and between subsequent readings of the same otolith by a single reader were analysed using a transition matrix modelling approach. Total mortality estimates could range from 0.8 to 2 year^{-1} depending on the interpretation of the ages. these values, whether interpreted from the optimistic to the pessimistic, are still very high in relation to estimated natural mortality rates. Ageing issues should be resolved as a matter of urgency. If total mortality rates are found to be high then the costly exercise of determining the presence of offshore, large animals would be essential.

A first estimate of recreational tailor catch from the recent QFMA recreational survey showed the recreational catch to be about 290t (with maximum levels of about 440 t), whereas the commercial catch has ranged from 100 to 200t per annum.

A generalised linear model of ocean beach recreational club data showed that year and location were significant factors. A major increase in standardised catch rate during the late 1960's and early 1970's was observed, followed by a decline in catch rate to the 1960's level. The catch rate for the last decade from 1982 to 1992 (the last year that data were available) remained relatively stable.

An algorithm was developed to allocate the tailor catch and effort to the ocean beach and other mesh fisheries. Standardisation of catch rate through generalised linear modelling did not highlight any significant trends in the data. The data, however, were very variable.

Previous size frequency distributions had not been weighted to sampled catch size. Reanalysis of the available data had little effect, but it was recommended that this method of weighting be used in the future.

6.4.2. PROGRESS TO DATE

A summary of data quality, stock assessment and management knowledge is given in Table 6.8.

6.4.3. MONITORING, RESEARCH DIRECTION AND PRIORITIES

1. Validation of the ageing of tailor is essential to the future assessment and management of this fishery. In the workshop it became apparent that the health of the stock was either good or bad depending entirely upon whether the ageing studies already carried out are correct or biased downward. For a small financial outlay a large return in management confidence could be achieved.

2. Determination of distribution of large and old fishes. In NSW and WA, large fish are found offshore where spawning occurs. Since these areas are less accessible to anglers, the offshore zone seems to buffer their stocks from overfishing. The Queensland stock appears at first sight not to have this natural safeguard. It was considered that a confirmation or denial of this possibility was a high priority. It could be determined directly by searching for large fish offshore, perhaps from charter vessel catches. Alternatively, it would be possible to track onshore schools acoustically to determine whether they move offshore any great distances or to determine whether there is a substantial population offshore.

3. Improve our understanding of the relation between fishery performance indicators and catch-per-unit-effort data. As with eastern king prawn and saucer scallops in previous chapters. Again a high priority.

4. Sample commercial catches (both beach seining and charter boats) in a representative fashion. The recommendations being developed from FRDC project (T94/161) should be noted. Commercial catches only make up a small portion of the total catch but it is a targeted catch and can be sampled with greater efficiency than recreational catches.

5. Fishery Independent Surveys; possibly aerial surveys. This would not resolve the offshore or ageing problems and so was given a lower priority than the first four strategies.

Category		Comments
Commercial	Catch	Spatial resolution not at Management Plan scale for the ocean beach fishery. Gear type below mesh net is not specified.
	Effort	As above. Search time not recorded. Combine crews from different endorsements either logs catch per endorsement (resulting in 2 days of effort being calculated) or as a single log (resulting in 1 day of effort being calculated). Definition of effort is unclear in multi-species and multi-endorsed fishery. This problem is exacerbated by target species and zero catches not being recorded.
	Catch rate	As above.
Recreational	Catch, effort and catch rate	Recreational catches larger than commercial fishery. Only once off estimates from survey, therefore no time series available.
Independent index of biomass or recruitment		None.
Estimates of natural mortality		Estimates from age data.
Estimates of fishing mortality or biomass		Estimates from age data.
Input controls		Limited entry, spatial and area closures, minimum legal size.
Output controls		None.
TACC Decision rules		N/A.
Performance indicators		None.

Table 6.6. A summary of data quality, stock assessment and management ptrogress to date for tailor.

6.5. REFERENCES

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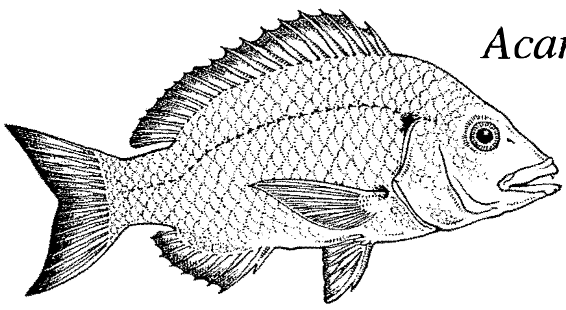
7

common names

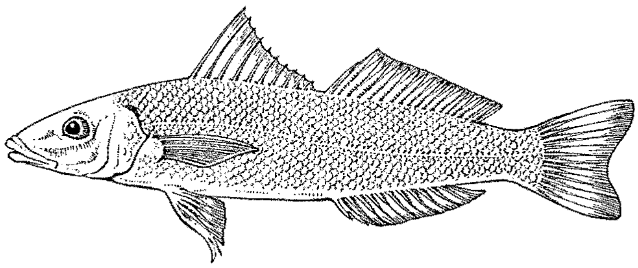
BREAM

Acanthopagrus spp.



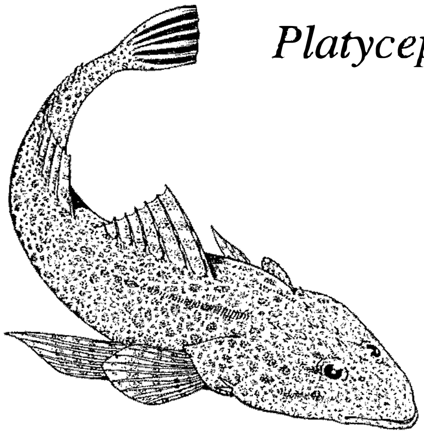
WHITING

Sillago spp.



DUSKY FLATHEAD

Platycephalus fuscus



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7.2. INTRODUCTION

7.2.1. DESCRIPTION OF THE FISHERY

The estuarine and nearshore finfish fishery is the longest-established fishery in Queensland, dating back to the mid 1800s. It is a multi-species, multiple gear fishery shared between a commercial fleet of some 300 small vessels, which land an average annual catch of about 900 tonnes, and a large population of recreational anglers taking a catch of a similar order of magnitude.

Indigenous communities along the coast of Queensland have been involved for centuries in small-scale fisheries for inshore species such as sea mullet. Little information exists on the magnitude or composition of catches from this sector in the southern part of the State, but they were probably minor in comparison with the present-day commercial and recreational finfish landings.

A suite of species, including yellowfin bream, summer whiting (two species), trumpeter whiting, and flathead, can be considered the mainstay of this fishery. These species are typically sub-tropical and generally do not extend the length of the Queensland coastline. This is evidenced by the fact that, over the period 1988 – 1994, 88% (by weight) of the State-wide catch of these species was derived from latitudes south of 22° 30'S (a line between Cape Clinton and the southern tip of the Swain Reefs).

7.2.2. DEVELOPMENT OF THE FISHERY

Commercial fishing in Queensland began in the early 1800s with settlement at the Redcliffe Peninsula, and until the turn of the century was largely confined to the foreshores of Moreton Bay and the Brisbane River. Whiting, bream and flathead have been the basis of the inshore commercial fishery since the early 19th century (Kailola et al. 1993).

From the early 1900s there are reports of significant catches of fish, up to 900 tonnes per year (Williams 1993). However, regular catch data by species or species group did not become available until 1945, when the Queensland Fish Board began to record landings at its regional depots along the coast.

Recreational activity has almost certainly been a feature of the exploitation of the State's inshore finfish resources since the development of the fishing industry. Some angling clubs have records of yellowfin bream and whiting catches from Moreton Bay dating back to the early 1920s. With the growth of population centres along the eastern seaboard, particularly in the south, recreational fishing pressure has been increasing steadily. Both recreational and commercial activities have been made more efficient by the evolution and ready availability of outboard motors, light-weight, trailable runabouts, off-road four-wheel-drive vehicles, and affordable electronic fish-finding and navigational instrumentation.

In the commercial 'mixed' fishery (all types of fishing operation including crabbing but excluding trawling), the species targeted depend to some extent upon the type of fishing gear employed. However, the bulk of the mixed fishery inshore/estuarine fish catch in southern Queensland is taken by mesh (gill) nets and tunnel nets. The main non-crustacean species taken in the mixed fishery include:

- yellowfin bream (*Acanthopagrus australis*);
- sand or summer whiting (*Sillago ciliata*);

- gold-lined or summer whiting (*Sillago analis*);
- trumpeter or winter whiting (*Sillago maculata*);
- dusky flathead (*Platycephalus fuscus*);
- mullet species (*Mugil cephalus, M. georgii, Myxus elongatus,* and *Liza argentea*);
- tailor (*Pomatomus saltatrix*);
- small mackerels (*Scomberomorus queenslandicus*, *S. munroi* and *S. semifasciatus*).

The ocean beach component of the mixed fishery, which takes mainly mullet and tailor, was considered in a separate section of the workshop.

Also included in Figure 7.1 are reported catches of the three important small mackerel species – school mackerel (*Scomberomorus queenslandicus*), spotted mackerel (*S. munroi*) and grey or broad-barred mackerel (*S. semifasciatus*). A number of other species, considered as by-catch on account of sporadic occurrence or

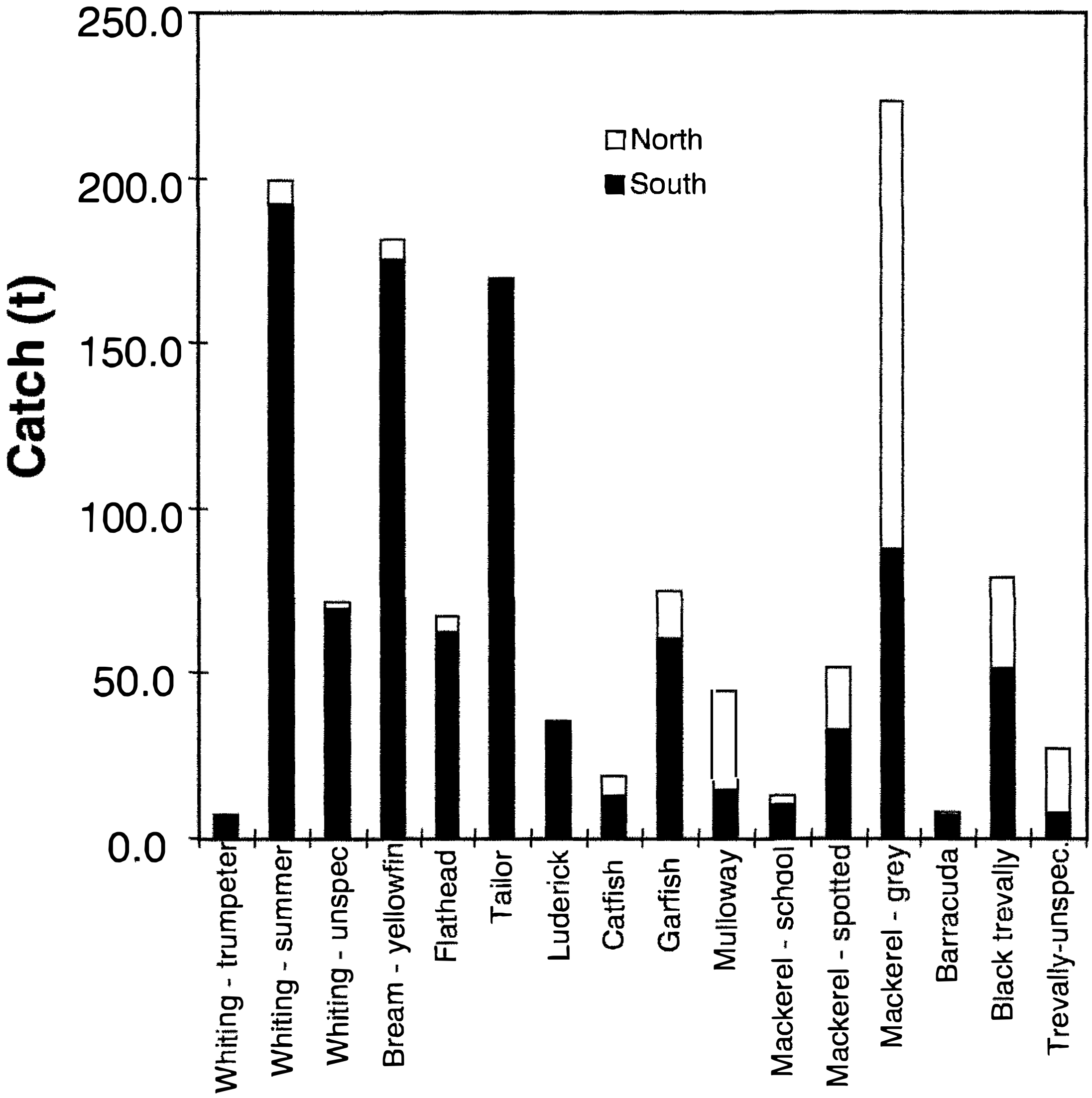

Figure 7.1. *Mean annual catch (1988–1994) of the main components of the southern estuarine fishery derived from the Queensland east coast north and south of Cape Clinton (22°30'S). (Note Black trevally are a siganid and not a carangid).*

relatively limited quantity rather than necessarily lower economic value, are also taken. Due to time and priorities, these species were not considered at the workshop.

The recreational fishery also targets yellowfin bream, summer and trumpeter whiting, and dusky flathead. Other species caught incidentally include tailor, luderick, tarwhine, and dart (Pollock & Williams 1983).

Commercial quantities of whiting (mainly the trumpeter or winter whiting *S. maculata*) are caught as bycatch in the prawn trawl fishery in Moreton Bay and other estuarine areas. Small quantities of flathead are taken as well, but these may include species (other than *P. fuscus)* which are not generally caught in the net fishery. The trawl fishery takes no appreciable by-catch of yellowfin bream.

It should be pointed out that there is another fishery – separately managed and currently in a developmental stage – which specifically targets the prolific stout whiting (*S. robusta*) offshore in depths of 25 – 32 m between Sandy Cape and Bribie Island. *S. robusta* do not occur in the estuaries, and are therefore not part of the estuarine/ inshore fishery.

The commercial estuarine-inshore mixed fishery catch is taken mainly by mesh and tunnel net. Significant quantities of trumpeter whiting are taken as by-catch by the Moreton Bay prawn trawl fleet. Some haul or seine netting also takes place around the foreshores of the bay for mullet, whiting, or (with nets of smaller mesh size in seagrass areas) for garfish.

Gill or mesh netting involves the deployment of a light monofilament net in an area where fish are likely to be moving and may swim into the net, becoming caught in the meshes by protruding fin spines or gill covers, or simply by trying to force their way through the mesh.

Dusky flathead, for example, are usually captured in mesh nets by entanglement. The existence of vomerine teeth, pre-opercular spines, assorted head ornamentation, and a large flat head in relation to the main body trunk appears to predispose flathead to capture in nets of various mesh sizes. Flathead are consequently captured in nets of a mesh size which would usually not retain a more fusiform shaped fish with an identical girth measurement. Most flathead larger than 50 cm are captured by the entanglement of several separate meshes over each pair of pre-opercular spines.

Estuarine species are often specifically targeted during a net shot by inshore mesh net fishers. Fishers are able to target particular species by considering factors such as mesh selectivity, bottom substrate, state of tide, and season. Consequently, the catch on any given day by a particular fisher will tend to be dominated by one species.

Tunnel netting is a 'draining off' operation involving the use of a fixed net staked out in the intertidal zone, usually on mud-flats in front of mangrove forests or near the mouth of a river or creek. The wings of the net are fixed in such a way as to shepherd fish towards a long sock or blind tunnel submerged in a shallow gutter on the ebbing tide. As the tide falls, the wings are normally dismantled so that ultimately only the tunnel remains, at least partly submerged in sufficient depth of water to allow the catch to swim freely until they are sorted. At certain times of the year concentrations of jellyfish (blubber) can build up against the net and force it beneath the surface, and drifting filamentous algae (blanket weed) covering the mesh can reduce the net's efficiency. Tunnel nets are not as selective as mesh nets and tend to capture a broader range of species.

Seine or haul netting is normally conducted from the foreshore or beach, generally with the aid of a small vessel to lay the net out in an arc, surrounding an area of water suspected of containing fish. The net is then hauled in to the shore (sometimes with the aid of a vehicle equipped with a winch) where it is 'dried out' in very shallow water enabling the catch to be sorted manually.

At the present time it is not possible in the QFISH database to discriminate between the various types of mesh and seine netting operation. This contributes to a significant difficulty in monitoring the status of these resources using catch rate (CPUE), as the different methods are clearly characterised by substantially incompatible measures of fishing effort.

As significant quantities of trumpeter whiting (*S. maculata*) are taken as a by-catch in the prawn trawl fishery, it is necessary, for completeness, to include otter trawls in the description of catching apparatus. Most trawl-caught trumpeter whiting are taken in the Moreton Bay area, where trawling is restricted to vessels less than 14 m towing (usually) twin trawls with a combined headrope length not exceeding 8 fathoms (14.6 m). Trawls are generally of the Sandekan or Florida Flyer design, with minimum stretched mesh of 1.5" (38 mm).

The recreational catch from the estuarine/inshore finfish fishery is taken almost exclusively by baited rod-and-line and handline (Kailola et al. 1993), with a maximum of 6 hooks per line. This type of gear is used from small boats, the foreshore, river mouths, and man-made structures such as rock walls, wharves, and jetties. Recreational anglers are not permitted to use nets apart from bait nets (maximum length and width 16 m and 3 m respectively) and cast nets (maximum diameter 6 m). The maximum mesh size permitted for both types of net is 28 mm to ensure that the catch comprises fish of a size suitable only as bait.

Bream, whiting, flathead, and tailor are the most popular angling species in the estuaries and inshore waters of southern Queensland. Yellowfin bream are the main species taken by recreational fishers in the estuarine areas of Moreton Bay, Caloundra, Jumpinpin, and Southport. These species are also all very important components of the commercial fish catch.

Several attempts have been made to estimate the size and species composition of the recreational catch. Pollock (1980) conducted a series of angler interviews at Jumpinpin and Caloundra in 1979, and estimated the recreational catch of yellowfin bream in that area to be 160 tonnes. He concluded that on a regional basis it probably exceeded the reported commercial net catch of 275 tonnes (data from QFB Reports, averaged over the period 1977–1980). The commercial summer whiting catch was estimated to be greater than the recreational catch in southern Queensland.

Pollock (1980) considered that during the previous decade the catch from the commercial net fishery had increased only slightly, in contrast to a much greater rise in angling activity. Small scale recreational creel surveys in Moreton Bay in 1993 indicate that the total recreational catch of dusky flathead is at least equivalent to, and probably exceeds, the total commercial catch.

There is a perception among anglers that decreases in their catch rates are due to commercial fishing activities. Moore (1986) found that 67% of Hervey Bay anglers believed that catch rates had declined. In 57% of these cases the decline was attributed to too many trawlers and anglers, in 20% to commercial netters, and in 19% to trawlers. Articles in recreational fishing publications in southern Queensland (e.g. Steptoe 1995) clearly attribute a perceived decline in recreational flathead catches to commercial netting activity.

QFMA has recently undertaken a recreational-fishery targeted telephone and volunteer logbook program, but final analyses of results are as yet unavailable. There is no formal mechanism for apportioning the available catch of inshore/estuarine fish between commercial and recreational sectors.

The commercial sector of the estuarine fishery supplies most of its product to the local south-east Queensland market, though some is sent to Sydney, depending on price differentials. Yellowfin bream are sold almost exclusively on domestic fresh fish markets, usually in whole chilled form (Kailola et al 1993). Large bream (>25 cm) from Moreton Bay are often sent interstate and sold at the Sydney Fish Market. On the basis of an average wholesale price (to the fisher) of $3.50 per kg, the commercial bream fishery is currently worth around $420 000. Price is size-dependent, ranging from $3.00–3.50/kg for average sized fish to $4.50–5.00/kg for large fish.

Whiting are marketed locally as chilled or fresh whole fish or fillets. Summer whiting species command high prices ($6.00–6.50/kg for mediums and $7.50–8.00/kg for large fish [typical 1996 prices for whole fish]) compared to winter whiting ($2.00/kg) because of their larger size and superior flesh quality. The combined value of the summer and winter whiting catch (i.e. not including trawl-caught stout whiting) is probably in excess of $1.3 million before any value-adding.

The estuarine fishery supplies local southern Queensland markets with fresh flathead throughout the year. A significant amount of dusky flathead sourced from throughout Queensland is auctioned whole, fresh iced, by Raptis and Sons at Colmslie, Brisbane. Prices obtained by fishers vary between about $2.50 and $7.50 per kg depending on demand and availability. Based on these prices and the quantity of flathead caught, the raw value of flathead to fishers (not including any value-added benefits from processing and additional employment) is estimated to be between $170 000 and $500 000.

7.2.3. MANAGEMENT

The main controls on the commercial fishery consist of limited licence schemes, gear restrictions, area closures which may be total or gear-specific, and seasonal closures (Quinn 1992). The Queensland fishing industry is closed in the sense of 'limited entry', and most of the individual fisheries are subject to transferable endorsements.

Commercial net fishers are subject to gear restrictions in terms of type of net, net length, mesh size, and drop. There are also weekend closures on all rivers and creeks south of Baffle Creek, and in Moreton Bay.

Size limits apply in both commercial and recreational sectors. Minimum legal sizes (total length) of the species most frequently encountered in the inshore fishery are as follows: yellowfin bream 23 cm, summer whiting 23 cm, tarwhine 23 cm, flathead 30 cm, luderick 23 cm, and 'lesser' mackerels 50 cm (Anon, 1996). There are no bag limits on recreational fishers at present for bream, whiting, or flathead, though they are currently being considered. Input controls on recreational fishing restrict gear to a prescribed number of fishing lines and hooks.

Until recently, no formal performance indicators or reference points have yet been developed for any of the State's fin-fisheries. To date, only *ad hoc* analyses of commercial catch-per-unit-effort have been used in an attempt to draw conclusions about the trends in the stock. Such analyses have been hampered by lack of resolution in the data, poorly-defined measures of fishing effort, and an inherent but completely untested assumption that catch rates provide an unbiased index of stock size.

The draft Subtropical Finfish Management Plan has identified appropriate performance indices and reference points (whether biological, economic, or social) in order to introduce a formal mechanism for assessing trends in the stock, and (most importantly) specifying a course of management action to be taken if and when the reference points are reached.

7.2.4. BREAM

7.2.4.a Biology

Table 7.1 below summarises the most salient points of our biological knowledge of the species.

This rather large topic has been well described in Kerby & Brown (1994). Estimates of the growth characteristics of yellowfin bream have varied widely among different studies (Kerby & Brown 1984). The work of Munro (1944), who used scales to determine age, suggested that growth is linear and relatively slow. In contrast, Pollock (1984), using length frequency analysis and tagging, estimated lengths-at-age of the first three age classes suggesting a growth curve conforming to the von Bertalanffy model (Figure 7.2). Scales are generally regarded nowadays as poor estimators of age, so the growth characteristics as estimated by Pollock (1984a) are presumed, until tested by comparison with otolith-derived data, to be more realistic.

Pollock (1982) estimated von Bertalanffy growth curve parameters: $L_\infty = 29.5$ cm, $K=0.51$, and $t_0 = -0.32$ years. These estimates were derived from mark-recapture data. Yellowfin bream exhibit protandrous sex inversion (Pollock 1985).

7.2.4.b Current catch and effort levels

Almost all of the commercial catch of yellowfin bream is taken by tunnel netting or gill-netting. During 1994, this amounted to about 96% of the bream catch reported from the southern estuarine/inshore fishery between Mackay (21°00'S) and the New South Wales border (28°30'S) (Table 7.2). The small quantity attributed to trotlining is probably a reporting error, as this technique is currently only used in the spanner crab fishery where the bycatch is almost non-existent and very unlikely to include yellowfin bream in any case.

Species	Age at Maturity (years)	Length at Maturity (cm)	Spawning Period	Habitat Preferences	Migrations
Yellowfin Bream (*Acanthopagrus australis*)	Depending on source: 2, 3 *m* 4 *f*, or 4	Depending on source: 17.5–20.5 cm FL, 18 cm FL *m* and 21 cm FL *f* or 20 cm.	June–August	Shallow turbid estuarine waters associated with sea-grass and mangroves.	Annual spawning migration from estuarine feeding grounds to surf bar entrances.
Sand Whiting (*Sillago ciliata*)	Depending on source 2 or 3	Depending on source: 26 cm FL or 21–30 cm FL	September–February or March	Commonly found in shallow water (<5 m) over a sandy substrate.	Northward localised movements (<15km)
Golden-lined Whiting (*Sillago analis*)	2–3	20 cm	September–March	Shallow water (<10m). Adults prefer muddy substrates.	Unknown
Trumpeter Whiting (*Sillago maculata*)	1*m*, 2 *f*	Depending on source: 12.6 cm TL *m* and 14.1 cm TL *f* or 18cm FL.	July–February or March	Silty and muddy substrates. Especially common in turbid areas.	Unknown. No evidence of migration outside of Moreton Bay.
Dusky flathead (*Platycephalus fuscus*)	3–4	Approx. 25 cm TL	September–March	Mud, silt, sand & seagrass beds to depths of 10m	Short & long distance migrations observed.

Table 7.1. Summary of biological characteristics for 6 species (based on Kerby & Brown 1994) (*m* = male, *f* = female)

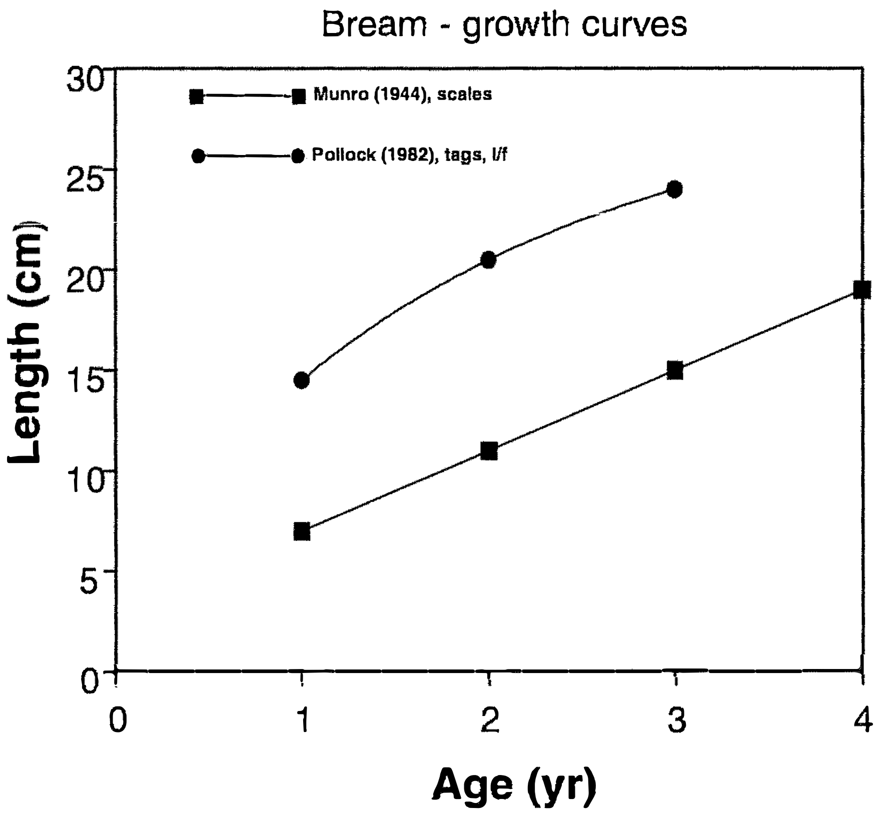

Figure 7.2. *Indicative growth curves for bream based on mean length-at-age data from Munro (1944) and Pollock (1982).*

Fishing method	Weight caught (tonnes)
Tunnel and gill netting	111.58
Trotline	0.99
Not specified	3.24
Total	115.80

Table 7.2. Total catch of bream by fishing method in 1994 Data source: QFISH mixed fishery table.

The yellowfin bream is very much a subtropical species, occurring in estuarine waters in the southern part of the State and ranging south into New South Wales. A congeneric species (the pikey bream *A. berda*) was also probably reported as 'yellowfin bream' prior to 1994, when it first appeared in the QFISH database. However, this would not have contributed significantly to the reported catch of yellowfin bream in the southern fishery, as the pikey bream is largely restricted to tropical estuaries of north Queensland and Papua New Guinea.

Historical commercial catch data are available only through the records of landings at the QFBs regional depots and Fishermen's Cooperatives. These extend from the Second World War through to around 1980, when the Board was sold to private interests. While not accounting for the entire commercial catch, these data are of interest in that they do not exhibit any consistent long-term trend (Figure 7.3). There appears to have been a post-war decline in landings over the 15 years to 1960, then a gradual increase to a second peak in the late 1970s. The long-term mean annual catch over that period was 220 tonnes, but individual yearly catches ranged from about 70 t in 1960 to 380 t in 1946.

The reported annual catch of yellowfin bream during the period of the QFISH logbook programme has also varied, from about 220 t in 1990 to 120 t in 1994. This variability is well within the 'historical' range mentioned above.

7.2.4.c Recreational catch trends

Records of fishing club anglers in the whole of Moreton Bay show little change in the mean size of bream caught between September and April of the years 1945 to 1980 (Pollock and Williams 1983). An increase in catch per unit effort occurred between 1965–66 and 1975–76, from 7 fish per angler trip to 15 (five year running mean), followed by a decrease to 13 by 1980–81. A similar increase in catch per unit effort occurred at Jumpinpin and Caloundra surf bar spawning areas between May and August of 1960 and 1975, and a decrease to 1980. Jumpinpin went from 9 to 27 fish per angler per trip (5 year running mean), and down to about 16 (two year mean). Caloundra went from 5 to 20 (5 year running mean), and declined to about 15 (two year mean). The decrease was concurrent with a substantial increase in recreational fishing effort. The total quantity of bream caught did not change significantly between 1975 and 1980.

Thwaites & Williams (unpublished) also examined changes in the recreational catch rates of yellowfin bream, based on records from fishing club competitions. They found no significant change at the Jumpinpin or

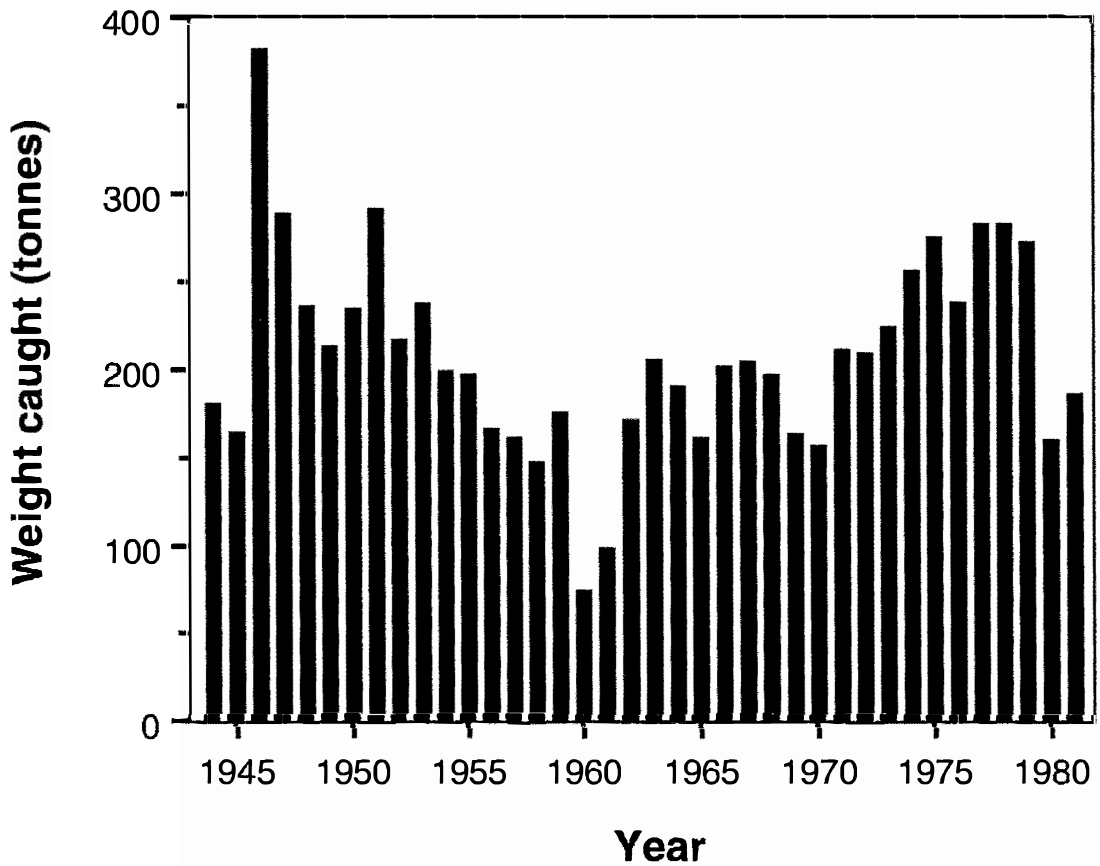

Figure 7.3. *Historical records of commercial bream catch received by the Queensland Fish Board at all branches and depots. Data source: Queensland Fish Board Annual Reports.*

Southport surf bars, or in the estuarine areas of Moreton Bay, from the mid seventies to 1991. However, they noted a decline at the Caloundra surf bar between a peak of 29 bream per angler day (three year running mean) in 1974 to 10–12 fish per angler day in the mid to late eighties.

7.2.5. WHITING

7.2.5.a Development of the fishery

Almost all of the commercial mixed fishery catch of whiting is taken by beach seining, tunnel netting, or gill–netting. During 1994, this amounted to about 96% of the whiting catch reported from the southern estuarine/inshore fishery between Mackay (21°00'S) and the New South Wales border (28°30'S) (Table 7.3). The small quantity attributed to trotlining is probably a reporting error, as this technique is currently only used in the spanner crab fishery where the bycatch is almost non-existent and very unlikely to include whiting in any case.

Fishing method	Catch (tonnes)
Gill/tunnel netting	166.68
Trotlining	0.02
Unspecified method	8.27
Trawl (inc. *S. robusta*)	2 507.77
TOTAL	2 682.74

Table 7.3. Total commercial net and line (mixed fishery) and trawl fishery catch of whiting in 1994 between Mackay (21°S) and the New South Wales border (28°5'S). Data sources: QFISH mixed fishery and trawl fishery tables.

Commercial effort levels are not yet available by gear type for the entire State. Neither catch nor effort levels are available for the recreational sector. *Sillago ciliata* is found along the east coast of Australia from Cape York, Queensland, south to eastern Victoria and northern Tasmania. *S. analis* is mainly restricted to north Australian waters, as far south as Shark Bay in Western Australia and Moreton Bay in Queensland.

The mixed fishery for whiting extends from north of Mackay to the New South Wales border, but almost all (95% by weight) of the State's reported catch comes from between Baffle Creek and the New South Wales border. The majority of the catch is evenly divided between Hervey Bay (27%) and northern Moreton Bay, including Pumicestone Passage up to October 1995, (30%). Significant proportions of the 1994 catch also came from the Bundaberg north Hervey Bay region (9%), Tin Can Bay (16%), and south Moreton Bay (6.5%).

Historical commercial catch data are available only through the records of landings at QFBs regional depots and Fishermen's Cooperatives. These extend from the Second World War through to around 1980, when the Board was sold to private interests. While not accounting for the entire commercial catch, these data are of interest in that they do not exhibit any consistent long-term trend (Figure 7.4).

The reported mixed fishery annual catch of whiting during the period of the QFISH logbook programme has also varied, from about 320 t in 1988 to 175 t in 1994 (Figure 7.5). Allowing for the fact that the historical data includes prawn bycatch of *S. maculata*, this variability is probably within the 'historical' range mentioned above.

However, the observed trend is a decline, by just over 45% since 1988. Catch per unit effort, crudely estimated using the 'boat day' as the unit of fishing effort, has remained roughly constant during this period, since effort has also decreased.

7.2.5.b Recreational catch trends

Thwaites & Williams (1994) examined summer whiting competition catch records of anglers from 12 recreational fishing clubs at five popular fishing locations in south-east Queensland (Inskip Point, Bribie and Moreton Islands, Jumpinpin, and Southport). All sites except Inskip Point experienced an increase in the average number of summer whiting caught per angler day between 1959 and the 1970s. This was followed by a decline between 1975 and 1991 at Bribie Island by about 10 fish per angler day. There was no significant change at the other four sites.

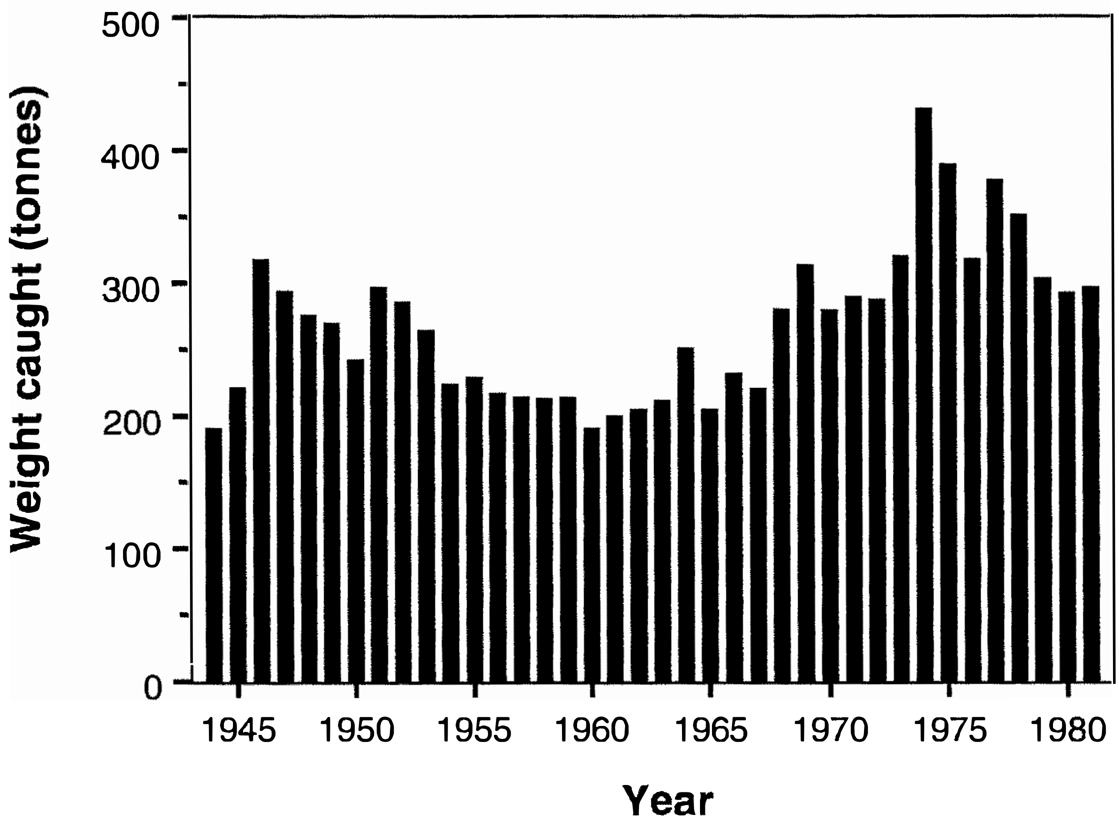

Figure 7.4 *Historical records of commercial whiting catch received by the Queensland Fish Board at all branches and depots. All whiting species and fishing methods are included. Data source: Queensland Fish Board Annual Reports.*

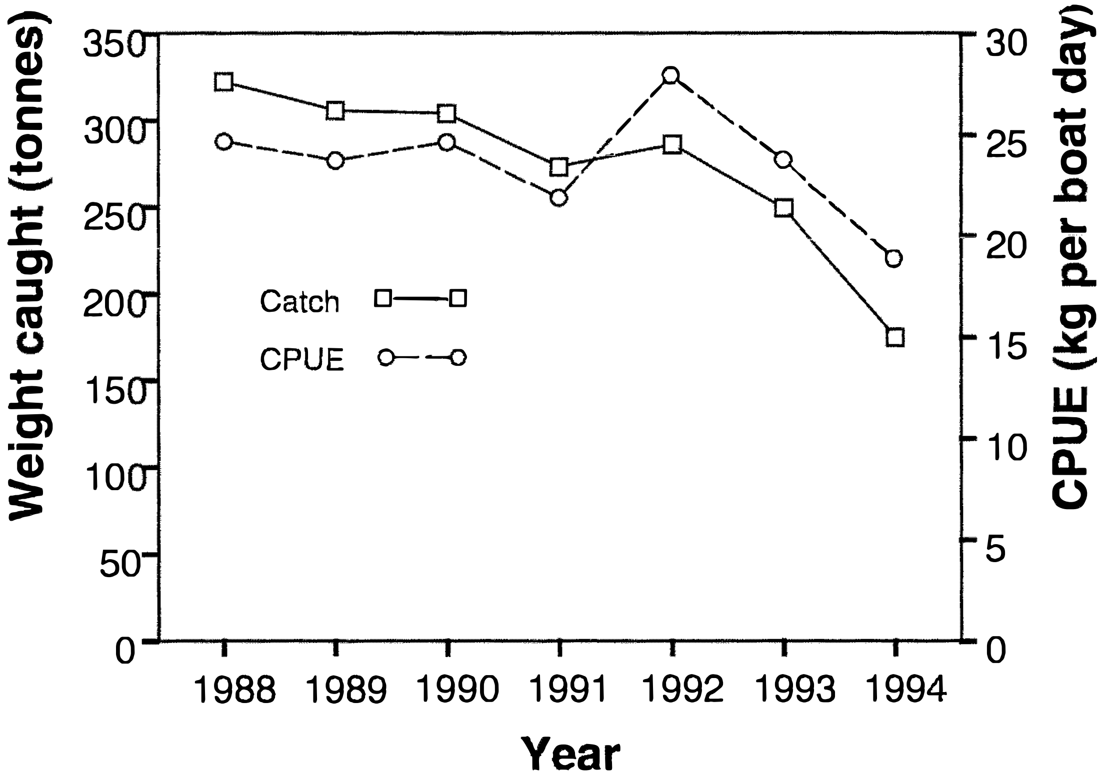

Figure 7.5 *Annual trends in commercial net catch and cpue (ie. excluding trawl catch) for all whiting species between Mackay and the New South Wales border. Data source: QFISH summary table.*

7.2.5.c Biology

The basic biological information for whiting are described in Table 7.1.

Thirty-one species of the family Sillaginidae are recognised (McKay 1992). The name 'summer whiting' includes the species *Sillago ciliata* and *Sillago analis*. *S. ciliata* is known also as sand whiting and bluenose whiting. *S. analis* is known also as the golden-lined whiting, Tin Can Bay whiting, and rough scaled whiting.

The trumpeter whiting (*Sillago maculata*) is also known as the winter whiting, diver whiting, and spotted whiting. There are three subspecies of *S. maculata*, of which only one, *S. m. maculata*, occurs on the east coast.

Sillaginids are widely distributed in the western Pacific and the Indian Ocean. *S. ciliata* is distributed from Papua New Guinea to Tasmania, but is most commonly found in northern New South Wales and southern Queensland (McKay 1985). *S. analis* is mainly restricted to north Australian waters. It occurs in Shark Bay, Western Australia, along the NT and Eastern Queensland coastlines, and southwards along the east coast of Queensland to Moreton Bay. It is also found on the southern coast of New Guinea (McKay 1985). *S. maculata* is found off the east coast of Australia from Lizard Island, north Queensland, to Narooma in southern New South Wales, and on the coast of Western Australia (Kailola et al 1993). It is also common on the coasts of east Africa, the Philippines, the East Indies, and China (McKay 1985). *S. robusta* occurs throughout inshore marine waters off south-eastern Australia.

Estimates of the growth characteristics of *S. ciliata* have been produced for both New South Wales (Cleland 1947) and Queensland (Dredge 1976) populations, and they appear to be very similar (Figure 7.6). However, Cleland did not differentiate between *S. ciliata* and *S. analis*, which must reduce confidence in his estimates.

Cleland's estimates are based on scales, while Dredge used otoliths. Dredge found both scales and otoliths difficult to interpret, and concluded that there are two distinct phases of growth in *S. ciliata*. He interpreted fish smaller than 20 cm separately from larger fish.

The maximum recorded length for *S. ciliata* is 51 cm (McKay 1992), but this is exceptional. Young (1989) at the Southport broadwater recorded maxima of 38 cm (female) and 36 cm (male), while Burchmore et al (1988) reported maxima of 31 cm (female) and 40 cm (male) from the Botany Bay (New South Wales) population.

S. analis grows to a maximum length of 45 cm TL (McKay 1992). Length frequency distributions, however, are difficult to interpret, probably as a result of the species' extended spawning period (Gunn 1978, Kerby and Brown 1994).

Maclean (1968) used growth checks on scales to determine length at age for *S. maculata*, while Weng (1994) used otoliths, scales, and length frequency analysis (Figure 7.7). *S. maculata* can grow to about 30 cm total length (Dixon et al 1987), although Weng (1994) found maxima of 22 cm FL for males, and 27 cm FL for females. Maclean (1968) reported a maximum size of 22 cm FL for both sexes.

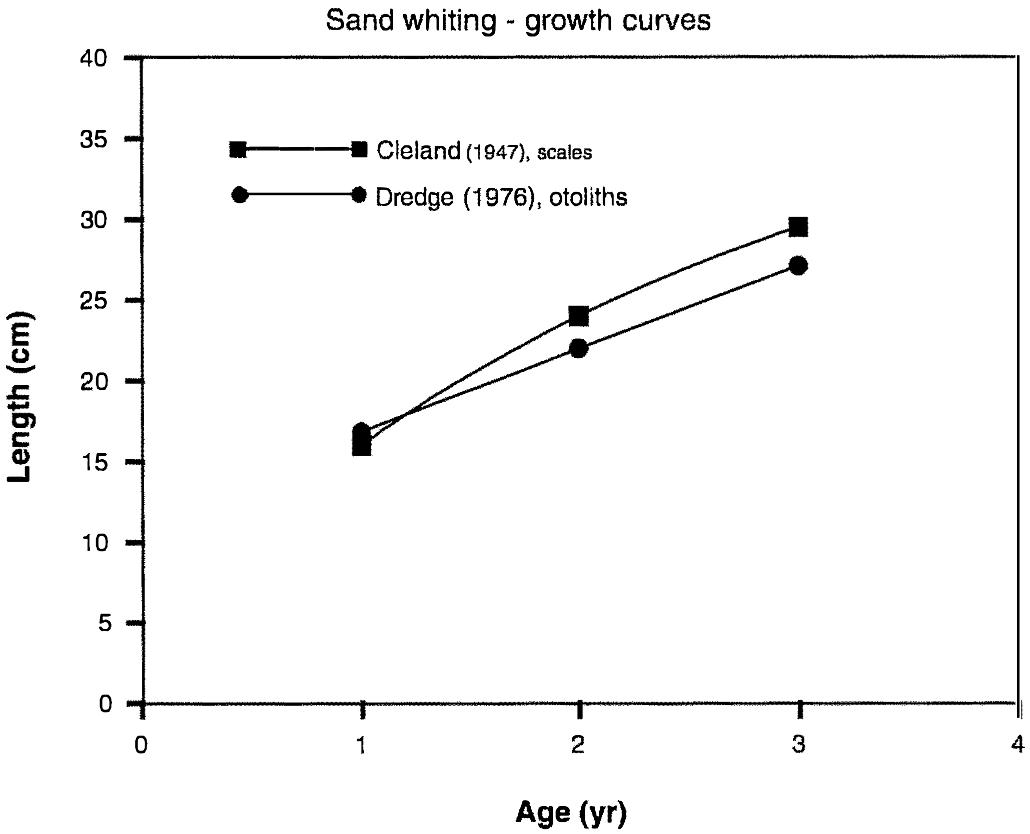

Figure 7.6 *Indicative growth curves for S. ciliata (sand whiting) from Cleland (1947) and Dredge (1976). Curves are based only on reported mean lengths-at-age, for a limited range of ages. Lengths are fork length.*

7.2.6. FLATHEAD

7.2.6.a Exploitation History

Almost all of the commercial catch of flathead is taken by mesh and tunnel netting. During 1994, this amounted to about 94% of the flathead catch reported from the southern estuarine/inshore fishery between Mackay (21°00'S) and the New South Wales border (28°30' S) (Table 7.4). The small quantity attributed to trotlining is probably a reporting error, as this technique is currently only used in the spanner crab fishery where the bycatch is almost non-existent and very unlikely to include flathead in any case.

Commercial effort levels are not yet available by gear type for the entire state. Neither catch nor effort levels are available for the recreational sector.

The dusky flathead (*Platycephalus fuscus*) occurs in estuarine waters from Cairns in Queensland to the Gippsland Lakes in eastern Victoria (Kailola et al 1993).

The fishery for flathead extends from around Townsville to the New South Wales border, but almost all (98% by weight) of the State's reported catch comes from between Cape Clinton and the New South Wales border, and the bulk of the catch (53% in 1994) comes from northern Moreton Bay, including Pumicestone Passage. A significant proportion of the 1994 catch (21%) came from the Tin Can Bay area. Smaller catches were taken in Hervey Bay (24.5°S to 25.5°S), in the Caloundra area, and in southern Moreton Bay.

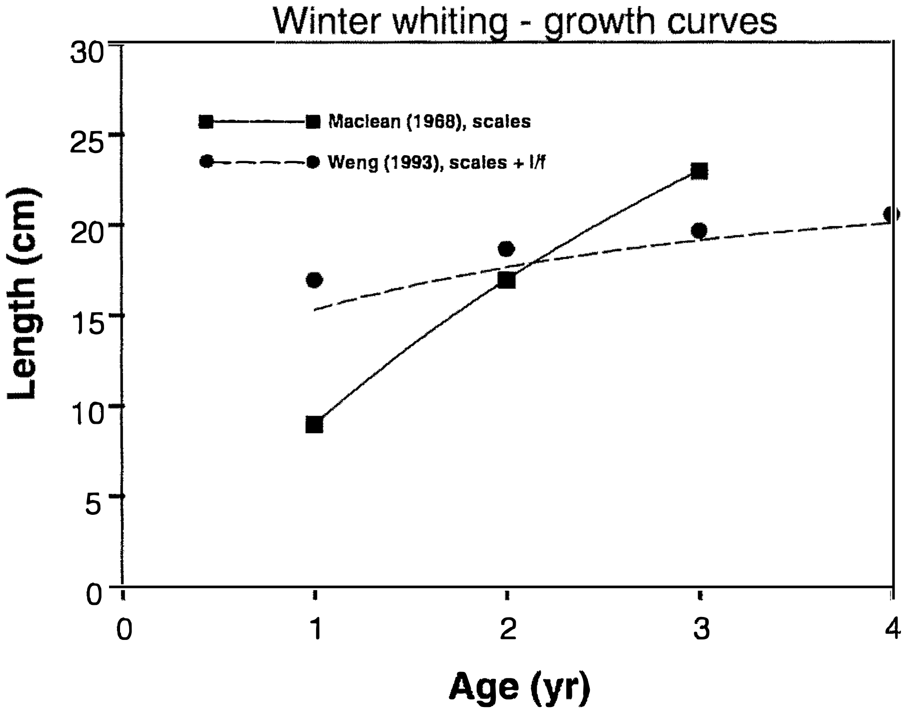

Figure 7.7. *Indicative growth curves for S. maculata (trumpeter whiting) from Maclean (1968) (total length) and Weng (1994) (fork length). The Maclean curve is fitted to reported mean lengths-at-age, while in the latter case the reported von Bertalanffy growth parameters were used to plot the curve.*

Method	Catch (tonnes)
Line fishing	0.05
Tunnel and gill netting	42.43
Trotline	0.18
Unspecified method	2.32
Grand Total	44.97

Table 7.4 Total catch of flathead by fishing method in 1994 between Mackay (21.0°S) and the New South Wales border (28.5°S). Data source: QFISH mixed fishery database.

As for bream and whiting, historical commercial catch data are available only from the Second World War through to around 1980, and do not account for the entire commercial catch. Flathead data also do not exhibit any consistent long-term trend (Figure 7.8). Following a period of stable catches between 1946 and 1959 averaging 91 t, catches up to 1980 averaged 71 t (apart from peaks in 1974 and 1975 of about 100 t). The long-term mean annual catch over that period was 77 t, but individual yearly catches ranged from about 53 t in 1970 to 106 t in 1958.

The reported annual catch of flathead during the period of the QFISH logbook programme has also varied, from about 83 t in 1989 to 45 t in 1994, with a declining trend (Figure 7.9).

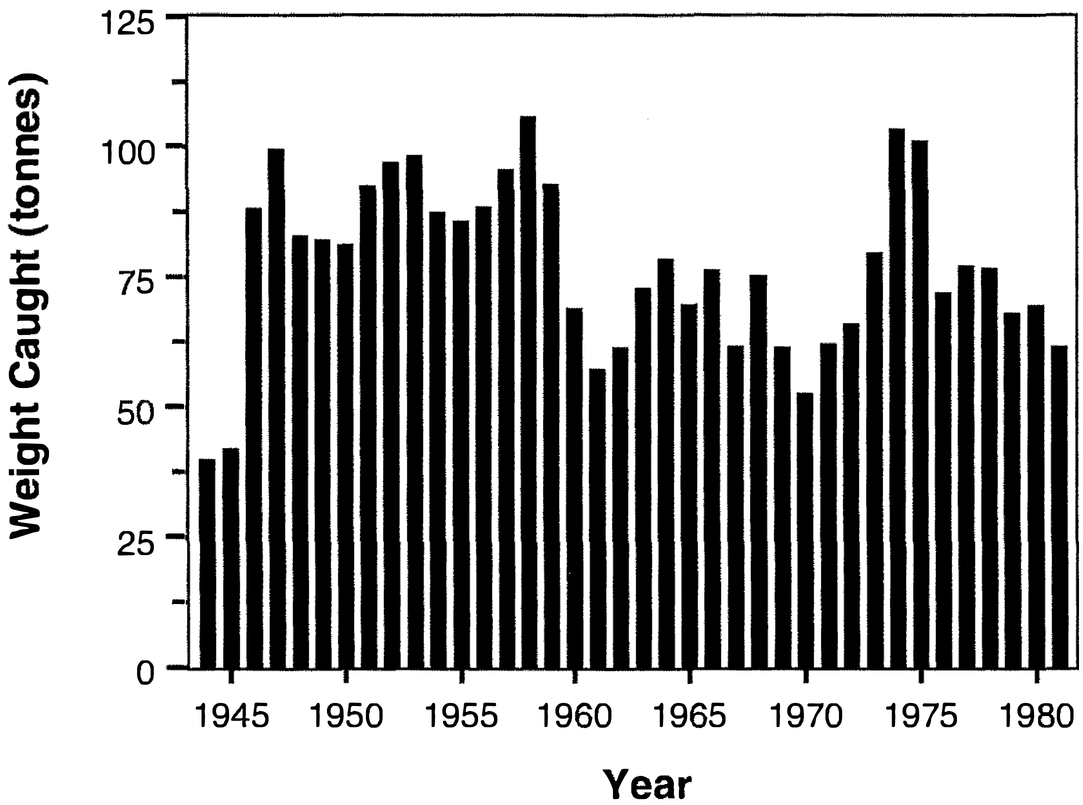

Figure 7.8 *Historical records of commercial flathead catch received by the Queensland Fish Board at all branches and depots. All species of flathead are included. Data source: Queensland Fish Board Annual Reports.*

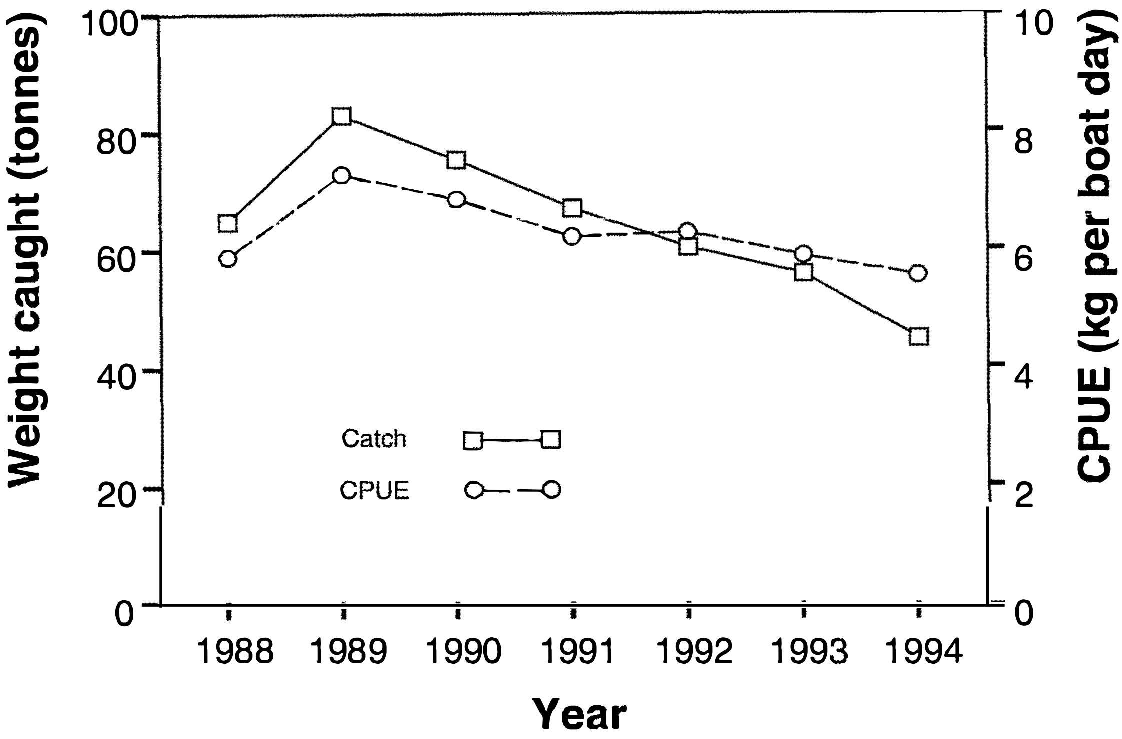

Figure 7.9 *Annual trends in the mixed fishery catch and cpue of flathead, for all areas between Mackay and the New South Wales border. Data source: QFISH summary tables.*

7.2.6.b Biology and behaviour

Table 7.1 describes the basic biology of flathead.

7.2.6.c Growth

Dredge (1976) estimated the growth of dusky flathead using otolith ageing techniques and length frequency analyses. Scales were not used for aging because growth rings are unclear. The mean lengths of fish with 2, 3, 4, and 5 otolith annuli were 23, 33, 44, and 52 cm respectively. Dredge (1976) found no significant difference in length-at-age between male and female dusky flathead.

Preliminary estimates of the von Bertalanffy growth parameters from recent studies at the Southern Fisheries Centre are as follows: L_∞ = 84.4 cm, k = .205 and t_0 = -0.94 (Figure 7.10; Cameron unpubl. data). Computed lengths-at-age based on these parameter estimates are presented in the accompanying graph. These estimates vary somewhat from those of Dredge (1976), possibly because of the difference in interpretation of the first annulus, which is often difficult to detect.

7.3. BREAM, WHITING AND FLATHEAD TASK GROUPS

1. Investigation of catch rates from CFISH specially in terms of fishing method and location
2. Estimate relative commercial to recreational catch
3. Discuss and analyse the usefulness of the recreational tagging database with special emphasis on movement, growth and distribution of effort
4. Re-examine growth rate estimates

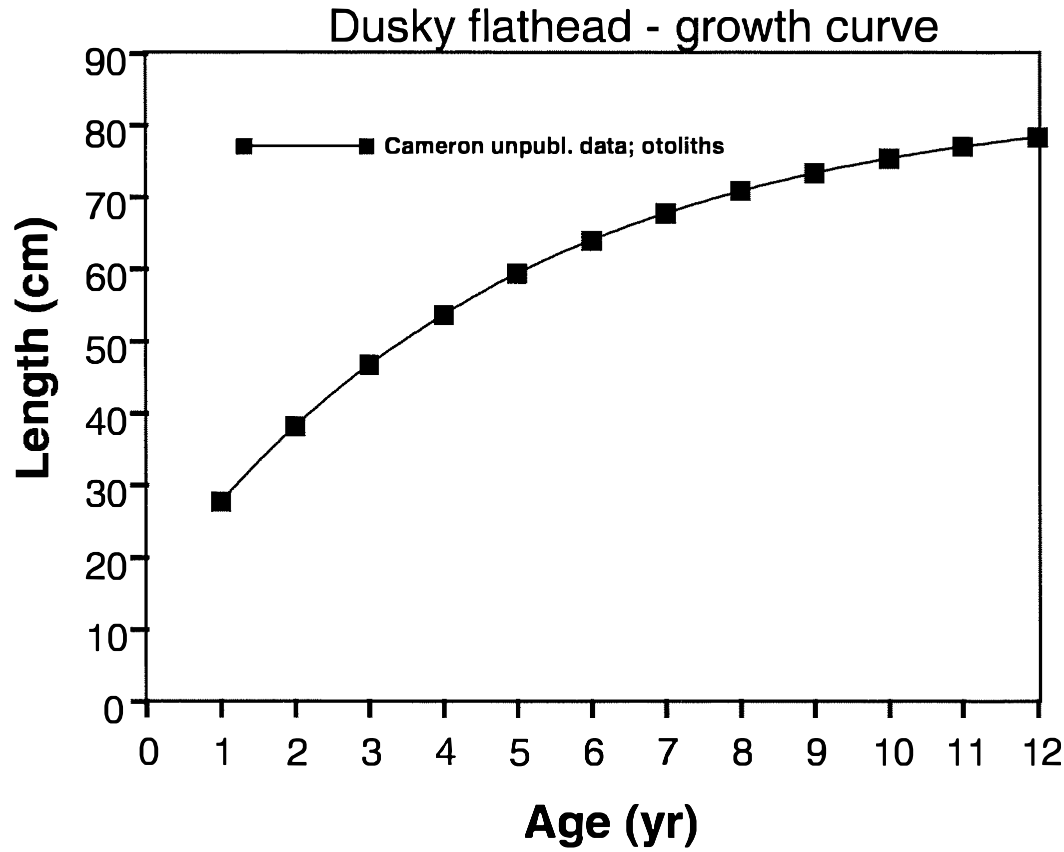

Figure 7.10 *Growth curve for Platycephalus fuscus based on computed lengths-at-age (D. Cameron, unpubl. data).*

7.3.1. INVESTIGATION OF CATCH RATES FROM CFISH

This group investigated commercial catch rates in terms of effort standardisation. A further objective was to determine how often the proposed management plan trigger points would be activated.

Analysis of biological status of stocks rely on a knowledge of the relationship between effort and catch. However, as in many fisheries, this relationship is affected by factors other than biomass changes. Effort standardisation is an objective method of investigating the various factors such as vessel characteristics, gear used etc. that affect effort.

This group only had time to complete an analysis of bream. Although the database does not always distinguish properly between the different species of bream, they assumed that most of the data were mainly catches of yellowfin bream.

The latitudinal range of data processed was 24.50 degrees decimal to the New South Wales border. The log of daily catch rate was modelled in a General Linear Model (GENSTAT) using a surrogate of vessel type known as 'vessel sequence number', year, month, half degree square QFISH grids and net type (whether >800 and <=800m net length). There were therefore about 11 000 records with net lengths ≤ 800m and about 29 000 records > 800m

A plot of standardised and unstandardised catch rates for bream are given in Figure 7.11. This model explains 37% of the variance. The standardised trend is much less optimistic than that of the unstandardised trends. The months

April to August are significant (t, p<0.001) and vessel sequence number explains most of the variance. Given these standardised catch rates for bream, the proposed QFMA management rules would have been triggered twice between 1988 and present.

This group recommended that this method of removing factors that affect catch rates, other than biomass, is essential to correct interpretation of biomass trends. In the analysis of bream, for example, the standardised index resulted in a different trendline, which would therefore be open to a potentially different interpretation and management advice.

Effort standardisation would be extremely difficult on whiting, as the data consists of several species with different life histories. However, the group did recommend that this analysis be extended to flathead. Effort standardisation of bream and flathead was completed by Ms Dichmont and will be reported on in detail in Brown et al. (in prep).

7.3.2. ESTIMATE RELATIVE COMMERCIAL AND RECREATIONAL CATCH

The species resolution of the recreational and commercial databases was investigated. This is particularly a problem in species such as whiting as they may be difficult to tell apart, but have very distinct life histories. It may therefore be questionable whether they could be managed as a single unit. This group was therefore also asked to highlight the fish categories that they were unable to break into species and that may be very different in their habitat and biological. characteristics. They also investigated the relative catch participation of the recreational and commercial sectors.

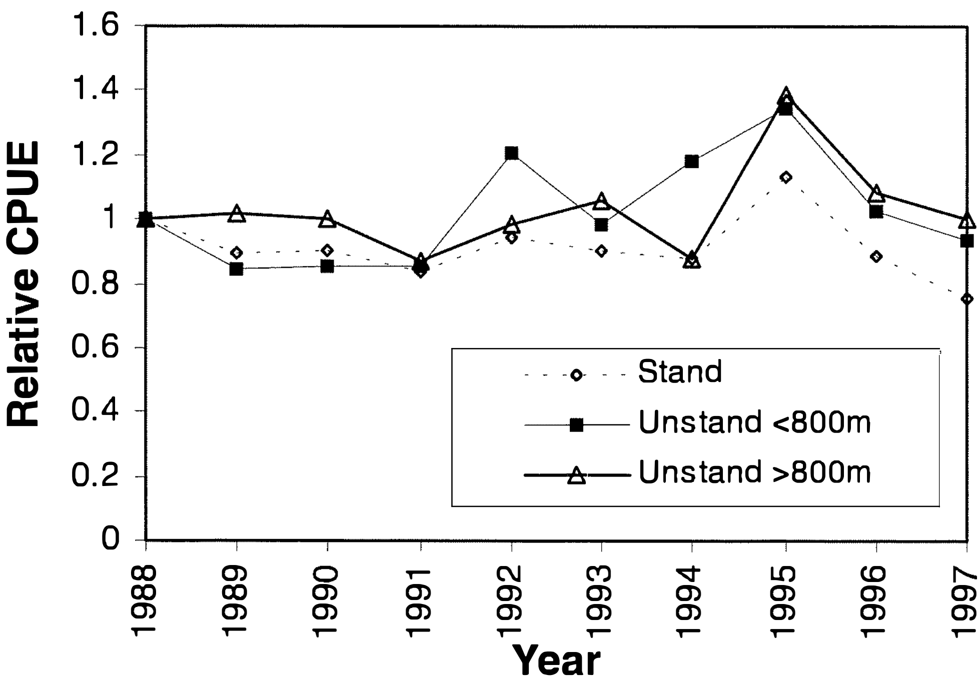

Figure 7.11. *Standardised catch rates ('Stand') and unstandardised catch rates of yellowfin bream for net length ≤ 800m and > 800 m ('Unstand <800m' and 'Unstand >800m'). Note that the indices have been scaled to unity in 1988.*

7.3.2.a Recreational catch

QFMA recently initiated a telephone and logbook survey of the recreational catch of major fish species within Queensland. This survey is a first statewide attempt at investigating recreational catch and participation demographics. The preliminary results were kindly made available to the workshop.

A first estimate of total recreational catches for each broad fish category relevant to this workshop session, are represented in Table 7.5. Average fish weights were taken from the length-frequency data of the recreational creel surveys completed in 3 estuaries by the Coastal Streams Project (Queensland Government New Initiative, Fish Management & Protection, 'Assessment of Fish Stocks in Coastal Streams', Southern Fisheries Centre, Deception Bay, 1997–1999). Since whiting catch consists of both summer and winter whiting, average individual weights were calculated by weighting individual summer and winter whiting into weights by the proportion of identified catch in the RFISH database. The calculation took into consideration that there was a decline in participation in the recreational data collection program over time. It was not possible to divide the recreational catch into species and only broad groupings can be used (e.g. Table 7.5). An example of the method of calculation is given in Table 7.6.

	Average individual weight (kg)	Average total catch (t)	Max. total catch (t)
Bream	0.278	455	681
Flathead	0.63	292	437
Whiting (spp.)	0.049	273	410

Table 7.5. Estimated average individual weight for recreational catch from preliminary recreational phone and logbook survey by QFMA. Whiting (spp.) includes the weighted average of summer and winter whiting.

Quarter	Daily Harvest	Correction factor	Corrected harvest
1st	2135	1	2135
2nd	4099	0.9	4554
3rd	2614	0.75	3485
4th	1038	0.5	2076

Table 7.6. Bream as an example of recreational catch calculation. Correction factor adjust for the decline in participation rate.

Total harvest is therefore estimated from the diary data as the sum of corrected quarterly harvests. The total recreational harvest becomes scaled by the ratio of diary participants to total recreational fishers.

Of the three groups, Bream spp. contributes the most to the recreational catch by mass. Flathead and whiting were equally important. This work is extremely preliminary and has yet to be analysed in detail by the Bureau of Statistics for QFMA and released in a detailed report.

7.3.2.b Resolution of species

Many fishers are unable to differentiate between the different species of bream, whiting or flathead. As a result, the resolution of the commercial and recreational databases is not at a species level. The objective of this group is to analyse whether it is possible to use the database to evaluate the catches to the species level or to produce an algorithm for species separation. If this separation is not possible, to discuss the importance of this information especially with respect to management needs.

The catch by species category for bream, whiting and flathead are given in Table 7.7. It is clear that several species categories only have data for some of the years as the species list was extended over time. In terms of bream, 99.4% of the total catch data have been recorded in the 'bream – unspecified' category. It was the general opinion of the group that most of this catch consists of yellowfin bream, but, there was no obvious method of dividing the catch without error.

Most of the whiting catch was recorded in the 'whiting - unspecified' and 'whiting – summer' categories. The group stated that most of the summer whiting catch would have been recorded in the 'sand', 'summer' and 'unspecified' categories. Excluded from Table 7.7 is a sizeable trawl by-catch of whiting (other than stout whiting) of about 60 t. Most scientists in this group were in agreement that more than 90% of this trawl catch would be winter whiting. The catches of the mesh net licensed fishery were interpreted to comprise mostly summer whiting.

Only one category of flathead is available for use in the CFISH database; 'flathead – unspecified' and it was agreed that this would consist mostly of dusky flathead catch. A total catch from 1988 to present is about 650t.

7.3.2.c Fishing sector separation

The commercial bream catch in Queensland waters is about 175t (and decreasing). Annual catches from the recreational sector were estimate at 455t (maximum 700t) for the recreational sector. The recreational to commercial catch ratio for bream is therefore in the order of 3 to 1.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	TOTAL
Bream - Tarwhine								<1	1	1	2
Bream - Unspecified	214	222	223	174	176	146	131	214	149	171	1820
Bream - Yellowfin					<1	<1			<1	9	9
Flathead - Unspecified	68	86	78	71	64	60	54	52	53	62	648
Whiting – Trumpeter/Diver	37	6	2	2	1	<1	<1	<1	5	4	58
Whiting - Northern					<1	<1		1			1
Whiting - Sand						2	<1	3	6	3	15
Whiting - Summer	290	305	308	269	186	19	18	21	27	33	1476
Whiting - Unspecified		<1	<1	10	106	249	195	182	211	279	1233

Table 7.7. Total yearly catch by CFISH species category for bream, whiting and flathead. Note that missing data means that this category was not available at the time or that it was not used.

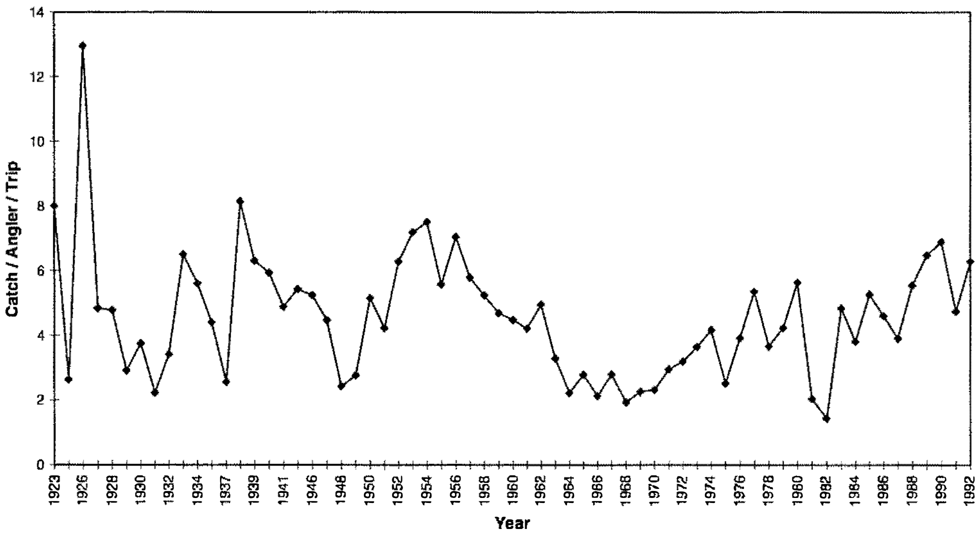

Figure 7.12. *Catch per unit effort (no. fish per angler per trip) of whiting from recreational club data caught at Jumpinpin.*

Dusky flathead commercial catches range from 75 to 40t, whereas the recreational catch is estimated as an average of 292t (maximum estimate 437t). The resultant recreational to commercial catch ratio is 9 to 1.

Some participants in the RFISH recreational survey in Moreton Bay were able to identify which whiting species they caught. Extrapolating this ratio (8% summer and 92% winter whiting), the recreational summer whiting catch in Moreton Bay would be about 90t and that of the winter whiting about 180t. However, the DPI New Initiative 'Assessment of Fish Stocks in Inshore and Coastal Streams' Project

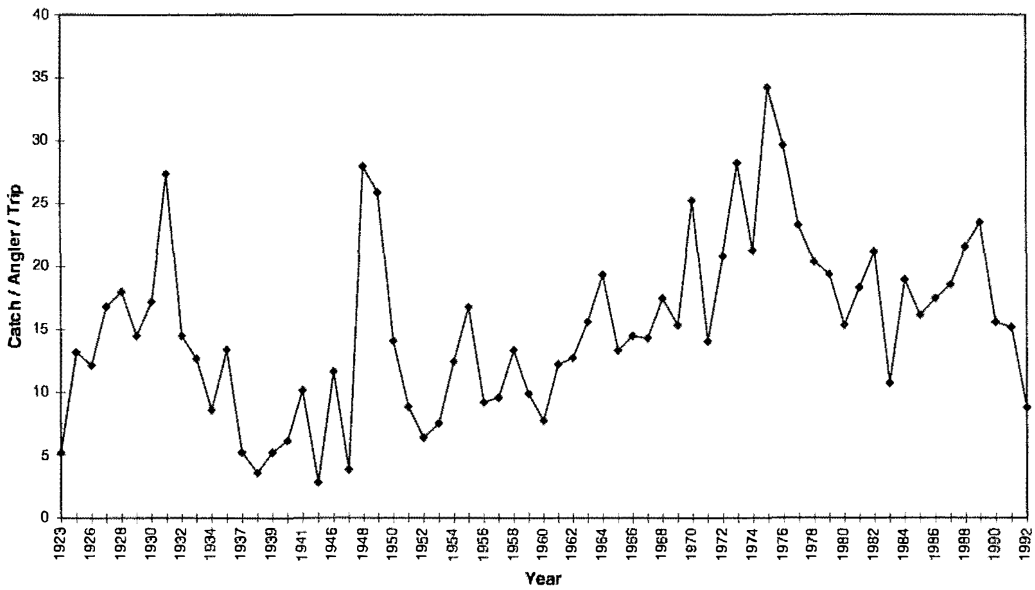

Figure 7.13. *Bream catch per unit effort (no. fish per angler per fishing trip) for Jumpinpin recreational data.*

estimates the catches in the 3 other major estuaries as being 100t of summer whiting and 200t of winter whiting. Generally, the recreational catch for winter whiting far outweighs the commercial line, net and trawl catch, whereas the summer whiting fishing sectors seem equal in terms of catch. However, the above rules of thumb are very subjective and it is really impossible to use RFISH or CFISH to discriminate between the catch of different whiting species. Unfortunately, these species have very different life histories and grow to different maximum sizes.

Recreational club data were made available pooled over fishing clubs. The relative importance of whiting and bream has changed much in the last few decades. Bream certainly has always been a more prized fish in the catch.

A plot of bream and whiting catch rate from club data (catch per angler per trip) in the Jumpinpin area indicates large changes from one year to the next (Figure 7.12 and 7.13). No overall trend is obvious, although an increase in bream catch rates from the 1950s to the 1970s can be discerned (Fig. 7.13)

The group was concerned that they were unable to divide the catch by species which have distinct life histories. No scientific algorithm could be developed, only approximate rules of thumb. This applies particularly to whiting spp.

7.3.3. DISCUSS AND ANALYSE THE USEFULNESS OF THE RECREATIONAL TAGGING DATABASE

The Australian National Sportfishing Association (ANSA) Queensland has been involved in a Statewide recreational tagging program with the major financial contributor being DPI. Sportfishers involved in this tagging program target several species such as flathead, whiting, bream, mackerel, mangrove jack etc. The tag-return data were kindly made available to the workshop.

The ANSA bream tagging database was investigated to determine whether it would be of use for:

- growth estimation;
- movement analysis;
- estimation of mortality rates.

The database contains about 6 040 bream records, of which 4 984 had both total and caudal fork length recorded. Of the released individuals, 305 were recaptured (236 recorded as total length and 50 as fork length). Most of the tags had been released in June.

7.3.3.a Growth estimation

A total length (mm) versus total weight (g) conversion were calculated (r^2=0.578) with the result:

$$W(g) = 0.000485 L_t^{2.339}$$

and total length versus fork length conversions (r^2=0.9726) are:

$$L_f = 0.9118 L_t + 0.5254$$

Weights of animals were estimated to the nearest 10 grams.

In terms of changes in length between tag and release periods, much of the data showed negative growth (Figure 7.14). Furthermore, it shows that most of the animals were returned within a month of their release.

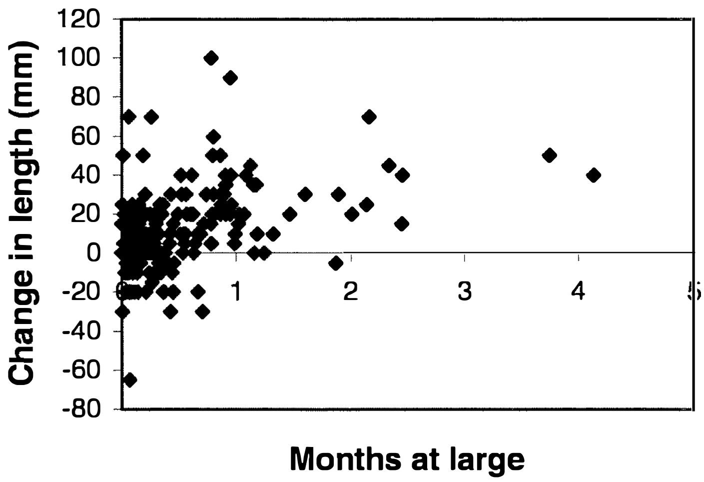

Figure 7.14. *Growth increment of returned bream in relation to time between tag and recapture. Most of tagged animals are returned within a month of release.*

In an attempt to reduce the records with negative growth, the group focused on recapture records based on data in which the same angler had done both the release and recapture measurements. However, no substantial change to Figure 7.14 was observed.

Length increments ≤ -10 mm were removed and classified as errors. A standard least squares von Bertalanffy growth model was fitted to the data, but very large residuals were observed (Figure 7.15). It was concluded by this group that the tagging data would not be very useful for growth analysis.

7.3.3.b Movement

Most of the animals remained within a short distance of their release sites, with only a few individuals moving more than 30 km (Figure 7.16). This group recommended that the movement data would be extremely useful for more in-depth movement studies, although most of the recaptures were taken less than a month after release.

7.3.3.c Mortality estimation

In order to calculate total mortality, length increments ≤ -10 mm were removed and classified as errors. An exponential decline model was fitted to the number of returns over time at large. Since most animals were recaptured after a very short period, this analysis does not have much credibility.

7.3.3.d Conclusions

This group concluded that the ANSA tagging data would be excellent for movement studies, studies of the distribution of effort and a comparison of length frequencies with other data sets (although this data does not have good resolution). However, the dataset is not useful for growth analysis and estimates of mortality will also produce spurious results.

7.3.4. RE-EXAMINE GROWTH RATE ESTIMATES

Various sources of otolith ageing data is available, the most important of which is that from the 'Integrated Stock Assessment and Monitoring Project' (ISAMP FRDC T94/161). This group only had time to investigate flathead data. Flathead was chosen as the ageing of this animal is known to have low variation and relatively good readability. Two issues were discussed:

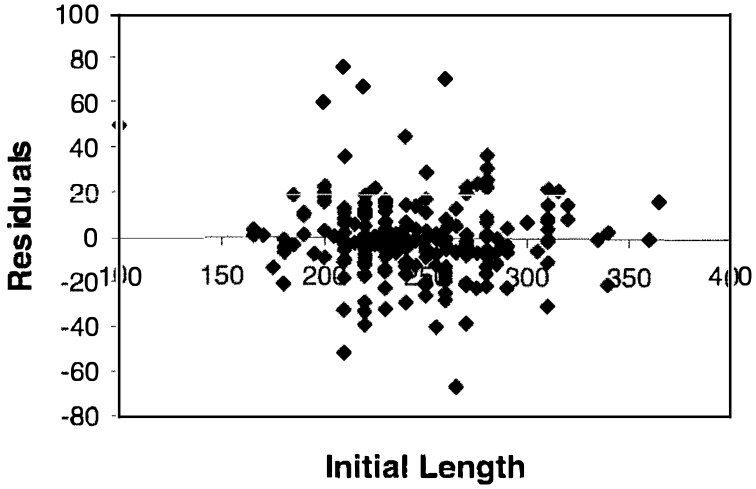

Figure 7.15. *Residuals of a von Bertalanffy growth model fitted to bream tag-return data. All records that showed a negative growth of 1 cm or more had been removed.*

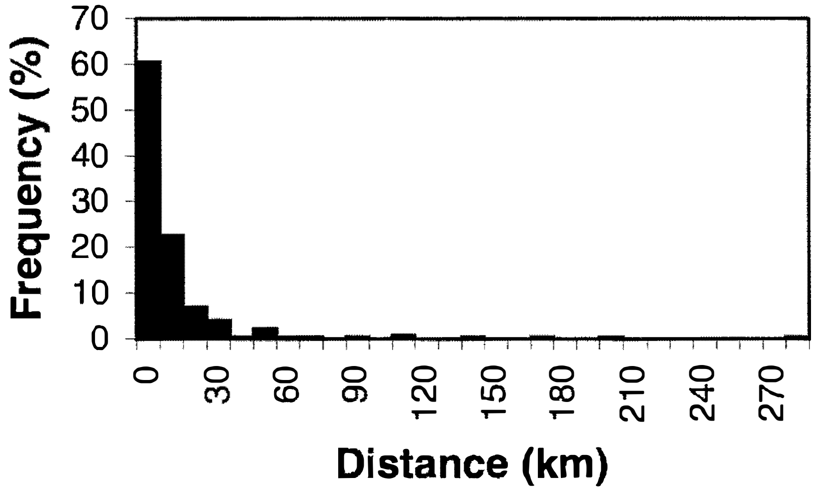

Figure 7.16. *Frequency plot of distance (km) moved between tag and recapture by bream.*

- otolith readability;
- analysis of growth curves and the effect of gear selectivity on the age structure.

7.3.4.a Otolith readability

A birth date was given to each fish. In the project, two readers aged each otolith. The group therefore had to discuss several ways of addressing any discrepancies between the readers. One method is to use all the readings including those that have ageing disagreement between readers. Another method is to weight fish that have been aged more than once so that each otolith would receive equal weighting. The traditional way of achieving this goal is to use an 'agreed' age between two the readers. On the occasion where the two readers disagree, a third reader is used. Thereafter, one rejects any otoliths in which no agreement was possible. Another practice is to use a readability index. However, the group highlighted that a potential problem could exists if one is consistently rejecting fast growers or certain age classes because they are more difficult to age.

7.3.4.b Ageing analysis

The following data was combined to produce a growth curve for each sex: Unsexed 0 and 1-year olds (from the Project 'Monitoring the Effects of Restocking the Maroochy Estuary') augmented for both males and females data. This method assumes that there are no differences in the growth rate of unsexed (small) animals. Data for each curve was therefore from

- unsexed growth data;
- 2 and 3-year old fish from the ISAMP dependent survey data. These animals were sexed and therefore were added to the relevant curve.

The group also discussed the effect of gear selectivity on the flathead age data. This aspect is important, as the data represent the commercial net catch and not the population as a whole. Smaller (and maybe larger) animals may be unselected. In the NSW commercial net fishery, there are fewer older fish than in the Queensland fishery. Age structures between gear types differed in Queensland. Tunnel netters caught larger fish, and therefore older age classes were represented in their catch. Recreational fishers tend to target larger fish, and there are also clear signs of size selectivity in the mesh net fishery.

Since not all 3-year-old animals are fully selected by the fishery, their inclusion in the dataset could bias the resultant growth curves. Similar problems exist in the fishery independent data. Because the survey method selected fish less that 30 cm, the mean size of the 2 year olds was biased downwards as some 2 year olds clearly exceed 30 cm.

A birth date for each fish was decided on the basis of marginal increment and date of spawning. Both methods

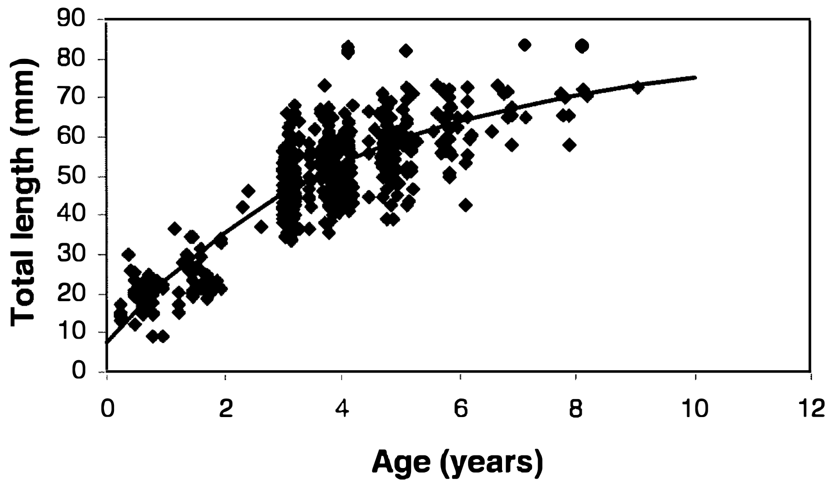

Figure 7.17. *Length-at-age curve for female flathead. Von Bertalanffy growth function modelled with unweighted (solid line) data.*

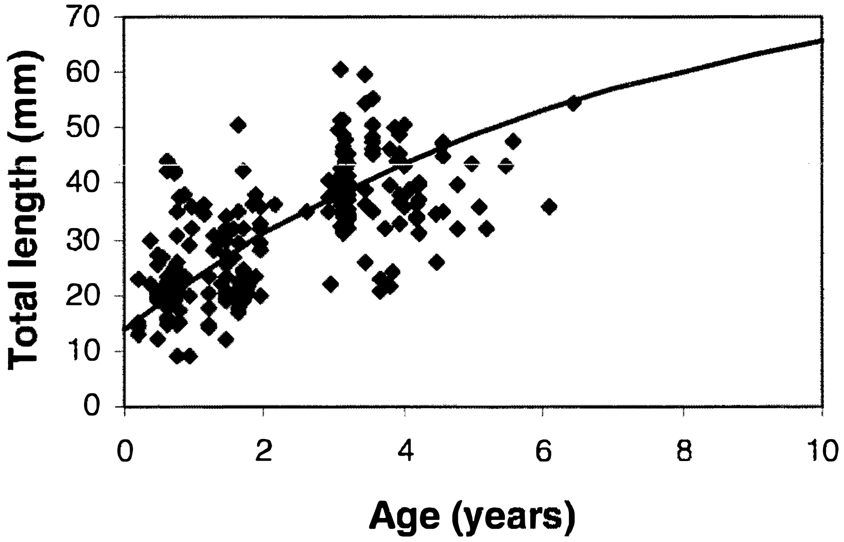

Figure 7.18. *Von Bertalanffy Growth function modelled with unequal weighting (solid line) from commercial flathead male length and ototlith data.*

resulted in the same birthdate (September – October). The group chose 1 October as the nominal birthday, and converted each annual age to age in days.

Both methods of analysis discussed above were used. The first was utilising all otoliths readings (including those readings from otoliths that have been aged more than once i.e. 'unweighted'). The other method only included readings from otoliths that had been read once or twice. For those that had been read more than twice, two readings were selected randomly and included in the analysis ('weighted'). This process improved the fit considerably for both sexes (Figure 7.17 and 7.18).

The sex based von Bertalanffy fits were very sensitive to t_0 mainly because there was poor representation of smaller size classes. As a result, the group recommended that smaller fish should be aged to improve the fit. For the same reason, more larger/older fish would also improve the fit. There was some discussion as to the relevance of using a Von Bertalanffy growth curve and the general conclusion is that a Schnute growth curve should also be investigated.

The results demonstrate that flathead show a clear sexual difference in growth rates (Table 7.7). Females reach a larger L_∞ compared to males and males are slower growing.

Parameter	Weighting	Males	Females
L_∞ (cm)	Equal	78.2	80.9
	Unequal	81.17	82.0
K (year^{-1})	Equal	0.158	0.247
	Unequal	0.145	0.237
t_0 (year)	Equal	-1.17	-0.396
	Unequal	-1.303	-0.418

Table 7.7. Von Bertalanffy growth parameter estimates giving otoliths equal or unequal weighting.

Total natural mortality (Z) was estimated from catch curves (*Ln*(frequency) versus age) as 1.5 and 0.97 $year^{-1}$ respectively. The group discussed the possible reasons for this difference in total mortality between the sexes. A possible explanation is that, as females grow faster and larger fish have lower selectivity than smaller fish, females may escape the 'window of predation' faster than males. A model was used to simulate this hypothesis which explained the catch curve very well but not the total observed catch. An alternative hypothesis is that behaviour differs between the sexes. This is based on an observation that in New South Wales waters a greater proportion of male flathead than female migrate offshore.

The following was recommended:

- Make contact with a scientist within the University of Queensland to determine the seasonal presence of larvae of each species. This may help in determining an appropriate birthdate.
- Flathead can be aged successfully and otolith ages should continue to be used in a monitoring program.
- The bream ageing data are reasonable, whereas the whiting ageing was difficult, very variable and error prone.
- The model hypothesised regarding female flathead and the window of predation, is plausible and should be developed further.

7.4. CONCLUSIONS

7.4.1. GROUP REPORTS

Standardised trends of commercial bream catch rate gives a much less optimistic view of the fishery than the unstandardised data. Given the declining standardised trend, the proposed QFMA draft Management Plan trigger points would have been activated twice since 1988.
The species resolution of the recreational and commercial database was investigated. This is an important problem to address in species such as summer (of which there are two species *Sillago ciliata* and *S. analis*) and winter whiting as they are difficult to tell apart, but have very different life histories. Yellowfin bream and dusky flathead catches tended to fall mostly within the "bream-unspecified" and "flathead-unspecified" categories, however, algorithms accepted by the workshop were utilised to define the catch of these species. Unfortunately, no satisfactory method of separating the commercial from the recreational catch was devised for whiting.

Of the major groups of species under investigation in this section that are caught by the recreational fishery, bream spp. contributes most catch by weight. A preliminary estimate of total recreational catch from the state-wide QFMA recreational survey undertaken in 1998 was calculated.

The Australian National Sportfishing Association recreational tagging database was investigated and analysed to determine whether it would be of use for growth estimation, movement analysis and estimation of mortality rates. A large number of animals showed substantial shrinkage and this would be most likely due to measurement error. It was concluded that the database would not be useful for growth rate estimation. Also, since most of the animals were recaptured after only a very short time period, analysis of mortality rates would not have much credibility. The data was seen as being potentially extremely useful for movement studies.

Length-at-age curves were analysed for flathead by combining all datasets. A birth date for each fish was decided on the basis of marginal increment and date of spawning. Two methods of analysing the data were presented. Flathead show a clear sexual dimorphism in growth rates with females reaching larger average maximum lengths. Small and very large fish should be targeted in the future to improve the fit.

Due to the lack of resolution of the data into species, the difficulty with defining effort in a multi-endorsed and multi-species fishery, few recreational catch or catch rate time series, and neither target species nor zero catches being recorded, little can be said about the sustainability of catches.

7.4.2. PROGRESS TO DATE

A summary of progress to date with regard to data quality, stock assessment and management knowledge is given in Table 7.8.

Category		Comments
Commercial	Catch	Lack of resolution to species for yellowfin bream and especially, summer and winter whiting. Gear type below mesh net is not specified.
	Effort	As above. Search time not recorded. Definition of effort is unclear in multi-species and multi-endorsed fishery. This problem is exacerbated by target species and zero catches not being recorded.
	Catch rate	As above.
Recreational	Catch, effort and catch rate	Generally recreational catches larger or the same size as the commercial fishery. Only once off estimates from survey, therefore no time series available.
Independent index of biomass or recruitment		None.
Estimates of natural mortality		Estimates from age data.
Estimates of fishing mortality or biomass		Estimates from age data.
Input controls		Limited entry, spatial and area closures, minimum legal size.
Output controls		None.
TACC Decision rules		N/A.
Performance indicators		None.

Table 7.8. A summary of progress to date with respect to data quality, stock assessment and management knowledge for bream, whiting and tailor.

7.4.3. MONITORING, RESEARCH DIRECTION AND PRIORITIES

Table 7.9 gives a review of the data sources analysed in this workshop session. Broad conclusions are given below.

a. The ageing and length frequency collections of bream and flathead should continue, as this provides insight into the status of these stocks. The ageing of whiting was much less successful and would not prove as valuable. In the long term, ageing information could provide estimates of total mortality and stock status for these species.

b. RFISH data should be validated with creel surveys (on-water) to get catch at age and length-frequencies.

c. Improve our understanding of the relation between fishery performance indicators and catch-per-unit-effort data, as with eastern king prawn, saucer scallops, and tailor above. However, there is a need to break the catch down to species level. This should be a high priority.

Data Source	Data Type	Comments	Bream	Flathead	Whiting
CFISH	Catch	In future, need to define gear type used, rather than use algorithm. Need to use standardised catch rates.	Yes Need to assume most data in combined 'bream – tarwine', 'unspecified' and 'yellowfin' categories are yellowfin bream.	Yes	No -No obvious mechanism of differentiating between different whiting species, which have very different life histories. -Change logbook to identify between species? -Need to include trawl by-catch.
	Effort	Difficult to define effort in the multi-species net fishery.	σ	σ	σ
RFISH	Telephone & Logbook survey	Provides an estimate of recreational catch, which is extremely useful. Cost recovery in the form of a recreational licence was suggested as the survey is expensive. Should ground truth this data with on-water creel surveys.	Yes Can't differentiate between species, but still extremely useful.	Yes	Yes Can't differentiate between species, but still extremely useful.
Recreational club	Catch rate	Very useful for observing catch rate trends over a long time period (1992 onwards).	Yes Most of the data for bream.	No	Yes Not very important component of the club catch. Mainly summer whiting.
ANSA	Tagging	Yes: Movement studies, Yes: Distribution of effort Yes: Comparison of broad-scale length-frequencies No: Growth analysis No: Mortality estimates.	Yes	Yes	Yes
Various FRDC,PPV & DPI Projects	Otolith ages and length	Useful for ageing analysis. Need small and large animals e.g. from independent surveys. Need to address gear selectivity problems with dependent data.	Medium readability.	Yes Low variance Relatively good readability Good growth function possible.	No Variable ageing Low readability Changes sex.

Table 7.9. Summary of monitoring discussions related to datasets use in the workshop. "Yes" means data is useful and "No" is that it is not.

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8 SUMMARY OF MAJOR RESEARCH PRIORITIES

The resources reviewed have been treated on a species by species basis, with each species being allocated a chapter in the Workshop Proceedings. At the end of each chapter, a detailed list of monitoring and research directions and priorities are given. The authors present two key recommendations for each species to represent proposals that were given highest priority by the workshop participants in this summary. These recommendations should not be interpreted as representing the exclusive list of proposals and time should be taken to read the full list of recommendations at the end of the report on each species.

8.1. SPANNER CRAB MONITORING, RESEARCH DIRECTIONS AND PRIORITIES

Currently, spanner crabs are monitored solely through the use of commercial catch rate data. There were many doubts expressed during the workshop concerning the validity of using simple catch rate data as an index of stock biomass. The workshop strongly recommended that independent surveys of spanner crab biomass were needed for long term monitoring in order to provide an alternative, more defensible index of abundance. This independent survey should commence prior to the implementation of the Individual Transferable Quota (ITQ) management system, as the integrity of the catch rate data series may be compromised for a period thereafter. This research was given the highest priority by the workshop.

Knowledge of spanner crab growth rates will greatly enhance Queensland's knowledge of possible natural mortality values as well as sustainable catch levels. In the workshop, the value of the NSW tagging data, which relates only to adult crabs, was greatly enhanced by dredge samples of juveniles. Although the dredge gear only caught low numbers of juvenile animals, the data improved the growth curve estimation. Without information relating to the beginning of the growth curve (concerning juvenile crabs), it is only possible to estimate L_∞ with any precision. Continued dredging for juvenile crabs was considered to be essential by the Workshop. Other methods of ageing crabs should also be investigated.

8.2. EASTERN KING PRAWN MONITORING, RESEARCH DIRECTION AND PRIORITIES

In the current management plan, it is proposed to use catch rate levels to act as performance indicators. Participants considered that improvement of our understanding of the relationship between fishery performance indicators and catch-per-unit-effort data was a high priority. However, the usefulness of this approach has yet to be demonstrated because catch rates may not be closely related to stock abundance. Effort should be standardised. This project should have a high priority.

With the introduction of Vessel Monitoring Systems (VMS) to the inshore trawl fleet, the potential for its use to gather information on fleet dynamics and the distribution of effort would be of tremendous value in monitoring the status of the stock. Methods of data capture and sampling intensity should be investigated prior to major investment in software and processes. The workshop rated research in this direction as a high priority because, if successful, VMS methods could in the long run have a high return for a low cost.

8.3. SAUCER SCALLOP MONITORING, RESEARCH DIRECTION AND PRIORITIES

Highest priority was given to the standardized scallop survey. The survey conducted in 1997 provided so much valuable information that it ought to be continued, ideally every year. It is, however, a costly project and will require financial support from the industry.

Similar to eastern king prawns, the proposed management plan uses catch rate levels as performance indicators. It is therefore necessary to improve our understanding of the relation between fishery performance indicators and catch-per-unit-effort data. Effort standardisation will be necessary to improve the relationship between catch rate and biomass. Furthermore, stock assessment techniques were most successful in this session and modelling can be used to support the proposed Management Plan with tested performance indicators. This project should have a high priority.

8.4. SEA MULLET MONITORING, RESEARCH DIRECTION AND PRIORITIES

Previous age composition data of the commercial catch appeared to produce the best index of the relative state of the stock and this age composition data collection should be continued. Due to the many age classes, this will be a long-term venture in terms of running Virtual Population Analyses, but the consensus was that the investment would be highly cost-effective and beneficial. A non-equilibrium yield-per-recruit model could be attempted in the short term.

Computer simulations, similar to those completed on spanner crabs within the workshop, are needed to investigate the Draft Management Plan management rules in terms of trigger frequency and usefulness. These simulations could ultimately be extended to other resources captured by the Ocean Beach and Estuarine fisheries.

8.5. TAILOR MONITORING, RESEARCH DIRECTION AND PRIORITIES

Validation of the ageing of Tailor is essential to the future assessment and management of this fishery. In the workshop it became apparent that the state of the stock was showing some indications of stress and overfishing, with the degree of overfishing depending entirely upon whether the ageing studies already carried out are correct or biased downward. For a small financial outlay a large return in management recommendations and resource security could be made. Another factor that biases the age structure collected from the fishery and therefore the estimated fishing mortality, is the theory that large animals move offshore and are not fished by the shore-based fishers. Research on the distribution of large and old fish is therefore highly recommended. In New South Wales and Western Australia, large fish are found offshore where spawning occurs and this appears to buffer their stocks from overfishing. Queensland tailor appear, at first sight, not to have this natural safeguard. Such research would not be a trivial undertaking. The offshore distribution of tailor could be determined directly by searching for large fish offshore, perhaps from charter vessel catches. Alternatively, it may be possible to track onshore schools acoustically to determine whether they move offshore any great distances.

8.6. BREAM, WHITING AND FLATHEAD MONITORING, RESEARCH DIRECTION AND PRIORITIES

The ageing and length frequency collections of Bream and Flathead should continue as this provides insight into the status of these stocks. The ageing of whiting was not successful and would not prove as valuable. Over the long term, for bream and flathead, ageing information could provide approximate estimates of total mortality and stock status.

It is necessary to improve our understanding of the relation between fishery performance indicators and catch-per-unit-effort data, as with eastern king prawn, saucer scallops, and tailor above. However, in this case, the major stumbling block is the definition of effort in a multi-species fishery and the lack of resolution to species of the catch and effort data. The fact that these species are also major targets for recreational fishers, with attendant issues on catch estimates, amplifies the difficulties associated with assessment of these species. Research on these problems should be given a high priority.

AVAILABLE DATA 9

9.1. INTRODUCTION

Data was collected from various sources, mainly from past FRDC and other funded projects, QFMA, recreational clubs, Australian National Sportfishing Association and New South Wales Fisheries (FRI). Part of the workshop's success has been gathering this dataset, often off old non-compatible computers or by repunching the data from old datasheets. The full dataset will be kept on CD at Southern Fisheries Centre, Deception Bay and any request to obtain this information should officially be made to Mr Mike Dredge, Industry Manager, SFC, PO Box 76, Deception Bay, 4508.
In many cases though, the data are confidential in its present form.

9.1.1. COMMERCIAL CATCH AND EFFORT DATA

The commercial catch and effort data for all species considered in this workshop were extracted from the QFMA CFISH database. CFISH is a subsystem of QFISH and is specifically commercial fisheries data sets. The data originates from a compulsory fisheries catch and effort daily logbook program that commenced in 1988. The data were retrieved by a 'dilemma' script, essentially all raw data records for the species and dates specified. This was then put into Access for use in the workshop.

9.1.2. RECREATIONAL CATCH AND EFFORT DATA

Some recreational catch and effort data supplied by QFMA was summarised from RFISH, a subsystem of QFISH specifically for recreational fisheries data sets.

9.2. SPANNER CRAB DATA

9.2.1. COMMERCIAL CATCH AND EFFORT DATA

9.2.1.a Spanner.mdb

Raw catch and effort data for the Qld spanner crab fishery from 1.1.88 to about 31 May 1998 extracted from CFISH.

9.2.1.b Basic Summary by Year (lifts).xls

Summarised Catch (t), effort (dilly-lifts) and cpue (kg/lift) by year across whole Qld fishery from CFISH data.

9.2.1.c Basic Summary by Year.xls

Summarised Catch (t), effort (boat-days) and cpue (kg/boat-day) by year across whole Qld fishery from CFISH data.

9.2.1.d CPUE (lifts) by Region and Financial yr.xls

Summarised Catch (t), effort (dilly-lifts) and cpue (kg/lift) by *financial* year and geographic region (within Queensland) from CFISH data. See file GRIDREFS.DOC for key to region codes.

9.2.1.e CPUE (lifts) by Region and Year.xls

Summarised Catch (t), effort (dilly-lifts) and cpue (kg/lift) by *calendar* year and geographic region (within Queensland) from CFISH data.

9.2.1.f Gridrefs.doc

Gives geographic limits for assessment regions, and also provides a key to the relationship between the "Historic" grid system and geographic regions.

9.2.2. BIOLOGICAL AND TAGGING DATA

9.2.2.a PARAMETERS.doc

Tabulation of known *Ranina* population parameters (various sources).

9.2.2.b Biotot.xls

Biological data from QDPI FIRTA Spanner Crab Project research cruises between 1981 and 1984 inclusive.

9.2.2.c Logbook.xls

Commercial catch and effort data from a voluntary logbook program run between 1982 and 1987 inclusive.

9.2.2.d Spcrtrip.xls

Catch and effort data from QDPI FIRTA Spanner Crab Project research cruises between 1980 and 1984 inclusive.

9.2.2.e Sxltot.xls

Individual sex and carapace length information from research cruises between 1980 and 1984 inclusive as in Spcrtrip.xls above.

9.2.2.f Spanner crab length based model specs.doc

The specifications for the length based model.

9.2.2.g Spanner biomass dynamic model results.xls

Results of the biomass dynamic model.

9.2.3. NEW SOUTH WALES (NSW) DATA

9.2.3.a Co-opdat and co-opgro.xls

Data from NSW Fisheries Co-operatives, supplied by NSW Fisheries (FRI).

9.2.3.b Fecundit and Fecundsu.xls

Fecundity data from NSW Fisheries (FRI)

9.2.3.c Mud.xls

N.S.W. Catch and effort statistics from commercial logbooks. Summarised by year.

9.2.3.d SK4DM.xls

N.S.W. Catch and Effort by record with spurious data removed. Not to be used to calculate total NSW catch as not all catch records are present, but is excellent for calculating Catch rate.

9.2.3.e Survey1, Survey2, Surveylf.xls

Independent survey data from NSW Fisheries

9.2.3.f Tagrelea and Tagthing.xls

N.S.W. tag and release data to estimate growth.

9.3. EASTERN KING PRAWN DATA

9.3.1. COMMERCIAL CATCH AND EFFORT DATA

9.3.1.a Eastern King Prawn Catch and Effort data.mdb

Raw CFISH catch and effort data for eastern king prawns from the TRAWL database. Logbook data retrieval for king prawns only (other species omitted) south of 20° S. Includes other summary (daily, monthly) tables and queries.

9.3.1.b Summary of monthly catch and effort.xls

Monthly catch and effort in the Queensland component of the eastern king prawn fishery from CFISH, commencing January 1988 to December 1997.

9.3.1.c Historical catch and effort data 1977-87.xls

Research logbook data implemented by Mike Dredge in 1970s. Contains about 10% of the eastern king prawn vessel records from that period, but heavily biased to Fraser Island/ Tin Can Bay Fishery. May be appropriate for historical CPUE estimates, but not total catch. Each large (3-digit) zone includes several of CFISH grids and is based on the original CSIRO grid pattern.. Description of blocks available on request.

9.3.2. BIOLOGICAL AND TAGGING DATA

Sub-adult length frequencies Moreton Bay 1988-90.xls

Monthly length frequency data for *P. plebejus* sampled from nine stations in Moreton Bay over two years.

9.3.2.a Adult female length frequency and reproductive data 1990-92.xls

Adult female length frequency data from offshore waters. Also contains data on ovary weight and histological condition of 6,000+ individuals from 4 regions (Swain Reefs, Lady Elliot, Mooloolaba and Cape Moreton). Samples obtained each month by the commercial fleet and research trawler for reproductive analysis. 1990-92.

9.3.2.b Adult male Eastern King Prawn Length Frequency Data 1990-92.mdb

Adult male *P. plebejus* obtained in the reproductive samples from the four regions listed above. Provides monthly length frequency samples of adult males from the four regions.

9.3.2.c Tagging data 1990-91.xls

Tagging data for 9,000+ tagged eastern king prawns. Provides growth rate data and also used to estimate mortality and emigration rates.

9.3.2.d Lunar affects.xls

Database on lunar and diel variation in reproductive condition and catch rate of adults in offshore waters, undertaken in 1993.

9.4. SCALLOP DATA

9.4.1. COMMERCIAL CATCH AND EFFORT DATA

9.4.1.a Scallop catch and effort data.mdb

Raw CFISH catch and effort data for saucer scallops from 1988-1998 with summary queries (daily, monthly etc). Also contains historical scallop data (BH) from 1977-87 from a volunteer logbook program operating from Bundaberg, Tin Can Bay, Yeppoon and Gladstone based on larger grids than the 30'* 30' CFISH grids Details of the grids, based upon a CSIRO national grid system, available on request. The data for 1977-80 includes approximately 60-70% of the states scallop catch. The 1981-87 data cover a smaller proportion. The 2 data sets have been combined, using the larger grids.

9.4.1.b QLD-C-F.xls

Summary of catch and effort data from Scallop catch and effort data.mdb. Monthly conversion factors have been applied to convert baskets to kilograms.

9.4.2. BIOLOGICAL AND TAGGING DATA

9.4.2.a 76-77 tag data.xls

Monthly tagging program from 76 to 78 for growth and movement information also used to estimate natural mortality. 76-77 data only.

9.4.2.b Bust-growth-est.xls

9500 tagged scallop release and recapture (2000) details for 5 sites for growth variation as a function of location and movement, 1991-1992.

9.4.2.c Scal-L-W.xls

Monthly scallop collection over 12 months in 1977-78 for reproductive biology and adductor condition as a function of time of year and size.

9.4.2.d Survival91.xls

Subset of Bust-growth-est.xls used to estimate mortality as a function of exposure time to air after capture.

9.4.2.e Tag-loss.xls

526 scallops given multiple tags for data on tag shedding rates, 1977

9.4.2.f 88-Bustard.xls

Survey data on numbers and size composition from 10'*10' preservation area off Bustard Head, December 1988.

9.4.2.g 89survey.xls

Survey data on numbers and size composition from three 10'*10' preservation areas, Hervey Bay , Yeppoon and Bustard Head in July 1989.

9.4.2.h Jan97survey.xls

Survey data on numbers and size composition from two 10'*10' preservation areas, Hervey Bay and Bustard Head in January 1997.

9.4.2.i oct97survey.xls

Large scale randomised stratified survey of the main fishing grounds (between $22^{0}30'$ S and $25^{0}30'$S) and the 3 preservation areas, Hervey Bay, Yeppoon and Bustard Head in October 1997.

9.5. MULLET DATA

9.5.1. COMMERCIAL CATCH AND EFFORT DATA

9.5.1.a Mullet.mdb

Raw mullet catch and effort data from 1988 to 1997 extracted from CFISH.

9.5.1.b Lew's Tot @ OBF vs non OBF.doc

Summary of commercial catches by region and ocean beach fishery catches vs estuarine catches.

9.5.1.c Historical catch H&M reports.docs

Historical catches from Harbours and Marine annual reports.

9.5.1.d Com catch by month.xls

Commercial catches by month by region.

9.5.1.e Total catch.xls

Yearly catch totals used for graphs within reports.

9.5.2. BIOLOGICAL AND TAGGING DATA

9.5.2.a 10432 lengths.xls

Length frequency from 6 sites in the period 1995 to 1996.

9.5.2.b 2264 data biologicals.xls

Ageing for subsample of length frequency.

9.5.2.c Shnute.xls

Shnute models of ageing data.

9.5.2.d Vonb.xls

Von Bertalanffy models of ageing data.

9.5.2.e Regress.xls

Regression of Total Length vs Fork Length, Wet Weight vs FL etc.

9.5.2.f Estimating growth from papers.xls

Published and unpublished growth curves.

9.5.2.g Male and female GSI.xls

Monthly GSI for 1995 and 1996.

9.5.2.h Juvdat.xls

Small amount of data on juvenile fish for age and lengths.

9.6. TAILOR DATA

9.6.1. COMMERCIAL CATCH AND EFFORT DATA

9.6.1.a Historic.xls

Data from the Queensland Fish Board dating back to 1944. The Fish Board operated until 1981. Data are from processor's returns. There was probably a large 'black market' component not recorded here. The data from 1987 on come from the QFMA's CFISH database.

9.6.1.b Cpue etc.xls

Summary of CFISH commercial logbook data for tailor from 1988-97.

9.6.1.c Recreational Catch and Effort data

9.6.1.d Fraser permits DOE.xls

Data from access permits issued by the Department of the Environment. This is an attempt to look at tailor fishing effort. However, Fraser Island is only a small part of the Queensland and NSW tailor fishery, and many people obtaining permits for Fraser Island go there as tourists, not as tailor fishers.

9.6.1.e All tailor club data.xls

Data recorded as part of club competitions. The data were supplied by QFMA, who obtained it from Queensland fishing clubs. Included on the sheet is a graph of the average weight of tailor caught. These show an increase after 1986.

9.6.1.f Location codes.xls

A list of the location codes used in the All tailor club data.xls.

9.6.1.g Fishing club-all surf beach tailor.xls

Surf beach tailor data only from **All tailor club data.xls.**

9.6.1.h Beach out.sas, Beach.pgm.sas, Beach.sd2

SAS files for GLM analysis of catch numbers (not weight) on ocean beaches, data from Fishing club-all surf beach tailor.xls

9.6.1.i Aldo's beach and rock data.xls

Compares the fork lengths of beach, rock, and breakwall caught tailor. The data were provided by Aldo Steffe of New South Wales Fisheries, from a creel survey of recreational fishers.

9.6.1.j Aldo's boat-based data.xls

Compares tailor catch from boat and shore based anglers. Results from a GLM analysis are included. The data were provided by Aldo Steffe of New South Wales Fisheries, from a creel survey of recreational fishers.

9.6.2. BIOLOGICAL AND TAGGING DATA

9.6.2.a St961105.xls

Shows dependency of fork length on 'catch', where a catch is a number of fish taken by a group of anglers in a single location during a morning or evening fishing session. Indicates tailors' tendency to school in groups of similar size.

9.6.2.b Not all data.xls

A SAS GLM analysis of the weight trends in the 'All tailor club data.xls'data. The 'not all data' refers to the omission of most of the catches, where no weights were recorded.

9.6.2.c Barry Pollock's tagging data.xls

These data come from a tagging program carried out from 1978 to 1980. Recaptures are also entered on the sheet.

9.6.2.d Pepperell.xls

The data come from a tag recapture program along much of the NSW coastline which began in July 1976, occurred intermittently until 1980, then more regularly until 1982. Provided by Julian Pepperell, formerly of New South Wales Fisheries.

9.6.2.e Tag data 87-88.xls, tag data 89.xls, recaps for 87-88.xls, recap 89.xls, Halliday's data-mixed.xls, Halliday's-Tag89.xls, Halliday's-Tag90.xls.

These files come from a DPI Tailor Tagging project undertaken from 1987 to 1990. The fish were caught, measured, and tagged by a group of club fishers.

9.6.2.f Ag961111- Z ests from all lengths.xls

Z estimates from length data from Fraser Island, using the equation Z=K(Linf-mean(L))/(mean(L)-Lcrit).

9.6.2.g AG961113-Z from rec, com lengths.xls

Separate estimates of Z from the all the available recreational and commercial sampling data to see if presumed size selectivity differences affect the estimates.

9.6.2.h Edited with extras2.xls

Tailor marginal increment analyses showing that otolith rings form in the latter part of the year, from August to December.

9.6.2.i All von B curves.xls

A number of von Bertalanffy growth curves devised for tailor around the world are set out here, including two from Terry Bade in Queensland (1980 MSc thesis).

9.6.2.j Bluefish length wt.xls

Bluefish length-weight relationship from Wilk 1977.

9.6.2.k Growth and comparisons of size by catch.xls

Length frequencies from Integrated Stock Assessment Project data.

9.6.2.l Tailor growth 98-06-25.xls

Growth curves calculated from Integrated Stock Assessment Project data.

9.7. BREAM, WHITING AND FLATHEAD DATA

9.7.1. COMMERCIAL CATCH AND EFFORT DATA

9.7.1.a Isamp species.mdb

Raw CFISH catch and effort data for bream, flathead and whiting from the Mixed database. Tables for each species group and queries for summarising data.

9.7.1.b Historic.xls

Summarised data from the Queensland Fish Board dating back to 1944. The Fish Board operated until 1981. Data are from processor's returns. There was probably a large 'black market' component not recorded here. The data from 1987 onwards are derived from the CFISH database.

9.7.2. RECREATIONAL CATCH AND EFFORT DATA

9.7.2.a Sample size to observe declining 15% catch rate.xls

Analysis of 1997 recreational fisher survey on bream and whiting in Pumicestone Passage. Looking at the option of monitoring catch rates using recreational fisher surveys.

9.7.2.b Sample size to observe declining catch rate.xls

As above with a 10% decline rather than 15%.

9.7.2.c CS rec fish total lengths.xls

Length frequency data for bream and summer whiting from Coastal Streams Project. Data from 3 regions – Maroochy River, Burnett River and Pumicestone Passage. 1997.

9.7.2.d CS spring 1997 survey catches br, flat, tail, whit.xls

Recreational fisher survey data from Coastal Streams Project spring 1997 for Maroochy River, Burnett River and Pumicestone Passage. Data on bream, flathead, tailor and whiting.

9.7.2.e CS winter 1997 survey catches br, flat, tail, whit.xls

Recreational fisher survey data from Coastal Streams Project winter 1997 for Maroochy River, Burnett River and Pumicestone Passage. Data on bream, flathead, tailor and whiting.

9.7.2.f Pumicestone 93 catch.xls

Pumicestone Passage recreational fisher survey, 1993. (individual fish data)

9.7.2.g Pumicestone 93 creel survey.xls

Pumicestone Passage recreational fisher survey, 1993. (individual boat data)

9.7.2.h Jumpinpin bream club data.xls

Yearly summaries taken from an RFISH historical fishing club database.

9.7.2.i Jumpinpin whiting club data.xls

Yearly summaries taken from an RFISH historical fishing club database.

9.7.3. BIOLOGICAL AND TAGGING DATA

9.7.3.a Fish97.mdb

The Integrated Stock Assessment Project 1995-1998 database. All the project's data are stored in here.

9.7.3.b Bream.mdb

Data purchased from the ANSA sportfishing program, club fishers tag and recapture details.

9.7.3.c Bream marginal increments analysis (prelim).xls

Marginal increment data and analysis for bream from the Integrated Stock Assessment Project.

9.7.3.d Growth rate - rough estimate.xls

Ages 1 to 4 omitted because of the influence of the legal size at this level. The 0 age fish come from research data. >4 age data from commercial catch sampling.

9.7.3.e Size varies by sex, catch, and gear type.xls

A SAS GLM analysis of size selectivity of catches (fish from 1 commercial fisher on one day). Length varies by sex, gear type and catch.

9.7.3.f Growth, M_F compare.xls

Estimates of von Bertalanffy growth rates from Integrated Stock Assessment Project flathead data. Comparisons of male and female growth rates in Moreton and Hervey Bays.

9.7.3.g Flatheadlengths.xls

Lengths from commercial flathead catch 1991-93.

9.7.3.h Flatage.xls

Ages estimated from otoliths for flathead from commercial, recreational and scientific samples, 1991-93.

9.7.3.i Growth boot – Camoe's pumicestn data.xls

Estimation of growth rates from Pumicestone Passage recreational fish survey, 1991-1993.

ACKNOWLEDGEMENTS 10

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COMPUTER SOFTWARE UTILISED 12

- **SAS/STAT & SAS/BASE**. Statistical Analysis Software v.6.12.
  SAS Institute Inc. North Carolina, USA.
- **Arcview** GIS v3.1. ESRI, Redlands, California, USA
- **Genstat**. V5 R4.1 The Numerical Algorithms Group Ltd., Oxford, UK.
- **Microsoft Office 97**, Microsoft, Redmond, WA, USA
- **Ad Model Builder**, Otter Research Ltd., Nanaimo, British Columbia, Canada.

ABBREVIATIONS 13

AMC	Australian Maritime College
CFISH	Commercial Fisheries Information System (a subsystem of QFISH)
CL	Carapace Length
CPUE	Catch per unit effort
Crab MAC	Crab Management Advisory Committee
Crab SAG	Crab Stock Assessment Group
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CV	Coefficient of Variation
DPI	Department of Primary Industries, Queensland
DPIF	Department of Primary Industries and Fisheries, Northern Territory
F	Fishing Mortality rate
GLM	General linear model
ITQ	Individual transferable quota
NSW Fisheries	New South Wales Fisheries
NSW	New South Wales
Ppt	Parts per Trillion
QFB	Queensland Fish Board
QFISH	Queensland Fisheries Information System
QFMA	Queensland Fisheries Management Authority
QUT	Queensland University of Technology
RFISH	Recreational Fisheries Information System (a subsystem of QFISH)
TAC	Total allowable catch
TL	Total Length
WA	Western Australia
YPR	Yield-per-recruit

14 TRANSCRIPTS

The Workshop transcripts are on the disk attached to this Proceedings. The transcripts are from discussions during and after the seminar sessions and during the monitoring discussions. Contents have been included in the files. Below are the appropriate filenames:

14.1. DISCUSSIONS DURING SEMINARS

- Spanner crab discussions during talk.doc
- Eastern king prawn discussions during talk.doc
- Saucer scallop discussions during talk.doc
- Mullet discussions during talk.doc
- Tailor discussions during talk.doc
- Bream, whiting and flathead discussions during talk.doc

14.2. DISCUSSIONS ON MONITORING AND RESEARCH DIRECTIONS

- Spanner crab monitoring discussions.doc
- Eastern king prawns monitoring discussions.doc
- Saucer scallop monitoring discussions.doc
- Mullet monitoring discussions.doc
- Tailor monitoring discussions.doc
- Bream, whiting and flathead monitoring discussions.doc